Student questions: Jenny Suckale colloquium on "The Role of Multiphase Instabilities in Nature's Extremes"

9/12/18

Question 1: What processes or lack thereof caused the ice stream to stop in the case 200 years ago when it did?
A: Unfortunately, we don't actually know that, but water probably had something to do with it.
Question 2: Why is there no vertical faulting in the glacial flows you discussed?
A: In the slow-flowing regions (the blue zones of the map I showed initially.)

Question 1: You discussed how ice channels can stop flowing, but what factors initiate the process?
A: I'm afraid that we don't actually know that.
Question 2: Is there any way to induce a jump in the margin of an ice channel (like the jump in the Kamb flow margin) that would terminate any of the active ice flows?
A; Yes, I think that would theoretically be possible but extremely risky experiment. When intervening in a highly nonlinear system like this, it's also possible that any intervention would actually lead to further destabilization.

Question 1: Are there any plans to apply the model for tectonic stress fields to volcanoes other than Stromboli?
A: Yes, we're currently doing that for El Laco in Chile.
Question 2: If the frequency of the degassing waves changed, how would that affect the recurrence period of the larger infrasonic pulses ?
A: If our hypothesis is correct that the degassing waves trigger the intrasonic pulses, the pulses would change with the frequency of the wave.

Question 1: How would you quantitively define ice as reasonably heterogeneous?
A: As the heterogeneities having less than a 10% effect on the dynamics I'm interested in.
Question 2: Could you make a similar model to better understand how the ice moves on mars and would that data give an insight into the past movement of water ice?
A: I think that you can write a model for anything and can get insights out. Not sure that I would take entirely the same model approach for Mars, but you could if you wanted to.

Question 1: Can Sleipner cause a total failure of the rock releasing all the gas that was dumped into it?
A: I think that's extremeley unlikely.
Question 2: Does pressure cause the melting of glacial ice or is it the friction?
A: Friction is the primary factor, pressure just shifts the temperature required for melting a little bit.

Question 1: Do you think the potential energy built up then released from a fracture is the force behind the extreme flows?
A: There are a lot of physical processes that build up force. Stored potential energy is one of them, but I don't think the answer is the same for all of the systems I looked at. For Stromboli, for example, there is no evidence of built-up since the volcano is constantly erupting.
Question 2: Have you looked at ice flows on other planets like Mars for example?
A: Not yet, maybe you should do that?

Question 1: What does it mean for lava to fracture since it isn't solid while it is moving?
A: Almost all "real" materials are somewhere between a fluid and a solid, which means they behave in both waves, just on different time scales.
Question 2: When lava stops flowing, can it still fracture?
A: Sure, why not?

Question 1: How do you take into account the type of rock underlying the ice when looking at the threshold of failure?
A: I don't. Ice is underlain by sediment. The bedrock is tens of meters away and likely not relevant dynamically. The fracture (or failure) I'm talking about happens in the sediments.
Question 2: Could the saltwater injected into the Oklahoma subsurface eventually rise to the surface like the CO2 in Sleipner does?
A: It could and it does in a phenomenon called backflow. Keep in mind, though, that it lacks the buoyancy that gas has.

Question 1: Can you predict if/when an ice shelf will die?
A: Unfortunately, not. I'm also not so sure that I care. A lot of interesting things will happen prior to that.
Question 2: You mentioned the ice shelfs could be affected by climate change, is it that the ice shelfs will speed up causing more ice loss to the Antarctic ocean?
A: Likely yes. The shelf are not necessarily a huge contributor to sea level rise, because they are isostatically compensated. The main ice loss comes from grounded ice speeding up because the ice shelfs are gone or thinned out.

Question 1: What do you see as being the "Next Big Thing" in the near future of your field?
A: We need to get better at managing the risk associated with extreme events.
Question 2: Would your work with multi-phase modeling be applicable to the study of undersea tectonics and tsunamis?
A: Sure!

Question 1: If we can see the stop or change of flow in something like kamb, may we possibly predict the eruption points shifting on stromboli?
A; I don't think so.
Question 2: Can this type of hydrologic system modeling be related to flows on icy planets?
A; Sure.

Question 1: Are there plans to apply your models to other systems not mentioned in the talk and which ones?
A; Hmm. Landslides, permafrost, …?
Question 2: There wasn't time to go over the water system. How different was that system from a modeling perspective compared to the other flow dominated systems mentioned in the talk?
A; You mean the water system underneath Antarctica? Quite unique really in many ways and we're still in the process of discovering how unique as there are so many things we do not know about it yet.

Question 1: Have stress modeling techniques or looking at fracture and flow together ever been applied to examining natural disaters, or could they be used to predict when these disaters could occur?
A: I don't think that capturing flow and fracture jointly has been attempted previously a whole lot. I also don't think it will help us predict disasters necessarily, but it could help us project whether and why interventions (either intended or accidental) can amplify (or suppress) extreme events. I personally think that could be extremely valuable.
Question 2: How does the flow of the mush contrast the flow of the ice and water in Antarctica.
A: There are many differences and similarities. One big difference between ice and lava systems is the complex geochemistry and limited data availability associated with the latter, which everything so much more difficult.

Question 1: Can the models used in Antarctica be use to characterize the flow and fracture of ice on Europa or other icy moons?
A: In principle yes. That being said, I'm not necessarily a fan of "recycling" models, i.e., applying them to a different context they were not intended for. But one could write a very similar model for Europa or other icy moons… maybe you should do that yourself?
Question 2: Has modeled CO_2 mobility in the Norway sequestration reservoirs been used to improve sequestration techniques yet?
A: Hmm, I don't think so. The main thing we learned at this point is that sequestration is more difficult that we initially thought. It's just challenging to make sure CO_2 actually does not make it back up to the surface and there is probably no easy fix to that issue.

Question 1: In your talk, you talked about the horizontal fault lines in Antartica - however, are there perpendicular fault zones in Antarctica that have similar water-rock dynamics?
A: Yes, there likely are veritical fault lines as well. We haven't looked as deeply into these, but there are probably some interesting secrets hidden in these.
Question 2: How long have the "ice rivers" been flowing in Antarctica, and have they changed at all in response to the variable climate of the last century?
A: We now believe that ice streams have always existed, even on previous ice caps that are long gone. Unfortunately, we don't understand why that is conclusively enough to isolate the effects of climatic change. Two locations where we see very rapid speedup and thinning that likely has a connection to climate are Thwaites and Pine Island Glaciers.

Question 1: Other than in Antarctica, are there any other areas on Earth where we may see the same phenomena with the ice sheets moving at drastically different speeds?
A: Greenland shows very similar behavior.
Question 2: How can you put your volcano models through further testing to make sure that you are actually describing what is being observed?
A: Great question. We're currently working on developing models that allow the integration of microanalytic data (e.g., crystal size distribution, zoning patterns, dissolution rims, etc). That kind of data is a treasure trove that previous models haven't really tapped into because these models operate at completely different scales. We have a suite of models at the granular scale that will hopefully enable us to make a closer connection.

Question 1: How might your eruption model change for a larger volcano with a greater normal stress?
A: I don't think that the normal stress is necessarily the key factor. Likely more important processes are the energy flux, the silica content of the magma, gas content, etc… We're at the very beginning of understanding magmatic mushes and I think that Stromboli can help us learn more about the fundamental physics before we go bigger, deeper and more complex.
Question 2: Does your model account for magma viscosity and % crystals in the mush?
A: Yes, that's a key component. All of the dynamics we model arises from these two factors.

Question 1: Would you be interested in expanding your models to accommodate reaction-induced mechanical behaviors? (e.g. https://doi.org/10.1016/j.epsl.2017.06.045)
A: Absolutely.
Question 2: That stromboli-type eruptions show multiple forms of periodicity suggests that machine learning could be used to ID similar patterns and possibly even disentangle the relative importance of each phase involved. Do you know of, or might you be willing to share, any datasets amenable to those kinds of questions?
A: Sure, machine learning is valuable for many things. Unfortunately, I don't have any data sets to share, because we do not collect or measure data. My group focuses on the modeling component only. All of the data we work with is in the public domain and compiled from previously published work.

Question 1: Are the mechanical and thermal models created specific to one site (here, a part of Antarctica) or can they be used to study other sites flexibly by varying the parameters?
A: All of our model are custom-developed for a specific site and research question. In principle, they could of course be transferred to other sites or used to answer different questions. That being said, the devil is in the detail and oftentimes a new site or question raises new issues or opportunities that require a different model appraoch.
Question 2: Not having a geology background, I would like to know if there is a possibility of a multiphase flow from all the four elements- (Fire, Ice, Water and Rock) working simultaneously over different timescales?
A: Sure. All four are relevant for Antarctica, actually (we have quite a few volcanoes burried underneath the ice). I personally prefer simple models but in theory you could throw in everything the want. The question then is, why would you want to do that to yourself and your model?

Question 1: Is the gas permeability of the magma to blame for the ~10 min strombolian eruptions because that's roughly the interval of mush failure?
A: The permeability is a big part of the problem, but certainly not the only part. I think the eruptions are a combination of different things including the large quantity of gas, the high crystallinity, the tectonic stresses etc. Neither of these in isolation would give you the eruption.
Question 2: I understand how flow can lead to fracture but what is an example of fracture leading to flow?
A: Antarctica is a great example. The failure (or fracture if you want) at the ice-sediment interface creates a pathway for water and sediment flux.

Question 1: How can your model be adapted to study flow features (lava flows and impact melt flows) on the Moon?
A: That depends on the specific research question you want to ask.
Question 2: Can your model be applied to evolving magmatic systems, particularly those with bimodal compositions?
A: That’s something we’re currently working on, so I’d say yes.

Question 1: Do you think the standard methods and trends of modeling should be altered to address the less polarizing view of fractures and flow since current models may suggest that they are unrelated processes?
A: Our models are intended as a complement to existing, standard methods. I think science progresses best when we have a diversity of models rather than a single one.
Question 2: You mentioned that a specific section of the ice cap lacks any movement compared to the rapid ice movement nearby, and that scientists aren't sure why. Do you have any hypothesis behind why there is such a high variability in movement in this area of antarctica?
A: Basically, because of the complex physical interplay between ice motion, meltwater generation and percolation and sediment stability. I don’t think we can explain this variability if we only look at the ice in isolation.

Question 1: Can or have you applied your models to mudslides, tsunamis, and avalanches?
A: Sure, I would expect all of these system to exhibit some similar behavior.
Question 2: The volcanic pulses seem similar to geysers, and the movement of the ice sheets on water seem similar to tectonics - are these good analogies?
A: I personally think that we tend to be too quick to envoke analogies in Earth science. Only because processes look similar on the surface, that does not mean that the physical processes driving them are the same or even similar. For example, I don’t think that geysers are a good analog for basaltic volcanoes. From the point of view of mass and momentum conservation maybe, but from an energy point of view they are profoundly different. The key difference is that water is stable at surface temperatures, but lava is certainly not. So, the energy flux is critical for the survival of a volcano, but not for a geyser.

Question 1: How is the surface parallel fault described in terms of strike and continuity?
A: I don't think we need these concepts in the case of Antarctica, since we know perfectly well where the fault is and why.
Question 2: Does your conclusion about Kamb suggest the ice melted and then refroze 30km away?
A: No. The ice has nothing to do with it. My models suggest that water was rerouted beneath the ice, which altered the stress distribution on the sliding interface and led to a rearrangement of the streaming zone. The ice passively reflects these subsurface changes, but does not play an active role in this.

Question 1: Is the modeling technique used for Stromboli applicable to all stratovolcanoes, and do the same principles apply to other kinds of volcanoes?
A: It depends. Some aspects are similar, others are different.
Question 2: What caused Kamb to die abruptly? And, over what time scale did this happen?
A: If likely died over a hundred or so years. We don't really know why, but likely because the water flux in the subsurface changed.

Question 1: Thank you so much for the wonderful talk. You focus on various extreme events, but which one extreme event do you think needs more attention today in terms of its science and understanding?
A: That depends on what you are trying to achieve. I would argue each is important in its own right, but to me, they really come to life when thinking about them jointly.
Question 2: According to you, are new theories that one develops by looking at one experiment or setting (of a problem) might be useful in another setting?
A: Sure. We learn more about these problems which each case we're thinking about. It's also important, however, to appreciate a new site for its novelty rather than jumping to conclusions based on a prious model that might or might not apply.

Question 1: In your coupled finite element model for evaluating the effect of tectonic stress on fluid flow in Stromboli, how do you account for variable rheologies within distinct phases?
A: In the finite element model, we don't because that is only intended for the stable volcanic edifice. We do capture rheological differences in our mush models.
Question 2: There was mention at the end about extending this work to large-scale geodynamic models, do you think your codes are suitable for these applications or would they need to be modified?
A: Our models are custom-developed for a specific problem and site. They are not meant as big community codes, but as small thought experiments to test a specific hypothesis. So, you would basically need to write a new model, but you could certainly reuse components of previous models.

Question 1: You are modeling things at not only different time scales, but also spatial scales. How do you determine the correct cell sizes in your mesh models?
A: We do convergence tests. If your cell size is small enough, you will get the same answer independent of grid size. In my opinion, convergence tests are an essential component of all numerical models.
Question 2: You briefly mentioned the earthquakes in Oklahoma. Based on your models, how should we be injecting the waste water to mitigate future earthquake events?
A: We have developed a specific model for that (I just didn't get a chance to talk about it). I think that's a decision based on the field scale and requires both injection and microseismic data. In our model, we find that not all wells contribute equally to seismic hazard, so it's probably a good idea to be strategic about which ones we keep operationg and which we don't.

Question 1: How can mush failure account for the systematic or relatively evenly spaced timing of eruptions in volcanoes with a steady state system? It seems like the eruptions should be random and not uniform.
A: Failure is not usually random and uniform. In my opinion, the tectonic stress field breaks the uniformity at Stromboli. It makes mush failure more likely in the crater regions. The episodicity is related to the energy and gas release (not unlike an earthquake cycle, although that's a dangerous analog, because there are many differences).
Question 2: I am curious about your research involving combining fracture and flow with extreme water events. How do you model a fracture in water - is by the separation of temperatures?
A: The fracture does not happen in water. The fracture (or rather failure) occurs in the sediments (similar to Antarctica).

Question 1: Will some other minor components of ice (e.g. salt) change the ice model?
A: Everything changes a model. I think the more relevant question is how would the addition of salt improve the model?
Question 2: Will different mush affect the "mush failure" model ?
A: Sure.