Student questions: Erika Rader colloquium on "Volcanic Spatter Across the Solar System: How Idaho + lava bombs = water on Mars"

2/6/19

Question 1: What are some other sources of gas that might create secondary vents besides water vapor? **On Earth there is currently no other known source for generating spatter than water. The key is that the water is rapidly expanding as it changes from a liquid into a gas form. We don't have conditions (the right pressure and temperature) here to have other liquids turn to gas with the addition of heat. However places like Titan, which have liquid methane, might be able to generate some firey explosions!**

Question 2: Are there any basaltic volcanoes in areas with permafrost, where a lava flow could release trapped methane? **Yes! There were volcanes all throughout the last glacial maximum when permafrost was much more expansive. However, a very recent example is a flow field up in the wilderness of Alaska where an eruption occurred between 1 and 2 thousand years ago (https://www.google.com/maps/place/Imuruk+Lake/@65.5200424,-163.5062726,17438m/data=!3m1!1e3!4m5!3m4!1s0x573260ce2688b76d:0x581317eba06c68bb!8m2!3d65.5844717!4d-163.2098492). This flow, called the Lost Jim flow, looks a bit different because of the permafrost. It's thick and inflated like a bouncy castle, yet no evidence has been written up that shows that the water or methane (which was most certainly released when it erupted) caused any explosions. This is probably because the melting and methane release occurred slowly instead of explosively.**
But methane release during an eruption is thought to have maybe contributed to the dinosaurs' demise (http://science.sciencemag.org/content/297/5588/1808?casa_token=i2hB2GemyMMAAAAA:mWroQD0ZP398g-nTGAKuIaGD78g7M1625L_jKS9iOh9cebzijEl9G71XHCj7pLugpVyhB3ddRm9gSxU).

Question 1: Have you or do you plan on testing spatter to "extreme" temperatures to compare against results you already have? **The temperatures we tested originally (the failed attempts) are actually fairly extreme. Hotter than normal basalt eruptions, which is why we had to cool it down a bit. But some people are interested in researching 'impact melts' which are blobs of melt that get shot out of a crater when a meteor hits a planet. Those melts are SUPER hot and will spray little beads out into the atmosphere, or just into space if there is no atmosphere. Those are called 'tektites' and ASU has some right up on the 2nd floor of ISTB4. Look for the neat spoon and tear-drop shaped black blobs!**

Question 2: Have you come up with any other ideas you would like to try, to replicate spatter? Using an air cannon at a set psi to shoot through the flow at set time intervals. It should cause the spatter to accumulate in a general area and there would be no need for manual stacking. It would be similar to the leaf blower but you could adjust the surface area of the flow affected, so you could produce globs of spatter. **Oh yes! So many! The problem with the aircannon was that the lava would drape over the edges of the cannon changing the force needed to expell the bomb. But a system with a consistent force is super important for forming a pile. The next phase of our spatter plan is to craft the bombs in the same way as you saw in the video, but place them into a catapult-like contraption. This will allow us to control the trajectory as well as the launching force plus have the appropriate thickness of skin on the bomb.**

Question 1: Could spatter volcanoes theoretically exist in the ocean? **Yes! This has happened and been found at the Vance Seamounts (https://www.sciencedirect.com/science/article/pii/S0377027308004563) but no one has witnessed an eruption like that yet. But that kind of eruption must have produced some extremely hot-fast pile ups to keep the outside of the clasts above the glass transition temperature and build those little cones!**

Question 2: Are these volcanoes heavily influenced by plate tectonics? If so, how could these be replicated on Mars without plate tectonics? **The volcanoes at Craters of the Moon are influenced by plate tectonics but not in the same way that subduction zone volcanoes are. In Southern Idaho, the plate drifted over the Yellowstone hotspot tens of millions of years ago. This caused the crust to heat up a lot, some of which got stuck in the crust until the big basin and range event started pulling Idaho, Utah, and mostly Nevada apart. That pulling opened up cracks that allowed the old heat from Yellowstone to generate melt and produce the spatter-erupting volcanoes.**
However, plate tectonics is not necessary for spatter. The volcanoes in Hawaii produce spatter, but those are hotspot volcanoes just like we see on Mars (at least regarding the big volcanoes). The smaller ones, no one really knows how they form, but perhaps they are just very small failed hot spots. No need for plate tectonics.

Question 1: Is it possible to create silicic lavas? **Sure is. I found spatter bombs on the top of obsidian flows (silicic lava) in Oregon before. Seems like they are universal, although not quite as common in rhyollites.**

Question 2: Have you thought about basaltic lava and regolith simulations for the Moon? **No, I haven't. People have done experiemnts looking at soil and lava, but not regolith. Perhaps you should be the first??**

Question 1: What is the difference between spatter and spatter bomb in size and shape? **The term 'spatter' is ther plural form for a bunch of spatter bombs. There is no cut off on the upper size limit, but to be a bomb, it must be bigger than 64 mm in diameter. Any shape is acceptable, as long as it shows evidence of having been hot and somewhat ductile when deposited.**

Question 2: What was the most difficult obstacle to overcome when recreating the spatter bombs? **Money and logistics! As always. The furnace is expensive and finding time when I could use it was challenging. I had to camp out in Syracuse for a whole month to hit the right window to do my experiments. Luckily, I was able to piggyback off some other student projects when I was just trying things so I didn't have to come up with grant money until I had a method that actually worked.**

Question 1: You showed the variability of welding between bombs. This should also be a function of the mass or the size of the bombs. The lava temperature emanating from the source should be relatively similar for all ejecta, but we see a markedly different final structure. The smaller bombs, cool faster, and seem to penetrate into the larger bombs (e.g. throwing a small rock into some silly putty). Have you explored the role of the size of bombs in the cooling rates, and welding structures of the final deposits? **Excellent train of thought! Yes, I have considered this and tried to examine this affect in the natural clasts as well as the experimental clasts. It is very hard to pull out of the data because you need many many blobs measured to be able to compare size categories within a sample population. Usually I could get 10-20 clasts in a single sample population. Perhaps with more development of this technique, we will get to the point where we can use the thermal history of the different sizes of clasts to calculate the fountain height or flight path of the clasts, which would be very neat and open up a lot of doors for how to use physical volcanology research in the future.**

Question 2: Excellent experimentation. How much effort have you placed in the design/build of a more representative spatter-producing system? The modified apparatus used in flow experiments which is working well, however, a "spatteratus" may be the key in future efforts. You can use the name when it happens! :-) **What a fantastic name! I have been working on designing a furnace-catapult system at Idaho and have only thought of terrible names so far. If the gods of scientific research and funding allow for its creation, I will absolutely take you up on this. The beauty of the catapult is that we can still hand-craft the bombs with the paddle, but then launch them in a much more controlled fashion after they have the right thickness of crust. Thank you for the suggestion!**

Question 1: Do intermediate or felsic eruptions also create spatter? **Yes! There are a few accounts of finding these rocks with non-basalt compositions including Ethiopia, Tenerife, and New Zealand. I even found some spatter bombs (though not welded together) on top of a obsidian flow in Oregon. Super cool! Those will be a lot harder to make in the "spatteratus"!**

Question 2: Could volatiles other than water be responsible for the possible spatter volcanoes on Mars? **This is a great question (which is what people always say when they don't really know)! Theorhetically, yes. CO2 could also be a culprit on Mars. If you want a more thorough answer than that, find this paper on your library's search engine.**
https://www.nature.com/articles/302663a0

Question 1: Beyond the surface deposits surrounding volcanoes, how long/deep into the rock record are lava spatters preserved and recognizabl? **Yes! A very important thing to keep in mind! These deposits can be fragile and degrade because they have so much glass in them and glass likes to weather more rapidly than other rock types. However, spatter has been found in deposits hundreds of millions of years old, granted in the very dry region of India (https://link.springer.com/article/10.1007/BF02704041). On dryer places with fewer resurfacing events (volcanic eruptions, earthquakes, subduction zones…) spatter could last for a whole lot longer.**

Question 2: On a related note, is there any current way to access the majority of mars' rock record, or are we limited to only observing surface deposits? **The very first tool to access the majority of Mars' rock record just dug in a few months ago! InSight is a little seismometer which will be able to "hear" the rocks all the way to Mars' core (https://mars.nasa.gov/insight/). This will tell us broadly about what Mars is made of, unfortunately, if that rock is spatter will not be known until rover or crewed missions to Mars target volcanic areas.**

Question 1: Besides the similar looking splatter formations on Mars and Earth, is there any other evidence that makes a connection between the two in terms of lava bombs? **Nope! This is a fascinating part of planetary science. First assumption: processes are generally alike until proven otherwise. Second assumption: if it looks similar… maybe it is similar! Planetary scientists spend their whole careers trying to find ways to use the little bit of data that we have from other places to show how things are the same, or different to Earth. So other than lava bombs happen when you have volcanoes and we see volcano-shaped things on Mars, there is not a lot to go on.**

Question 2: Are there any other experiments being done to test the connections between Mars and Earth's splatter formations? **It's a lonely road I walk. ;D**

Question 1: What leads to identifying spatter bombs as indicators of water? **The theory is that spater bombs that form from water interaction will be chilled faster than bombs generated from magmatic gas. So these bombs might have thicker crusts, have more raggedy edges, fewer bubbles inside. My student and postdoc next year hope to find this answer by studying the spatter bombs along the Laxa river in Iceland. Stay tuned!**

Question 2: How different are the blobs of lava on the moon from Mars? **We don't know yet! But if we think about how the physical constraints are different (lower gravitational force on the Moon, zero atmosphere) we can makes some guesses. First, the blobs will be more rounded because the surface tension of the liquid lava will be stronger than the pull from gravity. Second, the might be much more fused together because the lack of convection will mean they can't cool quite as quickly as they can on Mars. So we might have taller, steeper-sided, more bulbous-looking spatter cones on the Moon compared to Mars.**

Question 1: How can you tell if rocks are truly fused together or if the surface that they break across is just a broken fragment of itself, rather than a boundary where two pieces were fused? **Ah! A good question from a natural-born skeptic. It takes training to recognize what the margins of these bombs look like. In the experiments it is quite easy to tell since there's not a lot of contorsion going on and you can see all sides of every bomb, including the surface where the chip broke off from. However, in the natural deposits it is more challenging. We trace the margin of the bombs in person up close, then take a million picutres so we can draw out the lines on the photos that I showed you. If a bomb breaks into pieces and then those pieces fuse together, that is very interesting because it means the bomb must have been hot enough to fuse, but cold enough to break…. This is a difficult situation to be in and luckily, none of the deposits I've studied have shown this behavior.**

Question 2: Are the methods of experimentation used reliable enough to be compared to similar processes that would occur on Mars or does more data need to be collected before this assumption can be made? **More data definitely needs to be collected, but if Opportunity sent a photo back tomorrow that looked like a spatter deposit, you bet we would try to roughly constrain how hot those deposits were!**

Question 1: How would the atmosphere on another planet like mars affect the cooling rate of spatter? **The atmosphere on Mars (compared to Earth) is much less dense. This means that heat transfer is not as efficient as it is on Earth. So deposits would actually be hotter for longer, which would shift all the data I showed you towards lower accumultion rates.**

Question 2: How far can splatter bombs travel from the eruption site? **Oooo well the farthest I've ever seen was possibly 200 meters. There are other types of bombs (breadcrust bombs for example) that have been launched thousands of meters!**

Question 1: How would the low atmospheric pressure on Mars impact how gas influences spatter? **The biggest impact is on the cooling rate (see answer above) but there are also ideas about how the lower pressure might contribute to gasses coming out of the magma deeper in the crust. This means explosions that make spatter might occur deeper down, blowing big holes in the crust instead of waiting until they get the surface before releasing their gas.**

Question 2: How would different types of gases impact spatter? **I have no idea! Maybe different gases would cause the glass to turn crazy colors. That would be awesome.**

Question 1: What is the timescale of these splatter processes if there is water in the nearby neighborhood? **Minutes to weeks. The heat can stick around for a long time.**

Question 2: What pressure levels are these processes likely to take place? **Not sure, actually. The force of bombs being ejected can be quite high. Super-sonic even. I'm no physicists so I don't know how that translates into pressure levels.**

Question 1: When creating the individual bombs with gravel, did you need to standardize the amount of "crust" created, or did it not matter on that time scale? **Any good experimentalist must standardize and control every parameter! I am a shoddy experimentalist so all I did was mush it around until it 'felt done'. Turns out when you are right next to a giant roaring furnace and you have to don bulky gear to try and mix rock into rock with a paddle, it is very hard to measure things. Given the fact that we could not control the volumes of hot or cold material (some of the gravel would resist being mixed in), I focused instead on trying to get the right consistency of material. Perhaps future advanced will include a more standardized way to make this stuff.**

Question 2: Did you need to "preheat" the gravel before mixing it in with the lava? **No, but it did rain on us once and the gravel got all wet. It made shaping the bombs very steamy and difficult to see. Pre-heating the gravel is a good idea, though. It might allow for more realistic crystal textures to develop even faster. I will try it next time for sure! Thanks!**

Question 1: I know that in your introduction they said that you got into volcanism because of a trip to the Galapagos, but, what peaked your interest to begin with? **National Geographic documentaries. My family didn't have TV but we could rent a movie on the weekend and since all naughty things were not allowed that left us with documentaries of natural phenomena and animals. I thought I'd like to be a biologist for approx. 2 years in college but realized I was not cut out for all the pipetting.**

Question 2: What *is* the blue coating? (What is it associated with) **A mystery! We know that the blue coating on natural lavas comes from a high degree of titanium bonded with the iron oxide minerals, which reflect blue light. Why do they form? No idea. Why are they at COTM and some other places but not everywhere with high titanium? No idea. Is it high titanium in our experiments that makes it blue? No idea! We need some very powerful microscope time to see if the tiny crystals that form in those areas are titanium rich. Not a priority, unfortunately, since titanium-rich blue crystals will not save the world (or make it any money).**

Question 1: Could you inject gases like CO2 into the experimental melt to get a more realistic flow? **Yes, the gravel essentially does this. There are trapped gasses inside the gravel (water and maybe a bit of CO2) which is released when they are heated up by the molten rock. That's why there are so many bubbles inside the bombs. I love see them blow themselves up when all that gas can't escape.**

Question 2: Could you find spatter cones under the ocean to see how cones interact with that environment, and potentially use the findings to find evidence of water on other planets like Mars? **Doing field work on the bottom of the ocean is rough, and expensive! But, if someone offered me a seat in the submarine to go look at ocean spatter I'd totally take it. Could it tell us about water on Mars? It certainly might, but a lot of things would have to match up to link those two worlds together first.**

Question 1: What techniques allow for the the testing of the splatter bombs? **Drones.**

Question 2: Where on Mars would we start looking for splatter bombs? **The Martes Valles and all the other hypothesized rootless cone fields scattered in that area.**

Question 1: How does a thin or nonexistent atmosphere's effect on the release of gas affect the spatter cone? **See the answer to this question above!**

Question 2: Is the spatter effect limited to any particular kinds/viscosities of lava? **It does not appear to be! People have reported spatter bombs in virtually every type of lava, which is quite exciting. Can you imagine seeing a fire fountain that was shooting obsidian bombs up in the air? So neat.**

Question 1: What effects could the chemical composition of the material have on the production of the spatter? **Ah! See above but also, as the chemical composition changes from basalt (what I studeied) to thicker, more viscous lava (like rhyolite) the bombs might get bigger since it's harder to rip apart thicker stuff. No one has ever witnessed these kinds of eruptions (or at least no one who wrote it down or passed the story on to younger generations who then wrote it down). So we don't quite know!**

Question 2: Are you planning on doing different deposition experiments with the gravel mix? As in, are you planning on dropping the mixture off the forklift like before, or would that take to long and solidify the material? **My new hairbrained idea is to build a catapult, which would allow us to make the bombs in the trough with the paddle like before, but then we could still see the effects of flight and landing on the fusion and shape. Wish me luck!**

Question 1: What kind of technology (computer tools) do you use to analyze spatter? **There are software programs that we use to help us measure various aspects of spatter (ImageJ is the big one). But we also use numerical models to study the cooling rates of the experiments to make sure we aren't simulating something totally incorrectly.**

Question 2: What do spatters reveal about the nature of the interior of the Earth's mantle or core? **That it's a gassy gassy place down there.**

Question 1: Did having to manually prepare each spatter bomb effect your ability to recreate any natural conditions within your experiments? **Yeah, for sure. The process is quite tiring so doing them rapidly one after another is difficult. This meant that we could build giant piles, which is more realistic. However, I believe that we could do a better job of this if we had two spatter-bomb making teams working in alternating fashion. Then we could build bigger piles, which will affect the thermal insulation of the interior bombs much differently.**

Question 2: Does the composition of our atmosphere influence the characteristics of of spatter bomb piling/fusion? **I do not believe it does… but I'm not sure! Until this batch of questions from you guys, I never even tought about how different gases in the atmosphere react differently to cooling or bonding with glass.**

Question 1: If possible, in what ways could remote sensing be used to distinguish between the different types of splatter deposits? **Oh! So there are two ways that we are developing right now! The first is simply using imagery. By imaging the spatter enough, we could hopefully detect how fused, how squashed, and how bubbly the bombs are. These are all characteristics that a distinct in the types of spatter. The second way is that the cooling rate of different types of spatter may be preserved in the glass content of their rinds. We can detect that glass using spectrometers that are currently on (or will be on the next) rover missions to Mars. We need to do a whole lot of calibrating it to Earth volcanoes, which his the goal for the next few years.**

Question 2: Can the presence of vegetation produce noticeable signatures in the shape or composition of these splatter deposits or the lava flow itself? **It is very hard to get vegetation into a spatter deposit. Mostly, the burn and are gone long before the spatter has much time to pile up. HOWEVER, there is a super super cool rock that formed just north of ASU outside of Flagstaff that no one really knows what is up with it. It's blobs of lava, like spatter bombs, but they contain impressions of corn. Like whole cobs of corn. There's a great little paper about how scientists could not recreate this rock by shoving corn cobs into lava lobes…. But they didn't have a special lava-making machine so maybe there is more work to be done on these things! https://www.cambridge.org/core/journals/american-antiquity/article/lava-corn-and-ritual-in-the-northern-southwest/37B6FE684EBE4E682914933F0FD54A59**

Question 1: Why does the spatter distribution near Washington have linear patterns? **Many vents are linear because magma will take advantage of cracks in the Earth. The ones out in Washington likely formed from back-arc subduction forces pulling the coast closer towards the ocean.**

Question 2: Do lava in different planets have huge difference in component? **No, actually! Well at least not as far as we know. The Earth makes a lot of very different lava types and while we can hypothesize about differences on other planets, so far everything has been compositionally similar to something on Earth. I think……**