

Discovering how mountains grow

Professor Lindsay M. Schoenbohm



DISCOVERING HOW MOUNTAINS GROW

Lindsay Schoenbohm is a researcher who specializes in tectonic geomorphology. Here she explains some of the unique challenges that come with doing research in the field, and about her recent discoveries concerning continental plateaus.

To start, how did you become interested in Earth Science, and specifically tectonics and geomorphology?

I've been interested in geology since 8th grade, when I was first exposed to it in school. I love trying to wrap my head around the immensity of geologic time. I also like the forensic aspects of geology. You never have complete information and experiments often aren't an option, so you end up piecing together bits of evidence to make the best story you can. It's a fun challenge. And last, I love being outside and enjoy the many opportunities for travel and adventure offered through doing research in my field.

Your research team needed a combination of landscape analysis, structural geology, geomorphology, and sedimentology in order to understand continental plateaus more fully. Did you consult outside specialists for data analysis, or were they all directly part of your team?

Almost all of the research we do is collaborative – single author manuscripts in my field are rare. My students and I are competent in landscape analysis, structural geology and geomorphology. We work with other scientists who are experts in thermochronology, cosmogenic dating, sedimentology, geochemistry, and many other fields. We do field work with colleagues whenever possible, in large part because the field is such an excellent place for exchange of ideas. We do geology together every day, then sit around together over dinner talking about what we've seen and how it all works, and mapping out future papers and proposals.

How big a research team was needed in order to accomplish what you have done on this project? How did you delegate work and was it difficult to coordinate?

My core research team consists of my students and myself. I generally have 3-4 graduate students and 2-3 undergraduate students working with me at any given time. My students are partners rather than employees. I have an idea when they start about what they should work on, and I guide them along the way of course, but I expect them to have their own ideas and I support them in pursuing their own interests.

Did you have any difficulty securing funding for the project?

Securing enough funding for my projects requires ongoing effort. The majority of my funding comes from the Discovery Grant program at NSERC (Natural Sciences and Engineering Research Council), Canada's major funding agency for the Natural Sciences. These grants support my core research and provide funding for several graduate students. However, international field work can be wildly expensive; even though we camp much of the time, airfare and 4WD truck rental really add up. I've received funding from the US National Science Foundation in the past to help support my program. I've also moved over the years into more remote sensing work, done on computers in the lab, which is less expensive and can be very efficient.

Were there any other unexpected roadblocks while conducting your research?

I had some literal roadblocks while conducting my research. Twice I had students get stuck in the field while doing work off-road. In each case it took more than a week before we were able to pull their trucks out and get the research back on track. One student had to hike 80 km over a 5000 m mountain range to get help. The Argentine Gendarmeria were sent out to retrieve the other lost students. Another time we tipped our canoe going through some major rapids on the Red River in China. We've had people charge into our hotel rooms at night to shake us down for money. But for the most part I've been lucky and my research has proceeded smoothly.

You mention that your research team will constrain hazards associated with active faults in central Turkey. Is this a future project or did your previous work inform geologists working in this area?

We're just getting started on our hazards work in central Turkey. Two of my recent graduate students mapped fault strands, but in the next stage of the project we'll do trenching to really get at the frequency and timing of earthquakes along key faults in central Turkey. This information, coupled with estimates of the size of each past earthquake based on the amount of offset, can be used to predict the damage potential of future earthquakes. This isn't work I've done in detail before, but I'm eager to get started.



HIGH AND DRY: WHAT IT TAKES TO FORM A PLATEAU

Professor Lindsay Schoenbohm of the University of Toronto and her team have made some ground-breaking discoveries in the field of tectonics and geomorphology. A combination of field-based mapping, satellite image interpretation, landscape analysis, geochronology and other techniques were needed to understand the formation of continental plateaus.

Tectonics: A Relatively Recent Geological Puzzle

Even though students of geology are taught that the theory of tectonics is fundamental to the science, it actually has a very recent history of controversy. The theory was not formally introduced to the scientific community until the early twentieth century (at the time it was called the "theory of continental drift"), and was not widely accepted by geologists until the 1960s.

Researchers in the field of tectonics study the plates that form the crust of the Earth. These plates (an outer "shell" covering the Earth) move slowly over time, and while they move just a few centimetres a year on average, that movement can build dramatic terrain like mountains over the span of millions of years.

There are still controversies today regarding the specifics of how certain tectonic features form, but a consensus is slowly building, thanks in part to the work of Professor Lindsay Schoenbohm.

Schoenbohm is interested in features called continental plateaus – striking landforms whose origin has always eluded explanation, the most famous example being the Tibetan Plateau. They are typically associated with collisional tectonic settings in which two discrete plates collide. However, plateaus are not present in all collisional settings, and some plateaus form far from these areas. Furthermore, although all plateaus have the same shape – flat on top with steep sides – they display different styles and varying amounts of deformation. In other words, there are no common features with which to identify the exact processes that create, sustain and destroy plateaus.

Reading the Surface to Understand the Depths

Scientists have several ideas about how plateaus can form. One group argues for the importance of thickening the crust – by stacking one tectonic plate on top of another, by crumpling one plate, or by injecting magma. Once the crust is thickened, it

"floats" higher and starts to spread outward, forming a plateau. Other scientists think that thickening the crust is not enough – as the crust is thickened, the denser lower part of the tectonic plate, known as the "mantle lithosphere," is thickened as well and acts like an anchor on the plate, pulling it down. Therefore, a second group of scientists reasons that the mantle lithosphere must "detach" before a plateau can form. A third group emphasizes the role of climate, arguing that a plateau cannot form unless it is protected from erosion (by rivers and glaciers) in an arid environment.

Because of the way these possible formation mechanisms may feed into each other, and because the evidence for each can be cryptic, it is not easy to identify exactly which processes are driving the plateau growth. It is also not so easy to explain the forces that support the plateau's continued existence, since there needs to be an ongoing source of uplift for the plateau to remain a prominent feature of the landscape.

Schoenbohm's recent research focused on two plateaus. One, called the Puna Plateau, is located in north-western Argentina, and the other, known as the Central Anatolian Plateau, is found in central Turkey.

In Argentina, Schoenbohm focuses on the growth of the Puna Plateau. It is likely that the Puna Plateau's uplift is controlled by detachment of the lower part of the tectonic plate, but how, when, and why this happened remains a question. The Puna may have resulted from delamination, in which lower parts of the plate peel off and sink down into the "asthenosphere" beneath the plate.



It could also be the result of “dripping”, a process in which dense, colder parts of the plate sink into the relatively warm and fluid mantle below in the style of a lava lamp. There may have been one huge drip (the width of the plateau) or many smaller “driplets”, each 40–100 km across. In any scenario, the combination of the loss of the mantle lithosphere anchor and the injection of hot rocks to fill the space would have caused uplift at the surface. This uplift would have been big enough to affect the regional and global climate.

There are additional questions about the Puna Plateau that Schoenbohm hopes to answer. The steep mountain ranges along the sides of plateaus have long been thought to protect the flatness of the plateau interior. This works because as moist air tries to flow over the plateau, it cools and forms rain which falls heavily on the steep sides of the plateau, leaving the interior of the plateau arid and protected from aggressive erosion. Schoenbohm’s research has led her to believe that this phenomenon not only protects the plateau, but may actually help it to grow wider. As new mountains deform the area around the plateau, they create obstacles that the rain-laden clouds must pass over, forming a “bathtub” basin between the mountains and the plateau edge. If conditions are right, this basin can fill with small pieces of rock and dirt eroded from the mountains all the way up to the top, expanding the flat area of the plateau.

When it comes to the Central Anatolian Plateau, Schoenbohm is interested in explaining its internal deformation in a different way. Although similar in some aspects, the Central Anatolian Plateau differs from the Puna Plateau in that it is cut by major “strike-slip faults”. These are formed when tectonic plates break into two pieces that slide past each other in order to accommodate the growing pressure of the collision, causing major, periodic earthquakes. While there are many prominent strike-slip faults near the Eastern Anatolian Plateau,

there is still a debate in the community as to which of these faults are important, and how they help or hinder growth of the plateau. These faults also change as mountains continue to rise from the collision, making their significance difficult to nail down.

Real Results

The research team, led by Schoenbohm, has already made some key findings. Their work in Argentina has revealed that lithospheric dripping in the Puna Plateau occurs in small “driplets” rather than larger-scale drips, and they have identified two that have occurred in the last 20 million years. The team was also able to demonstrate that mountain uplift and local climate change, rather than global climate change, control sediment deposition in the “bathtubs” around the edge of the modern Puna Plateau. That revelation was the answer to a long-standing question in the field of tectonics, and suggests the importance of this mechanism in growing the plateau. In Turkey, Schoenbohm has demonstrated that the Central Anatolian Fault Zone, thought to be a major strike-slip fault, is actually a collection of less-significant, loosely linked faults, although they still pose a significant earthquake risk.

Schoenbohm’s continuing work will give scientists much insight into tectonic processes. While the team’s work is still far from done, they have made some huge contributions to the field of tectonics and geomorphology and have even more ambitious plans for the future. They will demonstrate in finer detail how activity deep within the tectonic plate and mantle can affect the landscape above, and elucidate the relationship between tectonic activity and climate. This task is famously difficult, but Schoenbohm’s interdisciplinary approach has already made important breakthroughs.



Meet the researcher

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Professor Lindsay Schoenbohm received her bachelor’s degree in Geology from Carleton College in Minnesota and went on to earn her Ph.D. in Geology from the Massachusetts Institute of Technology. She worked as a postdoctoral research associate at the University of Postdam in Germany and taught at Ohio State University before accepting her current position at the University of Toronto. She has won many grants for her research, and also serves as an Associate Editor for Tectonics. She currently teaches at the University of Toronto Mississauga where she continues her work in geomorphology and tectonics, specifically continental plateau formation.

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