AGU AMA: Hi Reddit, I'm Jeff Moore, assistant professor of geology and geophysics at the University of Utah, here to talk about rock slope failure processes, landslide monitoring and impacts. Ask Me Anything!

I am Jeff Moore (http://tinyurl.com/k5bz36x) assistant professor of Geological Engineering in the Department of Geology and Geophysics (http://www.earth.utah.edu/) at the University of Utah. I study processes that make rocks break (e.g. earthquakes, frost, heat) and ways to monitor rock slope failures (in-situ and remote), as well the hazards and impacts of very large, infrequent rock avalanches. I currently lead a major effort aimed at understanding how seismic resonance measurements (http://geohazards.earth.utah.edu/arch.html) can be used to track that changing structural health of natural features such as rock arches, with work in several National Parks. More information on my team’s projects and papers can be found on our website: http://geohazards.earth.utah.edu/index.html

Links to a few of my recent papers for more about what I do:
Beyond debuttressing: mechanics of paraglacial rock damage (http://tinyurl.com/k8gt3wj)
Dynamics of the 2013 Bingham Canyon rock avalanches (http://tinyurl.com/mk2luoa)
Resonance properties of a natural arch (Rainbow Bridge, http://tinyurl.com/ktign2g)
Resonant frequency monitoring of Mesa Arch (Canyonlands, http://tinyurl.com/l7o3srh)
Prehistoric rock avalanche that changed the landscape of Zion Canyon (http://tinyurl.com/lbmw8yx)

I hope to answer lots of interesting questions about landslide monitoring, impacts, and rock failure processes at the AMA!

Thanks for all the great questions! Signing off ... Jeff

Hi mate, great topic you're looking at! I have 3 questions if that's ok.

Are there certain ways to date landslides that you can't readily associate with a specific event?

Do the physical characteristics of landslides vary depending on the trigger mechanism?

Have you ever dealt with submarine landslides, and how do they compare?

Chbbyphntm1234

Sure thing, I’ll answer your questions in order:

1. Yes. Before I go further though I'll point out that it is not abnormal for landslides to have no ascribable trigger – while many slides do have a recognizable trigger (e.g. earthquakes, rain storms), many others do not – e.g. the large Bingham Canyon rock avalanches, Preonzo rockslide in Switzerland – they are undergoing progressive internal failure which cascades toward ultimate collapse. Anyway to your question – Dating Methods: there are several but the most commonly used for ancient landslides are radiocarbon and cosmogenic surface exposure dating. While the
former looks to date wood or organic fragments found in or behind landslide deposits, exposure
dating directly measures the age of a catastrophic (i.e. fast and sudden) landslide – it dates the
amount of time a boulder-top surface has been exposed to bombardment by cosmogenic particles.
Works great in many situations (e.g. our Zion study linked above).

2. Yes and no. Certainly in the case of rainfall / snowmelt triggered landslides there is the potential to
add a significant amount of water to the soil, which we’ve seen (e.g. Oso) can cause landslide
runout to have high mobility. The same slope failure in a less saturated material would likely not
travel as far. But this is not always the case. Otherwise, landslide behavior depends a lot on the
volume released, so triggers that can mobilize large volume slides can influence the overall
character. But in general (aside from soil saturation) I usually don’t find myself linking landslide
triggers and behavior.

3. No experience there, sorry!

Hi Jeff.

I’m curious as to the in situ monitoring methods you use and how they’ve changed over the last 2
decades?

Also, are there any developing technologies you are particularly excited about trying in the near future?

Cheers

IceBean

One of my go to monitoring methods is crack extensometers. I’ve used vibrating wire crackmeters for
rock slope monitoring with success in the past and I continue to use these in new projects. They are
generally inexpensive, work well in challenging field conditions, are tried tested and refined over
decades, and produce data that are easy to manipulate and interpret. The great recent additions come
in the form of communications – whereas we used to have to go and download data manually this is
now done remotely or better yet automatically via the web. I’ve also experimented with fiber optic
extensometers, which offer fantastic accuracy (micrometer) and sampling rates, but are still relatively
expensive. I think there is a lot of potential in fiber optics if they can be made more affordable.

A big aspect of my research now is experimenting with ambient seismic measurements as a means of
monitoring rock slope failure and landslide progression. We’ve experimented with large landslides in
Switzerland and I work here in Utah heavily on vibration monitoring of rock arches. The idea is that
changes in the internal mechanical system are manifested as a change in resonant properties of a rock
mass, so monitoring resonant frequencies over time provides a simple albeit indirect way of monitoring
landslide change. There has really been only one successful study (not by me sadly!) in geophysics
showing a progressive decrease in resonant frequency of a rock column as it detached and ultimately
collapsed, but this shows the method can work. We are running experiments at several places to test
the idea and methods further. The big technological advance here are the new class of broadband
seismometers, which used to be big and fragile but are now extremely small, portable, and low power.

A developing technology (for me at least), I’m currently quite excited about is laser vibrometry. Some
instruments are field portable and can measure insanely small displacements creating a non-contact
method of monitoring resonance properties of a rock or rock mass. The method is exciting because our
current techniques require in-situ sensor placement, which limits what and where we can measure,
whereas this remote non-contact method would allow resonance measurements over a broad variety of
features that are not otherwise accessible.
What's your favorite disaster film?

**Pokefraker**

Tremors!? Not really a disaster film but it does feature a wise and resourceful geophysicist. And while A View to a Kill probably tops no one's list of best Bond films, I do appreciate the geology themed supervillain plot.

What are some of the monitoring practices for large projects, such as the Bingham Canyon Mine? Also, is it likely that the mine will experience another large landslide again in the near future?

**slimclickings**

Large open-pit mines like Bingham Canyon regularly experience landslides, so monitoring plays a key role in risk mitigation and ensuring uninterrupted operation. [Note that I have no affiliation with the mine so I don't know any particular inside information]. After the Bingham slides, the mine released a pamphlet touting their monitoring methods – of these I'll point out two:

1. Ground based radar – phenomenal accuracy and spatial coverage, especially in an open pit mine lacking vegetation. The Bingham mine operates several of these continuously and they were invaluable in predicting the size and timing of the big 2013 rock avalanches. The main issue preventing broader application outside mining is cost… the units are still several hundred thousand dollars a piece (last I checked). And rigorous data processing remains challenging unless you purchase expensive proprietary software.

2. Observers – often overlooked, relatively simple and cost effective … employees in landslide prone work sites can be trained to spot signs of instability – e.g. ground cracks or rockfall activity, and report these through a centralized system and database. The Bingham Canyon mine wisely trains their employees on how to spot and report potential signs of slope instability. Nothing special here, required is a reporting scheme and dedication by employees and managers to keep the information flowing. While such data sets certainly have their bias, I'll point out that techniques aimed at automated data collection (e.g. local seismic networks) remain challenging to create, manage and interpret.

There are loads more of tried and tested techniques that work really well – crack extensometers and total station monitoring come to mind; these technologies have been around for decades and used successfully in the past to monitor (and predict!) the progression of landslides large and small.

First of all...you rock! What is the most amazing thing you have learned (in your mind) as a geologist?

**choppernamedtaco**

Oh, I am constantly amazed by geology … I love learning about all the crazy creatures that lived in the Earth's past, I love learning about how the Earth's spectacular landscapes were formed and evolve over time, and I also love trying to get people excited about geology as a lively rather than dead old static field. How the resonance of arches can represent their "voice" previously unheard is one of my favorite "discoveries" to communicate. Maybe my favorite thing to learn about these days (for personal interest) are geological processes on different planets and moons in our solar system, not only int he incredible array of processes on display but I also find it fantastic how clever science can be to sense and discover these details.

Hi! Are these kinds of rock slides considered a granular fluid or a fault (like a surface earthquake)? Are
there any laboratory-scale experiments which you find to be most helpful, such as rheology or tribology? Thanks.

Spooler2

Granular flow is the most simple description applicable to many rock slides. For large flow-like landslides with high mobility (e.g. rock avalanches), there are a variety of model descriptions. I am a user in this aspect, not a developer, I recommend the following recent paper as a good crash course in landslide runout modeling: [http://www.nrcresearchpress.com/doi/pdf/10.1139/cgi-2016-0104](http://www.nrcresearchpress.com/doi/pdf/10.1139/cgi-2016-0104)

There are 1000s of hazard models but less effort given to the other components of risk (i.e. exposure and vulnerability). Do you think more focus is needed to understand vulnerability and exposure to landslides to improve landslide risk assessment?

The_Mack_daddy

Certainly yes, but I would not say that we've mastered our understanding of rock slope hazards by any stretch. Imagine even a well monitored site – let it be a large rock slope failure, all the best monitoring in place to distinguish the unstable volume and use movement rates to predict the time of failure. If the entire volume fails all at one we have one hazard scenario, if it fails in 100 small compartments we have a completely different scenario, and anything in between is possible. Currently we are not very good at predicting how ultimate failure occurs and thus accurately characterizing even this hypothetical (e.g. Preonzo) well known hazard.

But yes, I certainly agree that more research and I think especially outreach are needed to deal with our exposure to landslide hazards. I think there's a lot we can be learning from the earthquake engineering community struggling similar aspects of risk management.

Stupid paywall ;)

Regarding your arch-resonance papers, I was curious if the resonant frequencies correlate to rock type? I realize you were looking at sandstones in both, but do you have any opinions on a scenario in which the exact same arch was granite or limestone?

Also, how does the size and shape of an arch play a factor in its resonant properties? Does erosion make an arch more or less likely to resonate, or provide no effect?

anchirite

Sorry about that … here is a conference paper we just had accepted for an upcoming meeting, it details the essentials of our method and in part addresses your question: [http://geohazards.earth.utah.edu/images/Moore_etal_ARMA17.pdf](http://geohazards.earth.utah.edu/images/Moore_etal_ARMA17.pdf)

Short answer, yes, resonant frequencies correlate with rock type. The resonant frequencies of a simple structure are a function of mass and stiffness, and rock type controls both of these parameters. Mass is controlled by density and geometry, while stiffness is controlled by elastic modulus and geometry. Higher mass, lower resonant frequency; higher stiffness, higher resonant frequency. In the above paper we analyzed four arches each within the same sandstone unit (Navajo SS), and found that features formed in the lower Navajo, which is enriched in iron, had higher stiffness than those in the upper-middle Navajo where iron has been leached. Iron acts as an additional grain cement, we hypothesize, increasing bulk rock stiffness.

The other major player in the resonant properties of an arch (or any freestanding geological feature for
that matter) is the mechanical boundary conditions – i.e. how the arch is adhered and attached to surrounding bedrock. This is more difficult for us to parameterize, and often we have to play an arduous game of guess and check, matching model results to field data, to get it right. This aspect is also discussed in the above paper.

Hi there from a fellow geophysicist. My question is how you go about discussing hydraulic fracturing with people who have very strong preconceived notions from public media?

shlam16

Good question, I'm not I have the best answers, but my approach is generally to try and find common ground early in the conversation, hoping to establish a respectful conversation rather than argument (where no one ever changes opinion). Strong opinions (on either side) usually carry strong bias, so I try to admit aspects of my (and both) side's media arguments that may be unfounded as a means of 'opening' the conversation. Danger here though is that you get misinterpreted, as has happened to me in the past, so I've also learned to be forceful about scientific facts established by data and what items are irrefutable from a scientific standpoint. As with many issues (like hydraulic fracturing) the facts tends to be twisted and politicized by all sides to achieve a particular goal. I believe scientists need to have an impartial voice as much as possible in these arguments, so that's the main stance I try and take.

Hello! What is an unexplainable thing about earthquakes? I should rather ask what is the most mind-boggling fact you discovered?

fusroketchup

That we can't predict when they're going to happen.

My team discovered that rock arches shake like crazy during earthquakes, ground motion is amplified up to 100x compared to adjacent solid bedrock.

Not a geology question but I'm considering going to the UoU, what is the geology branch of the university like?

SpectrumExplorer

Fantastic! We have an excellent geology department with a wonderful group of dedicated faculty, graduate and undergraduate students. Living and studying geology in Utah is second to none :) Undergrad or grad, the most important thing is you – how you approach learning and engage the resources around you! We professors are always trying to improve our teaching and mentoring, but the people I see getting the most out of their education are those personally engaged in going beyond the norm. Talk to your profs, ask lots of questions, find individual research projects, get involved in campus sustainability efforts, etc. - universities like ours offer many ways to expand your education beyond just sitting in lectures.

what, if any, changes will climate change bring to this area of study? is it reasonable to expect an increase in rock avalanches or seismic activity?

WifeWontLetMeReddit
One might expect an increase in landslide activity in actively deglaciating environments, and indeed recent observations have highlighted quite a lot of large landslides for example in Alaska. But to this I’d add we don’t have a good historical perspective on the occurrence of such events, especially in remote areas. Only recently we’ve begun using seismic data to remotely identify and describe large landslides, so are able to better describe their occurrence, but we lack accurate historical data sets in most cases to determine changes in activity.

Hi, I’m an American living in Nepal and when I go out in the mountains there is evidence of countless landslides that have taken out roads and trails. In all the time I’ve spent in mountainous places in the U.S. I’ve not seen as many landslides as just one short trip here. Do you know if there is something inherently unstable about the slopes of the himalayas or is it that the roads and trails are better engineered in the states so that landslides are less common? Thanks.

firefarmer74

I’m not too familiar with the geography and geology of Nepal, but I lived and worked in Switzerland for several years and had a similar feeling when I returned to the US. First off I’d say relief is a key factor – i.e. elevation change over distance – places like Switzerland and Nepal have generally higher relief landscapes than here making landslides more common. Second is likely high relief in combination with tectonics – earthquakes uplift mountains, break rocks and trigger landslides – so high relief in combination with relatively frequent earthquakes likely plays a role in overall landslide density. But third, you raise an appropriate point about road building practices in areas like Nepal. Consider something seemingly so simply as drainage – which most modern US roads do relatively well – poorly controlled drainage on roads in steep hillslopes tends to focus water in certain areas and trigger landslides. So yes, construction practices in my opinion play a large role. As an aside, living in a landslide prone area like that offers you a fantastic opportunity to study and learn about landslide conditioning factors and triggers, and ultimately hazard management practices, observe and soak it up!

Has your career lead you to form any insights regarding the Neocatastrophism VS Neouniformitarianism debate? Do you see earthquakes, landslides and floods as ever having been a rapid driving force behind the structuring of our planet, or have they always been minor blemishes in respect to the slow, shaping process of plate tectonics?

HerbzKal

No, sorry. I teach historical perspectives on the science of geomorphology, and reading up there I did have a moment where my mind was racing, trying to place our modern practices in these frameworks, but the moment was brief and deadlines immobile.