Spatial evaluation of stream erosion and knickpoint evolution using detrital mineral tracers in the Sacramento Mountains, New Mexico.

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Introduction

Mountain landscapes evolve through interactions between geologic processes, surface processes, and climate processes. Climate controls water availability to streams. Bedrock geology and faults influence a streams ability to detach and transport sediments from rock surfaces. This study investigated potential controls on spatial patterns of stream erosion by examining the strength of bedrock materials and tracing sediments to their bedrock sources in a small drainage basin in the Sacramento Mountains in southern New Mexico. The stream carved its channel into Paleozoic sedimentary and Tertiary intrusive rock units. The Sacramento Mountain Range is bounded on the western flank by a steep escarpment formed by normal faults. This study specifically examined two questions:

- Are convex geometries (knickpoints) in the longitudinal profiles controlled by rock strength?
- Can apatite minerals in stream channel sediments trace where flowing water most efficiently erodes bedrock?

Two mechanisms that may control the formation of knickpoints include the strength of bedrock or the growth of fault scarps during earthquakes. If a bedrock layer is difficult to erode relative to overlying or underlying rock layers, it will stand out in the profile relative to weaker units. Alternatively, faults cause offset and create steep scarps that intersect stream channels. To understand the spatial distribution of erosion and test if erosion concentrates at convex geometries in the stream channel, we need a tracer that identifies the sediment sources in a catchment. The low temperature thermochronometry method calculates cooling ages of apatite minerals in stream sediments and bedrock sources. Uranium and thorium decay to produce helium that apatite minerals trap only when they cool below ~70^{o}C (Farley, 2002). Sediment age distributions compared to bedrock ages identify the most common bedrock source (Ehlers et al., 2015). Since bedrock near the top of the mountain uplifted, eroded, and cooled first, it should result in an older age than the bedrock near the bottom of the mountain. If sediment at the mouth of a catchment represents surface areas eroded equally throughout the catchment, it contains mineral ages representing all elevations in the catchment. If erosion is focused at one particular elevation or bedrock unit, a higher than expected concentration of those ages will be observed in the sediments.

Methods

I collected four bedrock samples from bottom to top of the mountain range within the study catchment and two sediment samples from the mouth of the catchment. Students and I separated individual apatite minerals from each sample and dated them using the low temperature apatite (U-Th)/He thermochronometry method at the University of Michigan. In addition to tracing erosion patterns, we assessed the rock strength properties of different bedrock units observed in the catchment. Fieldwork included rock strength analyses using a Schmidt hammer and characterizing the rock outcrops and fracture patterns (Selby 1980). Spatial analyses using digital elevation models (DEM), slope, bedrock descriptions, and field measurements of rock strength determined how the rock properties influence catchment landscape and the stream profile.

Results

Apatite Quality

Analyses of apatite minerals from four bedrock samples produced ages ranging from 5 to 330 Ma. Out of two sediment samples, 19 grains produced ages. Results indicated poor apatite quality for both sediment and rock samples. Twenty-five out of twenty-seven grains contained low uranium concentrations. These low concentrations indicate the resulting ages are too old. This problem occurs when helium enters the minerals from an outside source, possibly including other uranium rich minerals.

Additionally, mineral grains at higher elevations in the catchment resulted in younger ages than the low elevation samples. Therefore, the typical expected increase in cooling age with increasing elevation was not observed, adding to the complications for using this mineral cooling age for tracing erosion.

Comparing sediment grains to bedrock grains

Although the mineral ages are likely too old to answer the geologic questions of when these rocks were exhumed and cooled, the consistency of all the minerals producing too old ages allow for some potential to match the sediments to the rocks. Of the minerals in the sediment, 68% of the ages differed from any of the bedrock ages sampled. This indicates that the source of apatite minerals was not captured in our sampling, possibly because it was covered with landslide deposits or buried by soil development. Alternatively, the source exists outside of the catchment and minerals were transported by wind from mountain ranges to the west. Large sand dunes to the north of this site demonstrate the importance of wind processes in sediment deposition in this region.

Stream profiles and rock strength

The strongest rocks tested in Dog Canyon occurred near knickpoints in the longitudinal profile. The Gobbler limestone formed the most distinct concave feature. When rock strength was compared to the slope of the hillsides within the catchment, only a weak positive correlation was observed.

Summary

Landscape features including knickpoints in the stream profile appear to be controlled by the strength of the underlying bedrock. The source of sediments in the stream channel requires further analysis because the apatite ages produced unexpected results and the source of the sediments was not captured in the bedrock outcrops observed here. Future work will investigate additional mineral assemblages, rock assemblages and adjacent areas in the mountain range to investigate spatial consistency of rock strength observations and patterns of erosion.

References

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