

AGU AMA: Hi Reddit, I'm Mike Brudzinski, Professor of Seismology at Miami University in Ohio, here to talk about earthquakes, how faults move, hydraulic fracturing, active learning on computers, and FanQuakes. AMA!

AmGeophysicalU-AMA <sup>1</sup> and r/Science AMAs<sup>1</sup>

<sup>1</sup>Affiliation not available

April 17, 2023

### Abstract

I am Mike Brudzinski, Professor of Seismology at Miami University in Ohio. I've spent most of my career studying earthquakes big and small. The big ones I have worked on are the megaquakes formed at subduction zones where two tectonic plates collide and generate the largest earthquakes and tsunamis on Earth. These earthquakes are rare but potentially devastating, so I have also worked on the much smaller fault tremor and slow fault movements that seems to occur right below and possibly leading up to the really big earthquakes. My colleagues and I just published a paper indicating the likelihood of earthquakes does appear to be higher when the deeper roots of faults are moving slowly. Lately, I have also worked on swarms of small earthquakes triggered by oil and gas activities. My graduate student did a popular AMA when our paper came out linking a series of earthquakes to hydraulic fracturing in eastern Ohio (<https://redd.it/2rjqad>). This highlights one of my other passions: training the next generation of earth scientists. I have worked on developing courses and teaching modules that follow a strategy I refer to as "active e-learning". This is where students learn science by actually doing it with computers instead of just listening to me lecture about it. In addition to making classes more engaging and flexible, the transition from student to researcher is more seamless and allows me to work with more students in my research. Lastly, I think science outreach is critical, and I found a fun way to do that recently by helping to measure how much fans shake the Ohio State stadium during football games. I'm looking forward to all sorts of questions about earthquakes, big and small, fast and slow, natural and human induced. And I would love to talk about education and outreach too! And let's continue the discussion on Twitter @seismohio

[REDDIT](#)

# AGU AMA: Hi Reddit, I'm Mike Brudzinski, Professor of Seismology at Miami University in Ohio, here to talk about earthquakes, how faults move, hydraulic fracturing, active learning on computers, and FanQuakes. AMA!

AMGEOPHYSICALU-AMA [R/SCIENCE](#)

I am [Mike Brudzinski, Professor of Seismology at Miami University in Ohio](#). I've spent most of my career studying earthquakes big and small. The big ones I have worked on are the megaquakes formed at subduction zones where two tectonic plates collide and generate the largest earthquakes and tsunamis on Earth. These earthquakes are rare but potentially devastating, so I have also worked on the much smaller fault tremor and slow fault movements that seems to occur right below and possibly leading up to the really big earthquakes. My colleagues and I just published a paper indicating the likelihood of earthquakes does appear to be [higher when the deeper roots of faults are moving slowly](#). Lately, I have also worked on swarms of small earthquakes triggered by oil and gas activities. My graduate student did a popular AMA when our paper came out linking a series of earthquakes to hydraulic fracturing in eastern Ohio (<https://redd.it/2rjqad>). This highlights one of my other passions: training the next generation of earth scientists. I have worked on developing courses and teaching modules that follow a strategy I refer to as "active e-learning". This is where students learn science by actually doing it with computers instead of just listening to me lecture about it. In addition to making classes more engaging and flexible, the transition from student to researcher is more seamless and allows me to work with more students in my research. Lastly, I think science outreach is critical, and I found a fun way to do that recently by helping to measure how much [fans shake the Ohio State stadium during football games](#).

I'm looking forward to all sorts of questions about earthquakes, big and small, fast and slow, natural and human induced. And I would love to talk about education and outreach too! And let's continue the discussion on Twitter @seismohio

---

[READ REVIEWS](#)

[WRITE A REVIEW](#)

CORRESPONDENCE:

DATE RECEIVED:  
March 07, 2017

DOI:  
10.15200/winn.148880.08239

ARCHIVED:  
March 06, 2017

CITATION:  
AmGeophysicalU-AMA ,  
r/Science , AGU AMA: Hi  
Reddit, I'm Mike Brudzinski,  
Professor of Seismology at  
Miami University in Ohio, here  
to talk about earthquakes, how  
faults move, hydraulic  
fracturing, active learning on  
computers, and FanQuakes.

Thank you for doing this AMA! It's always great to hear of cool innovations in science outreach, as well.

Are the earthquakes that are caused by fracking qualitatively different than those caused by tectonic plate movement? How well do principles learned about one type carry over to the other?

[neurobeegirl](#)

It is an open research question whether the earthquakes induced by injecting fluids are different than those caused by tectonics. There are some slight differences in the waves we record, but it appears those differences may be due to the induced earthquakes being shallower than most tectonic earthquakes. In our work, we have found that earthquakes induced by injecting fluids typically occur in swarms of tens to thousands of events, whereas the natural tectonic earthquakes in the central and eastern US tend to occur with a smaller number of events. We have used that swarm pattern to help detect induced earthquakes in our research. Swarms can happen naturally too, but we think that it may be natural fluids that are causing them, like in a subduction zone where an oceanic plate is thrust underneath another plate. The water in the down-going plate can be released along the way,

AMA!, *The Winnower*  
4:e148880.08239 , 2017 , DOI:  
[10.15200/winn.148880.08239](https://doi.org/10.15200/winn.148880.08239)

© et al. This article is distributed under the terms of the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and redistribution in any medium, provided that the original author and source are credited.



sometimes causing earthquake swarms in these places. We are using techniques and principles learned from studying induced earthquakes to help us detect and study these tectonic earthquake swarms too.

I live in Oklahoma where in the past 10 years there has been a sudden upswing in the number of earthquakes. While it seems commonly attributed to fracking activities there is plenty of denial-ism. I tend to hear the argument that these earthquakes aren't happening in the same area as the fracking and that this is just natural and there is no way humans can induce earthquakes. My question is what is your thoughts and what is the mechanics behind human induced earthquakes (how does it work?) Also, should I expect more powerful earthquakes in my area in the future?

[RozyShaman](#)

My colleagues and I are actively studying the mechanics behind human induced earthquakes and trying to figure it out so that question is not answered yet. There are a two primary ideas:

1. Injected fluids raise the fluid pressure in a fault zone and help to unclamp it
2. Injected fluids cause a change in the stresses either through changing weight or causing an area of high pressure that pushes on rocks around it

As for whether to expect more powerful earthquakes, our abilities to forecast earthquake hazards are still very limited, so I can't answer your question very specifically. However, the United States Geological Survey just released an updated estimate of the hazards from induced (and natural) earthquakes in the US, including in Oklahoma: <https://earthquake.usgs.gov/hazards/induced/>

Oklahoma has enacted limits to wastewater disposal to deal with the earthquakes, and the number of earthquakes over the past year has decreased. However, there were more magnitude 5 earthquakes this past year (3) than previous years, including the largest ever recorded in Oklahoma. So while there is some indication we are on the right track to reduce earthquake hazards in Oklahoma, it's hard to say what to expect in the future.

Hi Mike! I am a MU grad ('15) and I actually took your class my freshman year! I really enjoyed the e-learning experience. I can honestly say I learned a lot from your class and still remember much of it today. Thanks for doing this AMA!

My question is do you think e-learning could be implemented in many different subjects and classes? I personally enjoyed it but I feel it could be easy to take advantage of. What classes do you think it wouldn't work well in?

[timyt01](#)

Thanks for the positive review of my course! It takes a lot of work to create a course like that, so it always helps to get positive feedback. But this highlights one of the obstacles for others – most instructors have put together a classroom-based course that they are happy with, so re-envisioning it as an online course would take a lot of planning and development to implement something well integrated into an online setting. The subjects that I think would work best are ones where students would really benefit from learning skills on the computer or when students would benefit from guidance and practice. I eventually came to the realization that I really wanted students to learn geology the way we do it – by analyzing it on a computer. If I'm requiring students to use a computer to do the analysis, wouldn't it be better to just teach it online? The other realization I made is that scientists often learn things by trial and error or through practice. I was very excited when I found out that people were designing online tutorial systems for teaching that could allow students to get immediate, tailored

feedback while working on assignment. These systems could also allow students to take multiple attempts at an assignment so they could practice and refine their skills. So the question for instructors is whether these advantages and opportunities are worth the considerable time investment. For me it was, and I hope it will be for others too.

Thank you for doing this AMA!

Given the increase of earthquakes in the Midwest, due to fracking, how much has this increased the possibility of seeing the big one at Yellowstone go off in our lifetime?

[eyeless\\_atheist](#)

I'm certainly not a volcanic eruption expert, but it's hard to see an increase in the likelihood of an eruption from the growth of earthquakes which have all been below a magnitude 6 level and in locations quite distant from Yellowstone. And by that I mean the shaking that would be induced by these earthquakes at the volcano would be quite small. We envision that the large eruption you are asking about is driven by magma supply from below the volcano, and it doesn't seem very likely that the increase in induced earthquakes far away would increase the rate of magma supply. If there was evidence that a bunch of magma had pooled near the surface and created a bulge on the volcano, then perhaps even small changes in ground shaking could trigger the eruption of that material, but as far as I know, the Yellowstone system has not reached a critical point like that.

Thanks in advance!

I live in Mexico city, where we feel quakes even if the epicenter is a couple hundred miles away. I have an app that warns me beforehand, even telling me the strength of the impending quakes. How does this happen fast enough to notify me? How fast does the energy travel? And why would the degree of shaking be the same here as it typically is in the common epicenters here (I'm thinking because of the water in the soil here in the valley.

[guerochuleta](#)

I study earthquakes along the southern coast of Mexico precisely because of the hazards to Mexico City. As you indicated, larger earthquakes along the coast can produce large shaking in Mexico City even though they can be hundreds of miles away. That distance is what folks are using to help issue a warning via the app you described. Seismic waves travel about 5 miles per second, so it can take about 40 seconds to travel 200 miles. That is enough time to record seismic waves at several locations and process them with a fast computer to make quick estimates of the earthquake location and size.

Shaking tends to be larger in Mexico City because of how the city was built on a former lake bed. The lake was drained only last century so the soil and sediment is not well consolidated and still has some water in it as you suggested. These conditions cause larger ground shaking, and it can even liquefy more easily which causes even larger damage.

Are the earthquakes being caused by fracking fluid disposal creating new fault zones or are they activating current faults (or activating old faults)?

[CampBenCh](#)

The earthquakes we have been studying show patterns that indicate the operations are re-activating old faults instead of creating new ones. In most cases, the faults we are seeing re-activated have the same type of orientation that is aligned with the overall stress field in the Earth's crust. We say these

faults are “optimally oriented” and they should have the largest stresses placed on them naturally. This means they would be stressed to a critical point such that only small changes in conditions (like that from fluid injection) would cause them to move.

Hi Mike!

What do you think about the influence, or lack thereof, that slow slip events have on the timing of the next great Cascadia earthquake? I'm thinking specifically of this paper claiming that the stress changes from slow slip in Cascadia are too small to affect great earthquake timing (<http://www.bssaonline.org/content/104/1/128.short>). Do you think the situation in Cascadia would be very different from what you see in Mexico, and why?

Also, what are your thoughts on the involvement of scientists in politics, especially in the current political climate? As I'm sure you know, our professional organization (the American Geophysical Union) officially endorsed the March for Science. On the other hand, Robert Young published an Op-Ed in the New York Times claiming the march is a bad idea ([https://www.nytimes.com/2017/01/31/opinion/a-scientists-march-on-washington-is-a-bad-idea.html?\\_r=0](https://www.nytimes.com/2017/01/31/opinion/a-scientists-march-on-washington-is-a-bad-idea.html?_r=0)). As a young, un-tenured professor myself it's hard to know what the balance is here between pushing for science to be taken more seriously in politics vs. being seen as partisan and alienating people. I am especially concerned about alienating students and any career damage that political activity might do. I completely understand if you don't want to answer this question in a public forum, and if so, I apologize for asking it.

(You do know me personally, but I prefer to stay semi-anonymous on reddit, if you are curious you can PM me.)

[slowlyslipping](#)

I respect the authors of that BSSA paper a lot and they have done a thorough examination of how slow slip events could potentially trigger the next great Cascadia earthquake through stress relationships. I can see why they come to the conclusion that if a stress relationship occurred it would take longer than the slow slip event, so they wouldn't be correlated in time. And yet as we worked on our paper and reviewed the literature, we found many more cases of correlations between slow slip and earthquakes than I would have expected based on the BSSA paper. Moreover, the change in stress we calculated from the slow slip event in Mexico is quite small at the epicenter of the large earthquake, so we found these results to be puzzling -- why does it seem to correlate observationally but the predictions from a stress transfer model suggest it would be unlikely to correlate? It made us consider some alternative triggering models, and the one we decided had the most promise is this one (excerpt from our new EPSL paper:

“a slow slip event liberates fluids as the slip breaks a hydrologic seal that forms in between episodes (Audet et al., 2009). As the freed fluid attempts to flow upward along the plate interface it would raise pore fluid pressures in the lower portion of the seismogenic zone and potentially lower the effective stresses enough to trigger seismicity. Evidence for or against this hypothesis should be the target of future studies.”

A key unknown is whether the fluid pressures can propagate fast enough for this model to be effective.

Now to the question of what to do about scientists involvement in politics. As you might guess, I think the answer is really dependent on the individual scientist. Me personally, I think I can have the most influence in 3 areas:

1. Helping my intro-level students (non-majors taking my course for their liberal education requirement) understand how we do science and what we can use it for. I typically teach 50-100 of

those students per year, so that's a lot of potential impact over a 30 year career. Over the past few months it's become clear that I need to step it up in terms of communicating how important data-driven science is critical for making good decisions for society. I need to help students see that the science skills they learn to answer questions can help them to make good political decisions – and that we need them to be involved in our political system. This is focusing squarely on the long-term battle and won't change anything about the current government's disinterest/disparaging of science.

2. Finding opportunities to work with government officials related to my science. I have become much more involved in this since I shifted a lot of my research focus over to induced earthquakes, which was a conscious decision related to having more impact on society. I've worked directly with several state regulators and a variety of companies in industry to deal with the induced seismicity problem. I can point to cases where I've had a direct and sometimes immediate impact on outcomes and that is rewarding as a scientist.
3. Using outreach efforts like this to build trust in science. Honestly, answering questions from the general public is what we should be doing on a daily basis. I think it's our job as experts in a given topic to build trust, so that people will rely on our expertise, but I only think that will happen if we have a more regular interaction with people to demonstrate our expertise. One of the reasons I worked on the FanQuakes project is that I knew people would be excited about it – I love sports too – and that it was an opportunity to communicate my expertise to a broader set of people in Ohio. So if we do have an earthquake issue of some kind in the future, then people would be more willing to trust me if I have a recommendation.

And lastly, as a scientist, I have learned to live with uncertainty so while I have a best fitting model for who you are, I'll be fine with not knowing for sure. :) Perhaps I should add that I think more of how we evaluate (and interact) in science should be done anonymously so that our inherent and subconscious biases are less likely to create unfair privileges.

I am always happy to hear about science professors stepping up their teaching game. Could you say a bit more about how this idea (for "active e-learning") came about?

Also, a smarass question. Why are employees from Miami University required to add "in Ohio" at the end? There's only one Miami University in the world.

[lastpawn](#)

This links provides some explanation of what lead to the idea for "active e-learning": [http://serc.carleton.edu/getspatial/blog/geospatial\\_online.html](http://serc.carleton.edu/getspatial/blog/geospatial_online.html) Here's a quick summary: After trying to implement active learning strategies in a lecture hall for a number of years, I reached the point where I realized that online teaching could facilitate student learning by engaging students in the actual practices used by geoscientists (e.g., using computers to acquire and analyze data, and create spatial models of Earth systems). We could specifically design assignments to simulate how geoscientists collect and analyze data by retrieving data from web databases and plotting them in Excel or Google Earth. Much more extensive use of Google Earth to examine geologic phenomena provides an opportunity for students to interact with geology in 4 dimensions in ways that are simply not possible in a traditional lecture format. Students collect earthquake hypocenters from the USGS and then visualize the progression of seismicity using a time-slider in Google Earth. This process reveals critical information about earthquake rates and the clustering of seismicity on faults that are used to create hazard maps. In a similar way, the ability to view aerial photography across many years from different spatial perspectives enables students to better understand how landslide processes transform the landscape over time.

Other than "stop fracking," can oil and gas companies can do anything to reduce the risk of accidentally triggering earthquakes?

[TmickyD](#)

It is important to point out that the scientific community is less concerned about the potential for earthquakes from hydraulic fracturing than from disposal of waste water left over after fracking or from the disposal of extra water produced during a normal oil and gas recovery process that doesn't involve fracking. The waste water is typically injected into deep reservoirs, often below the rock layer that is fracked to avoid contamination of much shallower drinking water. But that water pressure can affect faults in the deeper, older rocks that are more faulted. There are some indications that the more water is injected, the larger the earthquakes could become, including some recent magnitude 4 and 5 events in Ohio and Oklahoma that caused some damage. Yet in Ohio we have only found 3 cases where waste water disposal is correlated with earthquakes, while over 200 deep injection wells do not cause detectable earthquakes. Our research suggests one of the best strategies is to install or utilize existing seismic monitors to see which wells are problematic. Then the companies can adjust the operations, like the amount and rate of injection, to limit the number of earthquakes. We have found that most induced earthquakes that are large enough to cause issues are preceded by many smaller earthquakes. Monitoring for those smaller earthquakes can help companies to know if they should adjust their operations.

Hi Mike, and thank you for doing this AMA.

I am a first year geology student and I've had one question that's been bugging me for a while. How fast do two plates move relative to each other during an earthquake? Also, if you know, how was this discovered?

[Callmegusgus](#)

Earthquakes typically create fault motions with the two sides (plates) slipping past each other at peak speeds of 1-10 m/s. I believe slip speeds are usually determined from ground velocity measurements recorded by a seismometer near the earthquake. This correlates with how fast the fault is moving if it's recorded near the fault.

The slip speed are often confused with the rupture speed, which is how fast the slip propagates along the fault during an earthquake. This happens much faster, typically at speeds of 1-4 km/s. Rupture speeds during earthquakes are can be determined using something equivalent to the Doppler effect. The common example for sound is the change of an ambulance siren from higher pitch (frequency) to lower pitch (frequency) as it passes you. When the source is going towards you, the apparent frequency is larger as you can envision the sound waves getting bunched together. When the source going away from you, the apparent frequency is smaller as the sound waves are getting spread out. This same principle occurs for earthquakes as they rupture. If a fault ruptures from east to west, then we use the higher frequency measurements in the west and the lower frequency measurements in the east to determine the rupture speed. The rupture direction and speed have an influence on where the shaking is largest from an earthquake, so we care about it for making hazard estimates.

In your use of the term "hydraulic fracturing" are you differentiating between hydraulic fracturing itself and wastewater injection wells? The two are usually conflated which seems absurd since they occur at vastly different depths. I've seen studys that show earthquakes in Texas were influenced by wastewater injection, have there been any that show the same for the fracturing process alone?

[BePokemaster](#)

In one of the other questions, I tried to clarify that the scientific community is less concerned about the potential for earthquakes from hydraulic fracturing than from disposal wells (either waste water left over after fracking or extra water produced during a normal oil and gas recovery that doesn't involve fracking). There are 2 general ideas for why the disposal wells are more likely to produce earthquakes:

1. Disposal wells can inject into deeper reservoirs below the oil and gas layer that is fractured, such that it is closer to deeper, older rocks with more developed faults.
2. The volume of fluid injected is larger because the disposal operations can last for years, whereas a fracture job typically lasts several weeks and then is complete.

There are several studies now showing earthquakes from the hydraulic fracture process alone. Our published study from 2015 found this occurred in 4 cases in Ohio, out of ~1400 hydraulic fracture wells. By comparison, we found 3 cases of earthquakes from wastewater disposal, out of ~200 disposal wells. A study investigating induced earthquakes in Western Canada last year found similar percentages: ~1.4% for disposal wells and ~0.3% for hydraulic fracture wells.

Hey, I'm an elementary school teacher, and I'm wondering if you could point me in the direction of any good resources for teaching geology? I teach in California, so a focus on the Sierra Nevada would be a bonus.

[sunfishking](#)

The Science Education Resource Center at <http://serc.carleton.edu> is the best resource I know of for teaching geology. Since I teach at the college level, I don't know how good the resources are for K-12, but I'd still recommend having a look based on how good the college level resources are.

Hey Mike! You have an awesome background and really interesting experience. Question: Are there definitive signs that precede a major earthquake?

[Reginaledit](#)

Hey Mike! You have an awesome background and really interesting experience. Question: Are there definitive signs that precede a major earthquake?

The short answer is basically no. Folks are working on many different ideas to look for potential connections, but even the most promising will likely only have a weak connection. For example, our just published paper supports the idea that slow movement on the deep roots of faults increases the likelihood of earthquakes. However, these slow slip events (lasting a month or two) occur every year or two in Mexico and the really large earthquakes recur every 50 to 100 years. So while the chances of an earthquake may be raised during a slow slip event, the overall likelihood is still low. Slow slip events are certainly not a definitive sign that a major earthquake is imminent.

Thanks for doing an AMA, professor! As an expert, would you say there has been an increase in earthquake activity and/magnitude worldwide in recent years?

[EspeonKing](#)

There has not been an increase in earthquake activity or magnitude worldwide in recent years, but there has been a definitive increase in earthquake activity in the central and eastern US over the past 8 years due to earthquakes induced by oil and gas operations. [This plot shows the dramatic change in the number of earthquakes per year.](#)

Oklahoman here. In the last few months Oklahoma has had one of the most severe earthquakes in our recorded history (beaten only by a quake in 1955, if my memory is correct). Based on what you know, how do you see the future in Oklahoma? Does the average magnitude rise? Does the frequency of higher magnitudes rise? So on and so forth.

[Mafiya\\_chlenom\\_K](#)

I hope [this answer to another question](#) helps.

Disclaimer: This will sound odd and is probably a stupid question.

I imagine that volcanic eruptions and earthquakes might somehow be linked, in the sense that a massive earthquake might somewhere stir up the innards of Earth and lead to volcanic activity, or vice-versa. Sort of like when a baby has gas and you rock it on your knee and pat its back to make it burp.

We often see the devastating effects earthquakes have on the surface of the Earth. To what extent, if at all, do earthquakes affect what goes on below the surface of the Earth and its core, which we normally don't see, and does there exist correlations or a causal relationship between earthquakes and volcanic activities?

Also, thank you for doing this AMA.

[IRLeif](#)

There are several studies over the years that have shown relationships between large earthquakes and volcanoes. A variety of different mechanisms have been proposed to explain these relationships, including the one you described where shaking of the magma shakes loose some bubbles of gas that can collect together and promote an eruption. One study (Walter and Amelung, 2007) also looked at volcanic eruptions following the magnitude 9 Indonesian earthquake in 2004 and found that eruptions were focused in areas that had been stretched by the earthquake movement. The stretching makes room for the gas to come out of the magma and as the gas moves upward through the magma it's easier for more gas to come out. This feedback loop creates a pressure increase inside the magma chamber that can lead to an eruption.

Hey Professor, thanks for doing the AMA, I've seen some really interesting responses. Do you have any advice to students like me who are interested in this field? What related skills would you find the most useful for someone wishing to study this field?

[JCoonz](#)

The two things I tell students are computer coding and working on a real scientific project that leads to either a national presentation (or better yet) some form of publication. The first suggestion is pretty straightforward in that much of what we do in geophysics and seismology uses computers to analyze the data. Most of the innovations in my research over the years have been through developing computer programs to analyze our data more effectively. The second suggestion probably sounds circular in that you are asking what skills to work on to be a good scientist and I'm suggesting you do science, but that's the truth. There is no better training for being a scientist than actually trying to do science. When scientists are working on their projects they often realize they need to learn new things or skills, and then they spend time trying to learn those things and skills on their own or from other experts who know how to do those things. Being a scientist is kind of like a long series of independent studies classes. So the sooner you can get involved in a science project with another scientist who can

help you, the better.