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Moderator: Jeff Nee
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Jeff Nee: Hello everyone. Happy Tuesday. This is Jeff Nee from the Museum Alliance and it's our pleasure to welcome you to this telecon today. Thank you to all of you for joining us and to anyone listening to the recording in the future.

Today we're hearing about the anatomy of the blue dragon lava flows. The slides for today's presentation can be found on the Museum Alliance and Solar System Ambassador sites. As always if you have any issues or questions now or in the future, please email me at JNee@JPL.NASA.GOV.

Our speaker today is Dr. Alex Sehlke, a post-doctoral research fellow at the NASA Ames Research Center. He started studying geosciences at the Leibniz University of Hannover, Germany and he got his PhD at the University of Missouri, Columbia. He's studied lava flows and surface morphologies around the world, including Hawaii, Guatemala, and Costa Rica.

And he's working as part of NASA's field investigations to enable solar system sciences -- also known as FINESSE. He's also part of the biologic analog science associated with lava trains, or BASALT. NASA does love its acronyms.

His full biography can be found on the websites. And without further ado, Alex, take it away.

Alex Sehlke: [Slide 1] Well, thank you so much for the introduction and thanks for having me today. It's a great pleasure to introduce all the results I've done for the project of FINESSE. And in the next 45 minutes, the talk [will] focus really on the FINESSE goals, which is the science enabling exploration and vice versa. The science that I'm presenting here is understanding the changes in lava flows -- especially the physical properties of the lava and how they correlate to surface morphology. Then [we'll discuss] the exploration -- how this relationship actually can be used to infer these properties by looking at the lava flow morphologies through remote sensing techniques, enabling us to better understand the landscape and its volcanic history before we actually go to the Moon or other planetary objects.

[Slide 2] Let's just skip to slide number two. And I'm giving, in the next couple slides, a quick rundown on some of the most prominent lava flow features that we have across the Solar System. I'll keep it really broad. Second slide is just lava flows on the moon. They're really long. There are a lot of them, especially in the mare regions. They can be even really specific, such as lunar rilles which are kind of like deep excavated lava flows into the ground.

[Slide 3] If you go to slide number [three], we see a couple more features. On the larger map, there's a lot of red dots. Those are actually a recent study that just came out, mapping out really recent lava flows up to ten million years, which are kind of lava flow blobs coming out of the surface of the Moon.

[Slide 4] Slide number four, skip to Venus, and we have a variety of land forms there too. We have these pancake shaped lava domes. And then we have large expansive lava flow fields as well, as you can see on the right side which is emanating from impact crater site most likely.

[Slide 5] If you skip to slide number five, we have lava flows on Mars. Again, the scale is huge. If you're looking at the map that's kind of rotated on the left, there's a little 200-kilometer scale on the left bottom. Those are large lava flows, [that] extend hundreds of kilometers. And they're mostly in the Tharsis region where we have a lot of volcanoes. There’s a kind of false-color image of the basaltic rocks that we have identified on the surface on the bottom right corner.

[Slide 6] Next slide, number six, still on Mars. And there we have a large lava flow field that’s coming in from the north, from the right side of the image on the bottom, which kind of looks rough, and then it stops somewhere where we see, on the left, kind of linear features, some kind of channels or something. We can clearly see the lava flow margin and it doesn’t really look -- at least in my eyes -- doesn’t really look smooth there at all. You see all kinds of features on the surface.

[Slide 7] If you go onto slide number seven, still on Mars. I always have to mention the largest volcano we have in the solar system Olympus Mons -- just as big as the entire state of Arizona.

[Slide 8] If you skip over to slide number eight, we have Mercury and we see the same thing -- huge lava flows. The entire northern hemisphere of Mercury is actually one coherent lava field that’s called the Northern Volcanic Plains. And if you superimpose that to the Continental US, it’s almost as large as that. So, it’s huge.

[Slide 9] And we have a variety of lava flow features, different morphologies in channels. They’re coming in from one side and that’s frame C. It’s just coming in from the left side of that image and then just abruptly stopping. If you go to the right panel, picture D, we can actually see it as lava flows filling up impact craters. And right below that there’s lava flows that are coming from both sides. So there’s lots of lava just flowing onto the surface.

Then on the bottom G, you actually can see that old ancient craters are totally buried. You can just see kind of the outlines by those lava flows. So there's lots of volcanic material on the surface that has been just running down the hills.

[Slide 10] If we go onto slide number ten, as an example, there's maybe even lava flows on the surface of asteroids, the larger ones. And here that is an image of asteroid Vesta. There're lots of question marks, so it's still debated if there's really lava flow features, but for sure there are signs that this is all magmatic history in the rock itself, as we have some samples that are asteroid samples that have landed on Earth that we attribute to coming from the surface of Vesta.

[Slide 11] Then, I think it's the last one. If you go to Io, which is a moon of Jupiter, it's constantly erupting. It is the most volcanically active body in the Solar System. And we see the same feature in here. You have a nice global mosaic on the left. If we look at it in one frame on the middle, we can actually see a huge lava flow as well. Changing its shape, starting out on the bottom center, kind of dark and kind of slim, and then it widens as it goes further up in that image. And if you zoom in a little bit more, you can see the edges change, even the colors change on the surface. It might reflect some different types of morphologies in here.

[Slide 12] And the next slide actually just a copy and paste error by me. So we have talked about this already so we can just skip over in here. So we're now on number slide 13. And this is where the hypothesis comes in here.

[Slide 13] We've seen a lot of basaltic lava flow. Basalts are covering the entire Solar System where we have volcanic activity. So it's useful, first of all, to study that kind of material on Earth to understand it better. So what I hypothesize in my project is that the lava flow morphology corresponds to specific values into the properties of the lava. And such properties would be crystallinity, vesicularity -- so how much bubbles and crystals are in the lava -- the density that's associated with it, and the eruption temperature.

Nicely, these all have an impact on the viscosity of the lava. Once we can understand this entire relationship which is kind of pictured in that little diagram on the right bottom side where it says "Lava Morphology." We can actually go backwards in that because lava flow morphology is what we can see, and I know and we know that the lava flow morphology corresponds to the rheology, which is basically the viscosity of the lava.

The rheology is really influenced by these two main things: one is the eruptive conditions, which is the magna flux coming out, but it's also depending on the temperature. The temperature has a lot of control in whatever's going on in the lava flow. It includes the density, and it also changes the crystallinity, and it has influence on the vesicularity.

Understanding this base, or connecting this base of these properties to the rheology and the morphology can actually help us to use this as an exploration tool, which is using the morphology to actually infer those properties.

And on the left side of that same slide, number 13, the little graph from the 1980s, it shows the two-specific lava flow morphology types that we usually find in basalts, which is one is called pahoehoe and one is called a'a. And we'll show you nice videos of that just after this slide so hold on a second. But these both surfaces basically are divided by a zone where things change in morphology. And this change in morphology corresponds to either a change in strain rate -- so how fast did it form the material, or how fast it's actually flowing through a channel, for example -- and the viscosity itself.

And now that we know the viscosity depends really on what's going on in the lava flow, it will always basically have a framework we can work with to understand what's happening in the lava and how we can exploit this mechanism.

[Slide 14] All right. I hope for everyone if you go to slide number 14 that this will work. On my YouTube channel, I've put up four or five videos that I'll use in this talk. What I like to do first is, for the ones that don't have as good a sense as I do, maybe, for the different types of lava flows, I've put up some videos here. The first one we're talking about is pahoehoe. Usually that is something that is found close to the vent of a volcano.

And there's a link underneath the image. If you click on that, it hopefully should direct you to my YouTube channel and it should show that video. I'll just give everyone a second to just click on it and let it load. While that's happening, I'll just explain what you can actually see in that one frame.

You see black stuff, which is basalt,and you see red stuff. That's the hot lava that's underneath the crust kind of coming out. You see it's flat and shiny. It's not really a rough terrain in that sense. You'll see it later. It's a little bit different. In the front, you can see kind of wavy things. Those are Pahoehoe ropes that form when a crust is moving but it's kind of stile ductile, so it still forms plastically. And then it cools. And underneath, there's still the hot lava. So let's have a look at how those things actually move.

And if you click Start, you can see these things just oozing out like honey or something like that. Looks like it's actually moving pretty fast. It can be even faster than that. We are quite far away from the vent, I would say about 10 miles or so. So it has already travelled a long distance, but it's coming out really flat. If you just want to repeat this again -- it's really short -- you can see how nicely it's flowing.

And I've beenthere on the big Island of Hawaii, at the Kilauea volano in 2012, and actually have sampled that stuff. So I stuck my hammer in it. It's really exciting. Which is shown in that next video.

[Slide 15] So what I will basically do on slide number 15 and that is in a link down there, I will crack open one of these lobes to actually sample the lava flow. Not just fun purposes, but also for scientific research.

So if you click on the link, I will take my hammer and I will crack open the crust. You can see the crust is still kind of plastic. And then I'll scoop my hammer in it and it just drips off the hammer. It's really fluid lava that's still underneath. It's really hot. We are shielding our faces with our hands. We're not really having any super-protective gear because it was a really spontaneous trip with the USGS at the time when we were at their conference in 2012.

I'll just repeat it again. Crack it open, really have a look at what's inside. Scoop it out with my hammer and it will just drip and fall down. We poured water on it just to cool it down really quickly because if we let it cool slowly, it will crystallize and it will change over time. So we want to have a real-time look at the lava as it's being erupted.

And just in case, are there any questions that I have been running over too fast? Please say so. If not…

Jeff Nee: I've got a quick question, Alex about…

Alex Sehlke: Yes, sure.

Jeff Nee: You said you cool it really quickly because you wanted to… what was that again?

Alex Sehlke: So yes, it wasn't really elaborated nicely, but so we want to cool it off just to freeze it, to basically quench it. What we do is pour water on it. We cool it really fast. So whatever crystals are in there, they have no time at all to keep further crystallizing.

And the reason why we're doing this, and want to do this, is to preserve the initial texture, and crystal content, and vesicularity that's happening right there at that spot in time. So if we cool it slower, it will keep crystalizing. So you have to basically freeze it and say, "you're not allowed to change anymore at all." So that's basically what we're doing.

Jeff Nee: Okay, thanks.

Alex Sehlke: Yes.

Kathy Lowry: This is Kathy Lowry. How does the atmospheric conditions -- the amount of gravity, et cetera -- affect the crystallization and the flow pattern?

Alex Sehlke: So that's a good question. What will eventually happen if we go lower gravity, you have less pressure. I'll come back to that point a little bit later, too. So the lava flow might just be thicker. It might be moving at a different pace because you're having less stress on the lava flow and therefore will be a different strain rate. So that affects and it will actually affect the lava morphology in the end, too.

And in terms of other atmospheric conditions -- let's say a thicker atmosphere like we would have on Venus -- you would have much more efficient convective cooling because you have a denser atmosphere that's cooling off from the top of the lava flow. If you have something like on the Moon, where there is essentially no atmosphere, you would have more radiative cooling.

So cooling might be faster or slower, which will have an effect on the lava flow morphology as well. Does that answer your question? Okay. I hear no follow up. I assume that was satisfactory.

[Slide 16] I will now skip ahead to slide number 16, which is now a different volcano. And I've been there in 2014 when I was a grad student at the University of Missouri. We were lucky enough that we planned our field deployment in Guatemala, the Pacaya Volcano, which is shown on the right-side image- you see the summit crater in the back.

And a week before we actually went there, the side of the volcano decided to erupt. So we were super lucky to actually witness a volcanic eruption there. They are really active volcanoes, first of all. They erupt every other year. But actually, being there, they're not really that long. They're maybe over the course of a week being actually there and watching it, and sampling the rock again. It's fantastic for doing science.

What we're looking at is close to the vent. There's a little map on the left bottom where we see what's called the 1,500-meter line, or elevation line. It's cutting into that red lava flow that's kind of pictured in here. And we're standing right by the corner where it's number four, five, and six. So we're standing up on that ledge looking downwards onto the flow, really close to the vent.

There's another YouTube video if you click on the link. Hopefully it will show up. And it's farther in the distance. What we can see is lava flow in a channel running down on the flank. It looks different. It's not as shiny and flat anymore. It's actually moving quite fast. If you're looking at the left bottom of the video, you can actually see the darker streak right in the middle, which is the crust that's translated or moved onto the surface. And on the channel walls, it's actually the hotter material exposed.

It's moving relatively fast. I think we determined it was about three meters per second or so. It was relatively fast. We actually have been down there in one of the corners; it was super-hot. Just we couldn't stand it for a long time because we weren't prepared for it. That's how lava flows when it's not really that hot anymore. It looks hotter because of the exposure of the camera. It's just adjusting to our lighting conditions so it might look just as bright as before. But it's actually not. It's cooled down quite a bit already. Maybe 100 degrees less than that which is maybe 1,100 in that case.

But that's how it flows down on a channel close to the mid-section of a lava flow volcano. And see if there was anything else to say. No.

If we go to the next slide, hold on. I just want to repeat the little map on that same slide, number 16. The next slide will be at the terminus, which is basically the flow till which is the end where it currently has migrated the farthest. And it will look completely different from what we have seen before, which is called the A'a lava. And let's go to slide 17.

[Slide 17] And there is the next video up here. Before I start the video, or you start the video, I'll just tell what you can see in the image here. First of all, the lava flow -- you'll see running people in front of it, all grad students and me too -- is much higher. It's now several meters. It's now maybe as high as my knee. The lava flow is much thicker. It’s because it’s more viscous in the end. It’s colder and it changes internally.

And the migration form now is not that we have flat lobes that break open and then there’s stuff oozing out. It’s actually bits and pieces falling off this front and tumbling around to the bottom. Then once the lava flow is moving over it, it gets picked up again and it’s kind of moving like that.

So the closest analogy I can come up with is kind of a snow plow truck that’s just moving stuff and then in the front we’ll see all these things just tumbling around, and get carried away, and get picked up again, and so on.

If you’d like to start the video now, I’ll just keep talking. So we can see that in here there’s pieces falling off mostly, but it still looks like the entire center’s moving plastically. There is no large chunk about to fall off in my video. And here, it falls down and just tumbles around.

We’re actually I’ve been sampling that too and that’s me there. There’s a piece that’s just been falling off. And I was really, as a grad student, I was like “it’s just as easy as in Hawaii.” This was about two years later. But it’s not, actually. It’s not that oozy or fluid anymore. It’s actually a solid piece of rock. You have to use your hammer and actually really whack it to break it open. It’s a really tough job. It didn’t look like it at all because if you put a lot of pressure on it, it still moves kind of plastically, but in the end it’s actually really solid rock and you need a lot of force to actually deform it, and therefore [move it].

It was a really long process but what you can see in here is that we now have seen the full spectrum of lava flow morphologies, starting in Hawaii with something that is really smooth and flat and really fluid, to something that moves really slowly, is really hard, is really viscous. It breaks and it looks different. It has a different surface texture; it's kind of rough. It's not smooth anymore. It actually can cut your hands if you don't wear any safety gloves.

[Slide 18] So if you move on to slide 18 -- and just one more word before that. That transition can happen within the same lava flow. It doesn't need to [be that] you always have Pahoehoe in one flow and then I don't have an A'a in the same flow. It happens if you cool to the right conditions, usually within the same flow. You can start with lava flows that are A'a right way because they are erupting at a much lower temperature. They're not always erupting at the same temperature. But if they're hot enough, they erupt as Pahoehoe and then will eventually change into A'a.

And it's somewhat summarized in the next slide, which is slide number 18, which is talking about the viscosity in most cases. Viscosity really depends on the temperature of the lava flow. The cooler it is, the higher the [viscosity]. I can get that from cookie dough. If you take it out of the fridge, it's cold. You can actually cut it nicely into chips or disks to make it cookies. But if it's warm, you actually can roll it and deform it nicely. So that's the same thing that happens in the lava flow, too.

The viscosity depends on the composition. Lava flows have different compositions. Basalts change in their iron, magnesium, and sodium, potassium content, for example, and even more. But they also depend -- viscosity really largely depends on the crystal content and the bubble fraction in the lava. So as the lava will cool, they will eventually crystallize and when they crystallize, of course the crystal fraction will increase. But it will also change the residual liquid in composition. So it's a really complicated feedback relationship in here.

But really the bottom line for that slide is as lavas cool they will change their flow behavior, which is expressed in lava flow morphology.

[Slide 19] If you go onto slide number 19, turning back to that one graph that I showed earlier from the 80s, it was basically a qualitative assessment in where the Pahoehoe and A'a happens. Based on the work that we've done in Hawaii, we actually could quantify what kind of viscosity range that this happens -- usually Pahoehoe, less than 1,000 (Pascal seconds), and that's usually what viscosity is usually measured in. Increase by three orders of magnitude and you will eventually change the lava into A'a surfaces.

[Slide 20] Let's go to number 20, talking a little bit more about fluid dynamics in the end here. This a graph that has different units on the axes [from slide 19]. The Y axis is now the pure sheer stress, in Pascals, and the X axis is the strain rate. And we have different flow behaviors in here. So we have Newtonian fluids, which is a straight line. You can see them here.

And the slope on these lines is basically viscosity, which is the strain rate and the stress. If you have a slower slope, you have low viscosities. If you have a higher slope on these graphs, you have high viscosities. So those are usually fluids that have no crystals or whatever in there.

We can change that flow behavior from Newtonian to a non-Newtonian fluid, which in that case, in the case of lava flow, we call it a "pseudoplastic fluid." It's called, or translates into, "sheer thinning." What that is, it's not a straight line anymore. It's actually a curved line. And what that will tell you if you're having low strain rates, it will have a higher slope on that curve. You could put a tangent on it and it would give you a higher slope. And that means at low strain rates, you have higher viscosity.

If you actually increase the strain rates, going on the X axis to the right, along that dotted line, it will actually flatten out and it will actually come lower on a slope and it will have a lower viscosity, and that's the sheer thining.

The fascinating [thing is], within having the same crystal content, you can change the viscosity of it just by changing the sheer stress conditions on here, which is a really important thing if you're looking at lava flow morphologies.

And then the really special case later on is that red dotted line. It's called a Herschel-Bulkley fluid. It's basically the same thing as we talked about earlier. It's a pseudoplastic fluid that has a yield strength. The yield strength is basically a minimum force that you have to overcome to actually start deformation. And we'll give you an example on one of the next slides that we see.

[Slide 21] If you go to slide number 21, that's basically what I've just said. So I skipped ahead.

[Slide 22] So let's go to slide number 22. It gives you an idea of what these fluids really could be. So Newtonian fluid is something like water and oil. It doesn't depend on the strain rate, or the stress conditions, or with having the same viscosities.

Bingham fluid would be your toothpaste. If you squeeze it out of your toothpaste bottle or whatever, it will actually come out as a nice cylinder. It won't deform unless you put your finger on it, and that's the yield strength, for example. You have to apply the extra force to actually start deforming it.

And when you have Pseudoplastic fluid, the closest you could have in your real, ordinary life is ketchup. Remember sometimes to get it to come out you actually have to shake it, so you put some force on it. It actually becomes more fluid and it comes out of the bottle. And that's what a pseudoplastic fluid really is. You're lowering the viscosity by applying some force to it.

[Slide 23] And to conclude about all the work in Hawaii, we go to slide number 23. We have mapped out the lava flow morphology changes. It starts close to the Mauna Ulu vent. So all that orange on the map is Pahoehoe and at some point it transitions. There's a green area and it turns into A'a- that gets determined at some point, about four to five kilometers and then it just being that really rough terrain that we've seen earlier in the video and in that little image on the bottom in the center panel. That's what that looks like.

[Slide 25] If you go to slide number 25, based on the work in Hawaii, and coming out of that small diagram [at the top left], what we really could quantify is that the morphology corresponds to physical properties. It's the first time it actually has been quantified. It has been always kind of a relative term, "okay, higher viscosity or lower viscosity." But in that case, it was a really nice area to do that work to say, "okay, that changes, and that can affect crystallinity, and that can affect yield strength, and [that can affect] all of these parameters over that course of temperature."

There's another diagram [on the bottom left] which just has those three-color tubes in here: Pahoehoe, the transition zone and the A'a field which is experimental work. And I'll talk about that later on in the demonstration of the Blue Dragon model. So that's what I've been working on for FINESSE. We can do those experiments in the lab to determine at what temperatures these viscosities happen for the real case in the model. Anyway, we have quantified [parameters], and this is how the entire project for FINESSE -- how I came up with it is "Okay we have seen it. It's happening at specific values at Hawaii which is on the right diagram: it's a classification diagram for basalts. The green star is for that particular composition.

We know that lavas have different compositions, and therefore the crystallinity will be different at different temperatures. Also to make the case that these transitions from Pahoehoe to ‘A’a happen at specific values, you have to have a different natural laboratory to go to, and do the same kind of work, and look at this in the same way to find out, “does that happen again?” and, if so, it’s a true thing.

[Slide 26] Without further ado, I’ll just go to Slide Number 26 and I’ll take you out to the Blue Dragon lava flow up at Craters of the Moon, a national monument which is up in Idaho. And there’s a couple images on Slide Number 26. On the left side, you can see the basin and range region, mostly of Nevada, and there’s a little red rectangle zooming in and that’s Craters of the Moon, the entire lava flow field sitting in this Eastern Snake River plain.

And if we zoom in a little bit more we can see now different patches of gray. You can see things. And there’s a little yellow dot in there. And that’s basically that panoramic view that we're having on the bottom of the slide, standing on spatter cones, which is the source vent of that Blue Dragon lava flow, that’s spreading out to the left and to the right, and covering the entire area.

[Slide 27] If you go to Slide Number 27 that is actually is the last video for today and I will show you a nice overview. We’re going along the entire flow, giving you some imagery we collected with an Unmanned Aerial Vehicle, UAV, imagery instead of satellite images. So we're getting a really high resolution to look at it. So if you click at the link it will show up Google Earth first, and we’ll zoom into our area, Craters of the Moon. We‘ll start out at the visitor center, and then we will follow going down, a bit south, and we'll see the spatter cones with the parking lot. Then if we go further south you'll see more spatter cones. That's the high point sticking out.

And then we're coming into an area that's looked a little bit more yellow. That's our own imagery, that large hole, big collapses of lava tubes. That's the Blue Dragon lava flow coming up now is as you can see lots of lobes. They're kind of bright patches. They almost look as shiny as in Hawaii.

At some point, we go further down flow, we're seeing nice channel walks developing. Those brighter patches will disappear, and get less and less and less visible. And actually the terrain will change into that horrible look to your eyes; [it's] really rough to walk on. You can see lots of high points. You can see the pressure ridges, which are kind of like a wavy feature we'll see with your eye on the lava flow. And the further down flow we go, it will become even more prominent. Depending on where you're at in the video you'll stop out at the flow terminus there.

So what you have seen in that video is the transition happening again in a different lava flow of different compositions erupted at Crater of the Moon. And basically, we're going there to find out why is it happening again, and does it happen in the same manner as in Hawaii?

[Slide 28] And if we go on to Slide Number 28 we see one of the first images where those big holes were. We have Derek Sears for scale. You can see it's a flat surface that has lobes. We have the big hole just behind Derek Sears. On the right you see that little higher point sticking out. That's one of the spatter cones up in here.

[Slide 29] If we go further south, further down flow, let’s say about 300 meters from the point we had just looked at, we can actually see this sitting at a higher point on one of the levees. You can see in the middle it says on the top “direction of flow going east.” And you can see in the middle there's a brighter patch which is that kind of lobe feature that we’ve seen in the Hawaii video. It’s nicely flat.

[Slide 30] And it’s a little bit more detailed in the next slide on Slide Number 30. You can see it just looks the same way. I have to tell you that the lava flow here is much, much older. It’s about 2000 years old so there's some erosion and weathering and deposition of anything that's transported by water or wind here. So it’s not a prime example as in Hawaii, but you can see still flat shiny surfaces and the lobes up in here.

[Slide 31] If you go even further down flow, you can see now it’s completely changed. It’s not as nice anymore, and it resembles more that texture we’ve seen in Pacaya in Guatemala, that lava flow where it’s blocky, it's rough terrain, and it's really not nice to walk on. You can break your legs easily if you just step on the wrong piece of rock. It’s just sitting on there loosely and just really dangerous to walk on.

But it's also much higher in relief. Also the surface roughness overall will change. You can easily hide behind one of the larger blocks and people can’t find you anymore. And if you go further in the distance and we see 100 meters or yards you might be covered up until you hip, whereas on the Pahoehoe flow you maybe your ankles or knees are covered. So there's much more relief the further down flow as you go, as the lava flows down in its channel.

[Slide 32] If you go on Slide Number 32, it’s from our field deployment that was just happening a month ago. Further outflow again, there’s a lot of large cracks, and it’s a separate study that we're going to expand this work on. It's really the anatomy of the Blue Dragon, so the flow is called Blue Dragon flow.

Now what we're doing is we're taking that entire flow apart in terms of mapping it out nicely. We're taking samples from every kind of surface: from the channel walls, to the interior, and even into the depths. So that’s what we're doing up in here; we’re actually getting depth profiles of changes in physical properties by Jeff Karlin, one of the teachers up in Idaho, crawling, or volunteering to crawl, into that crack. We had him secured with ropes to get him out eventually, again to get those pieces out there, which is a fantastic scenario to study changes not just with flow distance, but even with depth within the same flow.

[Slide 33] If we go to Slide Number 33, we have those visible images or photographs that we've seen in that video taken. And those are usually stereo pairs. We can create Digital Terrain Models, DTMs in a really, really high resolution.

In that case, it is 5 centimeters per pixel. So we can actually have a pretty model of the lava flow, and really correlate and do all kinds of statistics on the surface flow morphology on the computer rather than in the field. To give you an overview of what we have done, the entire flow is about 2.75 kilometers long. If you follow the entire centerline, you can see a lot of yellow stars in here; that’s where we have sampled over the 2016 deployment. And we have added about eight more samples this year, totaling up to 35 samples within the lava flow. So it is a really detailed study that’s coming out of the FINESSE project. We're really systematically looking at the changes in the lava flow properties.

[Slide 34] If you go to Slide Number 34 there's actually examples of these rocks. Not all of them, because it's a lot, but you can see, in the little hand sample, that they are kind of flat. The first one is right at the spatter cone. It's called a lava bomb. It's kind of looking chaotic. It's really light and vesicular.

And the next one, from further down the flow, it's a piece of the lobe. It's kind of rounded in surface. A little bit further down flow, the same thing, it's kind of a flat surface. Then at some point, sample Number 10, we start [to see] these textures that look kind of jagged, rough, spiny, that are not the typical Pahoehoe anymore. So we collected real samples in the field that show actually the position even on the skin of the rocks itself. And it will change throughout the entire length of the lava flow up to the last sample.

[Slide 35] Okay, now let's have a more zoomed-in look at these rocks and give you an idea of what's happening on a microscopic scale. So we're taking all of these samples now and looking at them with the scanning electron microscope (SEM). What we see is that they start out being really vesicular at the beginning, and there's not a lot of crystals in here. There are bubbles around it, low crystallinity.

[Slide 36] If you go to Slide Number 36 what you see in the black and white SEM images later on is the crystallinity will increase, bubble sizes change and the shapes even change too. We'll really run down quickly because there's a summary slide coming up too.

[Slide 37] Further down flow, you can actually see that it looks crystalline and little gray and white speckles in the gray images appear here more and more.

[Slide 38] Further down flow, 38, the contrast is not really working out nicely on that slide.

[Slide 39, Slide 40, Slide 41, Slide 42] But if you go on further down until Slide Number 42, it’s summarized in a more zoomed in look that will actually give you the changes on one slide. You can see those crystals coming in more and more the further down we go, and that’s really controlling the viscosity, and therefore the flow morphology, here.

[Slide 43] It’s on the next Slide, 43, it's actually summarized in terms of graphs, and we have the first graph, it’s distance versus crystal fraction. You can see it’s not really changing much within the first kilometers. That gray field that we mapped out as the morphological transition zone, we can actually see the increasing crystallinity in here. We have two more plots on the right on the same Slide Number 43 that’s showing the bulk density in the distance and the pore volume fraction.

You can see the increase in bulk density increases up until the transition zone, and it kind of becomes flat in that red dotted line. It's not a fitting line per se. So we can see it’s kind of flattening out within the transition zone and does go higher afterwards.

And the pore volume fraction will decrease with increasing distance. So what is happening in that lava flow is that it’s tumbling around. All this lava is getting reworked in basically squeezing out any bubbles in the lava, so it becomes more and more dense. What’s also happening is that while there are less bubbles in the lava itself, they each are actually closing up. They're not connected anymore, so there’s no coherent pathway to bubbles that you could connect from the surface into the interior of the rock itself. So they're actually becoming really isolated. And that’s a way to measure that too. So we can actually really track down the changes in those properties.

[Slide 44] If you go to Slide Number 44 -- and I'm hoping I'm running not too quickly for this but I've got a check on the time -- you can see actually we're doing some preliminary statistics with the DTMs. It's really important that we have those DTMs because you can now look at the morphology and changes in roughness, and that's really what we want to determine later on in the exploration tool. We can do this on the plot of the right side in elevation versus flow distance.

And we can see it further down flow, and with increasing flow distance, that line becomes thicker, black line becomes much thicker. It's not because I manipulated it somehow. It's because the roughness changes. We have much more relief in the lava flow which makes that plot, that line, thicker. So you can actually determine later on the changes in height from one point to the other, and we see that this increases. And you will have that showing in one of the slides that's coming up.

[Slide 45] If you're going to Slide Number 45, this is a more detailed view here, giving you a little bit more context about the flow morphologies or surface textures that we've looked at before. Close to the vent, first one is where the smooth patches disappear. We have Pahoehoe ropes. It's looks kind of flat and then go and this was a transition zone. It's becoming rougher, within the transition zone, and eventually, coming to the flow end, you can see the flat line becomes really wavy. It's really high point, low point. It's really rough terrain, so the flow roughness increases down flow.

[Slide 46] And it's summarized in one of the slides, number 46. It's just flow distance against the RMS height, which is the root main square height. It's basically the difference between one point and another. You can see it's been [measured] in 50 meter intervals as a first look, based on the centerline itself, just one centerline throughout the lava flow from vent to toe. We can see that, with increasing distance, you can actually mathematically quantify the surface roughness increase overall.

And now that you have determined the flow distance and the roughness values in flow distance and the physical properties, you can now combine these two things into getting a mathematical representation of the surface roughness and correlate these to the physical properties which is on Slide Number 47.

[Slide 47] In that case we have done it for the bulk density which is basically the larger plot is the combination of the two on the right side where you can see the surface roughness is a really simple way to look at this. There're more sophisticated ways, and I'll talk about this in the next slide, but you can see there's a trend, there's a correlation, between however you want to fit it. You can fit it with the blue line. You could give an R squared correlation coefficient.

If you want to give it a more curved line, it's even a better correlation, but the real case, there will be some increase in bulk density, and at some point it will level out, because there is a maximum density a lava flow can have.

So it's the way you want to present it. Anyways, with that one we actually could prove that we can classify the physical properties based on a mathematical representation, in that case surface roughness. But it's a really simple way.

[Slide 48] And our colleagues at Idaho State University, which is a grad student Hester Mallonee and Professor Shannon Kobs Nawotniak in Pocatello, they're actually looking at this much more sophisticatedly, and they're about have this finished. What they're doing is doing the same kind of thing using UAV imagery and doing that RMS height. But they're also doing surface ratio. It's basically a 2-D ratio over a 3-D ratio, and then on different resolutions, you can actually see different reference values in the end. So they're currently working on this and [whenever they're at that point of having it done], we'll run that code over that flow roughness I just showed you and actually apply our findings to that method here.

[Slide 49] All right now there's a little break and it's the last part of that talk. Usually I call that talk in the earlier versions- inferred thermal physical properties, because, as a volcanologist, you would be actually super excited if you could look at the flow morphology and already can predict the temperature. Usually how volcanologists would do it would [be to] get a real rock sample, take it into a laboratory and measure the chemical compositions and so on, to determine what the eruption temperature was. But if you're looking at something like Mercury, or on the Moon, you can't just go there and pick a rock up. So how nice would it be to infer eruption temperature, giving you a sense of the mathematic history of that particular area, and possibly explain something about the thermal evolution of that region and the body itself.

[Slide 50] Well there's a way to do this by morphology. And it's going back into the laboratory where you can measure the viscosity. The main method is doing this at high mathematic temperatures between 1600 to 1150 or 1100 degrees. It's the lower viscosity range. It's called a concentric cylinder apparatus, where you basically have a cup of platinum where you melt your rock in there. You stick a spindle in it, and you rotate it at a constant rate, and it measures the torque that it needs to be at that spinning rate, and therefore with mathematical descriptions you can get viscosity values.

[Slide 51] If you go on Slide Number 51, there's a plot that a volcanologist would do maybe, but what it has is you observe viscosity on a large scale on the y-axis and then reversed temperature on the x-axis. For reference, I give a calibrate scale on the top. I can give you more a sense of what the viscosities of these lava flows actually are. When they’re coming out, they're like honey and their viscosity increases up to maybe sour cream, or even up to peanut butter in Pahoehoe cases.

[Slide 52] So if you go to Slide 52 there’s a lot of things going on in here, which is basically all kinds of melt viscosities for all kinds of planetary surfaces that are measured over the course of the last seven years. But there’s also part of the lava flow on Blue Dragon.

We can see that it will start crystallizing somewhere around 1250 degrees is where those stars symbols are coming in. That is really driving up the viscosity and it's plotted in these stars up here. It’s really deviating from that red fitting line where there would be no crystals. It's just a temperature effect on the melt itself. But as soon as you add the crystals, viscosity will increase several orders of magnitude.

[Slide 53] And it is summarized in Slide Number 53, where you have that same plot we’ve seen from the 80s early on, where we have viscosity on the X and strain rate on the Y. We can collect all these points of different strain rates in the laboratory and we can predict, because we have earlier quantified what viscosity and strain rate ranges these Pahoehoe and ‘A’a should be. We can plot this data up here at those specific temperatures, and we can infer at what temperature that morphology would change for that particular lava flow and its composition.

[Slide 54] And we'll almost be done- here is Slide 54. So what you could do with these laboratory experiments is really label that lava flow field based on morphology saying, “okay close to the vent, it looks like it has been at 1250 degrees and above.” Then it's transitioning somewhere at 1200 degrees Celsius and then it turns into ‘A’a somewhere, at temperatures below 1150 degrees Celsius. So that’s what you can do to infer thermal properties of the lava flow based on remote sensing and some laboratory work.

[Slide 55] And the last Slide 55 is concluding take-home messages, just summarizing really quickly. Hopefully I could convince you that the lava flow morphology really depends on what’s happening in the lava flow itself. And we have a repeating pattern, and it’s happening at the same orders of magnitude in these different properties as we've seen in Hawaii. Therefore, it's a real thing and it should apply to any type of lava flow, whether it's on Earth or somewhere else in the Solar System.

So we can do that work to actually estimate or infer those thermal physical properties of the lava flows. I’m sorry I’m a little bit long overtime but I’m happy to ask answer all of your questions now.

Jeff Nee: Great, thanks Alex. While people are un-muting I have a couple of questions myself. First of all, I love all the food analogies. That actually really helps me.

Alex Sehlke: Yes right. It’s something you need.

Jeff Nee: And I’ve just got to say that I’ve never really had such a concise explanation between the difference between Pahoehoe and ‘A’a. I really love the videos as well, so thank you for those.

Alex Sehlke: Oh that's great to hear.

Jeff Nee: I also had a question about you were saying how we can't go and get samples for these places but we do have lunar samples. How much have you correlated your results with the existing lunar samples that we have?

Alex Sehlke: So basically none of them yet. So what I do is just basically trying and find out the fundamental dynamics or kinetics that's happening in the flow. So at some point, what we would need is really to have a flow surface image in a DTM, as we have shown here, to get an idea of the mathematical description of the surface roughness, to get an idea of where that corresponds within the flow.

The way it really works is looking at the morphology first and then infer the crystallinity itself. I would have to have a look at the rock from the Moon. The people, the lunar scientists, do this. They are looking at the rock and can tell you everything about it: the eruption temperature, and the crystallinity, and so on. So they're already a step ahead, so they don't need me in that part anymore and they can already do all that work based on the samples they have. And this really targets if we can't go there, then this will be really helpful tool.

Jeff Nee: Great thanks. And just so that I'm clear, is there a difference between DTMs and DEMs?

Alex Sehlke: Oh no, it's the same thing.

Jeff Nee: Okay.

Alex Sehlke: It's the Digital Elevation Model. People always change it up. I sometimes change it within the same presentation, but it's the same thing.

Jeff Nee: Okay, just wanted to make sure. All right let's see is Andrea on the line? Did she want to say anything about International Observe the Moon Night?

Andrea: Yes I'm here. I just wanted to thank you again Alex for that great talk and yes remind everyone that International Observe the Moon Night is on October 28 this year. I encourage all of you to go out and look at the moon and talk with your friends and neighbors and communities about it. We are launching a new Web site for this event very soon so look for that with a nasa.gov address coming soon.

Man 1: I have a quick question from Slide Number 9 if I can ask it?

Jeff Nee: Sure.

Man 1: In looking at those pictures you've got those listed as lava flows on Mercury. And I'm curious how do you tell the difference between the termination of a lava flow and maybe a wrinkle ridge or linear scarp like on Mercury or the Moon?

Alex Sehlke: So yes wrinkle ridge I guess it's some sort of…

Man 1: There was a tectonic…

Alex Sehlke: …flow - yes. Yes so wrinkle ridge could be a volcanic feature if the lava is more fluid. A linear feature is a tectonic feature, as we have compression on Mercury going on. There're those scarps as well, especially if you're looking at maybe frame E. If you're looking at the flow fronts, they're people actually looking at the fractals, like how wavy they are. In that case you could do that kind of work, you're looking at how much they deviate on being just a straight line and actually having a wavy outcrop or flow front. That’s a way you could do this I guess.

Jeff Nee: And that I just had one final question about your video 2A at Pacaya. There seems to be a dark stripe like right in the middle of the river. Is that place just cooler than the outsides or…

Alex Sehlke: Yes that’s what it is. That’s a really good observation. So what’s happening as you get closer to sometimes to the edges, it really depends on what the geometry of the lava chain on itself is. There are less disturbances in the middle. It's more of a linear flow most likely. So whatever crust is actually sitting on the top. In that case, it’s crust that’s just sitting there; it's cooler. And on the edges on the walls you have some more turbulence going on where there’s a little bit more overturn or disruption of the crust because it gets jammed and logged onto the sidewall and it kind of tears apart. Then it exposes the hotter lava on the bottom.

So in the end, yes it’s a temperature gradient on the surface if we will say it that way, in the middle it’s a bit cooler because of the crust. It's just sitting there stationary getting transported down flow. And on the edges you have the hotter interior exposed.

Jeff Nee: Oh that’s so interesting because I would’ve if you would’ve asked me before I would’ve guessed the other way around but yes it makes sense when you explain it like that.

Alex Sehlke: Yes.

Jeff Nee: Yes. Okay, I know we're at the top of the hour but I do want to remind people that you’re always welcome to email us questions and we'll get them to Alex if you have questions later. And I know some people prefer PowerPoint. And if you need help getting any of these images out to make your own PowerPoint just let us know and we can help you with that.

So thank you everyone for joining us today. And thank you to Alex for a wonderful presentation. Alex, any last words for people?

Alex Sehlke: Well yes if you have any questions please feel free to shoot me an email. I'm happy to answer those. The videos will be on the YouTube channel so you can always leave a comment right there if you have one or just get in contact in some other way and I'm happy to answer all your questions.

Jeff Nee: Yes. Again my name is Jeff Nee. And my email address is jnee@jpl.nasa.gov. The next Museum Alliance telecon is on Thursday, September 14 and it's about weight watching from space all about the GRACE follow-on mission. So information as always is on our Web sites and we hope to hear you there. Thank you again to Alex and to Andrea for putting this together. It was a lot of fun.

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