ABRASION, DISSOLUTION, AND THE EVOLUTION OF SCALLOPED FEATURES: MESOSCALE MODELING

BOSCH, Rachel, Department of Geology, University of Cincinnati, Geology-Physics Building, P. O. Box 210013, Cincinnati, OH 45221

Slide 1. Good afternoon. Thank you all for coming out to my talk today. I know it's pushing 3:00 and for a lot of you that means coffee time or nap time and I'm going to do my best to keep you entertained and awake. Thank you for the introduction. I am going to be talking about abrasion, dissolution, and the evolution of scalloped features with an emphasis on my approach using mesoscale modeling. I'm also going to be talking a lot about these mesoscale features as we see them in caves. So here are some scallops on the wall of a canyon in Mammoth Cave. So for the purposes of this talk, when I say mesoscale I'm referring to features of about a centimeter to a meter in length. So I'm undertaking this project to inform the categorization of these mesoscale sculpted rock features as well as how they can help to improve the conclusions that we reach when we study these scalloped forms with regards to river incision or landscape evolution.

Slide 2. So those scallops we saw in the previous picture were in limestone, a soluble rock, but here, however, we see some of these mesoscale sculpted features in basalt, which in insoluble. Those are in a dry river bed.

Slide 3. So there are similarities among these different kind of features, and we can categorize these to some objective, independent parameters. Obviously the rock type is going to have some kind of influence, but there's a question of what there characteristics do these features share that will allow us to build an objective classification?

Slide 4. So let's just pause and reflect here because these are obviously some very different field sites—these things are all over the place. We can observe characteristics of these features that allow us to categorize them, but we also must include the physics that are associated with creation of these features and we have to think about time scales and at what stage they are in their development when we observe them. When we categorize them we need to take into account not only their geometries and the rocks that they are in, but also the fluid flow, sediment flux, shear stresses, pH of the waters, temperatures . . . There are going to be a whole lot of parameters involved.

Slide 5. So the base of most of the process that I'm using to approach this problem is structure from motion. I'm sure a lot of you are familiar with it. If not, ask me afterwards—I'm not going to get into all the details of how this works. This (top left) is a first-order surface stream in Clermont County, Ohio. Down here (bottom left) is our structure from motion reconstruction of that same stream. And then up here is a polyhedral mesh built using the mesh from the structure from motion. So we're going to be combining field observations—observations of real world conditions and modeling to establish a range of fluid flow and other behaviors that are associated with these sculpted features.

Slide 6. This is a knickpoint on the same surface stream I show on the previous slide. Knickpoints are sculpted features. So, we can measure velocity, flow rate, sediment transport characteristics. All of these things are going to be able to be incorporated into the model, but I want you to check out this hydraulic jump. [plays video]

Slide 7. This is how I'm representing the group of parameters that we can use to describe the sculpted features. In the middle is our morphometrics. We have flow conditions, bedrock characteristics, and then we have our time-scale factors.

Slide 8. For the first, geometry measurements or morphometrics, we have good confidence in the data. We can measure these things in the field with good precision and accuracy.

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Slide 9. Rock characteristics—there are well established field techniques—Schmidt Hammers, things of this nature that we can use to measure the different mechanical characteristics of the bedrock.

Slide 10. Now, flow conditions are slightly more tricky, but still an area where we have good confidence. We can do flow measurements in the field and flow modeling is at a state right now in this year of 2018 where we have good confidence in our flow physics modeling.

Slide 11. The time dependency is a little bit trickier. We really need to know what are the life spans of these features. We can constrain them by knowing that they have to be younger than the rock they are in. In caves, they're going to be younger than the age of the passages that they're in. We can used techniques such as cosmogenic nuclide dating. For instance, if you have sediments within a feature, your features going to be older than that.

Slide 12. Let's look at some more scallops here. We have scallops that are preserved in caves and in arid climates where our weathering is very little to none at all. So this is a good place to work on dating those sediments.

Slide 13. One project I'm going to be doing to this end is placing erosion pins into actively forming scallop fields. This (on the left) is Barclay Trimble, the superintendent of Mammoth Cave, in Roaring River. Here are some scallops. So what I'll be doing is setting some stainless steel pins into a scallop field right at the water's edge. And this, because I don't have a micro-erosion meter yet—this is my sketch of one. So that's what I'll be using to measure the erosion rates in the scallops. These measurements, combined with burial dating of sediments, and calculations of erosion rates will serve to better constrain the timeline of development of scallops in caves.

Slide 14. So using our combination of the stratigraphic relationships of where we find these features, the CRN dating, modeling, and the erosion pins, we get a better hold on the time dependency.

Slide 15. So let's just revisit how I'm going to approach some of these more straightforward ones.

Slide 16. In addition to physically measuring these features in the field, the structure from motion allows us to take this back to the lab and really spend our time getting precise measurements of a much greater number of features. So we can set up an algorithm and make it more efficient and be able to collect a lot more data on the morphometrics of these features.

Slide 17. So we're going to talk a little bit about flow conditions now.

Slide 18. So we have three different in-cave locations of erosional features. Here we have a couple of well-defined directional scallops (on left) and then we have this rock that is beside a trail that is very well-sculpted in all kinds of ways.

Slide 19. So we would infer that a paleoflow at one time may have been from left to right in this upper-left,

Slide 20. and down here, we can see active water flow, and from the morphology of these scallops, we assume that the waterflow was all from top to bottom there,

Slide 21. however, there is no directional information to these scallops on the right. Who knows what's going on here? So these scallops have long-been interpreted, beginning in the 1960's with work by

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Blumberg and Rane Curl, to describe flow directions and flow velocities. It's been interpreted that they arise purely from dissolution, pretty much because we find them in limestone and limestone is soluble.

Slide 22. However, take a look at that pothole! It's got a whole pile of clastic sediments, which to me is some circumstantial evidence that there might be more than one process at play in sculpting these features.

Slide 23. To continue informing the breadth of parameters describing these features and to start to address this conundrum of what are the underlying processes, I am using modeling. So again we are using structure from motion. This is a field of scallops in Boone Avenue in Mammoth Cave (lower left). This is our structure from motion reconstruction (upper left). And then this (right) is the polyhedral mesh resulting from this surface. So I built this mesh in a computational fluid dynamics software tool, and we can use that to solve for flow conditions and for sediment transport over that surface.

Slide 24. And so we get flow field information such as this. This is a velocity contour plot along that same surface I was just showing you. From that you can see where your velocities are higher, your going to have lower pressures and then along the bed this is going to be telling us what the shear stresses are like.

Slide 25. We can also see the flow structures when we look at this [video]. This is a visualization of the streamlines, so the things that look like individual particles are like tracers for parcels of water. You can see that there's flow separation and then on the concave, lee side of the scallop you have this recirculation zone where the water is coming back up. And then where you hit that point of inflection where the scallop goes from concave to convex, it reattaches and starts flowing up towards the next crest.

Slide 26. So, to summarize this is the whole pile of parameters that I'm planning to get at through these various approaches. I plan to make a giant table, populated with as many of these parameters about each sculpted form that I can, and put that into a Principle Component Analysis to better describe the relations and to what degree each scallop feature is dependent on these various parameters.

Slide 27. Following that, I would really like to take this methodology back to the field and see how it applies to help us better identify various sculpted features and then use those to interpret more about landscape evolution. This is a map of current and proposed field sites. If you have any great ideas about where there are sculpted features I would like to hear about them.

Slide 28. So thank you to my advisor Dylan Ward and this wouldn't be possible without all of these people and the funding and logistical support I have listed here.

Slide 30. Finally I want to mention that this talk is dedicated to my daughter, Sam, who turns fifteen today. I offered to bring her to GSA with me to meet all of you, but she had a robotics scrimmage this morning that she absolutely had to go to.