EVIDENCE FOR MULTIPLE STAGE DEVELOPMENT OF GRANITIC SPIRES, CASTLE ROCKS, IDAHO

JEREMY LAUCKS
Washington and Lee University
Sponsor: David Harbor, Washington and Lee University

INTRODUCTION

The valley of Big Cove is bordered on the east by a set of hogbacks formed in Proterozoic Elba Quartzite and on the other three sides by ridges of granitic gneiss of the Archean Green Creek Complex and Elba Quartzite. The spires known as Castle Rocks are formed in granodiorite of the Oligocene Almo pluton. The spires are surrounded by alluvial fan deposits, except on the northwest where the granodiorite is in contact with the Precambrian basement. The morphology of the spires themselves and the relationships between the spires and the fan deposits are suggestive of a classic two-stage development in which weathering is produced by groundwater underneath the regolith, followed by stripping of the regolith. (Twidale, 2002). The study area is a new Idaho State Park opening May 2003. This research is part of an effort to provide the park with information to aid in developing interpretive resources for visitors.

Methods

Observations of spires on the periphery of the main Castle Rocks were expected to yield the most information about spire development, as they are the most recently exhumed. Weathering features, specifically panholes (or solution pans) and flares (or flare slopes or structures), were measured with the intent of using them as a proxy for exposure age. Flares are concave sidewalls on spires that are interpreted to form beneath the regolith (Twidale, 2002). Well-developed panholes were not observed on freshly exposed surfaces, and thus are interpreted to develop primarily after the regolith is removed. Sixteen flares were measured at ten locations. Width and depth of panholes were measured at 12 locations by choosing a representative panhole. Two panholes were measured at one location, as there were two distinct stages of panhole development. Distance from the ground to the panholed surface was also measured. Global Positioning System (GPS) coordinates for each of the measurements and other observations were recorded.

DATA AND OBSERVATIONS

Weathering features

Flare heights ranged from 0.5 m to 4 m and are weakly bimodal, with a peak in the 0.75-1.5 m range, and a second peak at 2.25-3.0 m (Figure 1). Panhole width and depth, width to depth ratio, and width multiplied by depth (as a proxy for volume) were plotted against the height of the panholed surface above the ground surrounding the spire. Panhole size

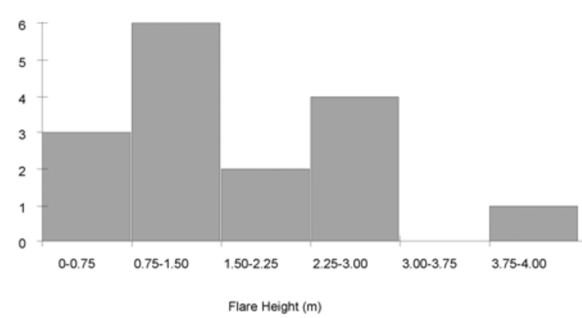

Figure 1: Histogram of flare heights

does not correlate to height. One surface observed showed two different degrees of panhole development with only a few centimeters of height difference (Figure 2). Part of the surface appeared to be recently exhumed, and in fact was in the process of being uncovered, while the higher area

Figure 2: Two stages of panhole development. 1L water bottle for scale next to a well developed panhole. To the right and slightly lower are very shallow panholes

appeared to have been exposed for some time.

Alluvial Fans and Spires

Shallow bedrock exposed around the bases of spires suggests that the alluvial fans in Big Cove may actually be pediment surfaces, however, the depth of alluvium in other areas of the fans was not investigated. They will be referred to as alluvial fans for the sake of simplicity. South and southeast of Castle Rocks both abandoned and modern fan surfaces are present (Figure 3). Streambeds in the modern fans are 0.5-1 m deep, though locally there is significant disturbance due to irrigation. The modern streams are incised as much as 20 m, into the abandoned surfaces, such as along Stines and Johnson creeks. Drainage patterns in Big Cove are suggestive of stream capture. Almo Creek and Edwards Creek are incised into the same fan surface, but drain between different hogbacks. Edwards Creek flows north of the southernmost hogback, while Almo Creek flows to the south. Relict solifluction lobes cover the upslope regions of abandoned surfaces.

Elba Quartzite cobbles and boulders are exposed on the surfaces of the fans. The cobbles are generally subangular to subrounded and a few centimeters to tens of centimeters in diameter, however some exceptional boulders are up to 3 meters in diameter. Similar cobbles were found in areas around the edge of the main group of spires (Figure 3). Cobbles a few centimeters in diameter were also found tightly wedged in cracks in the spires rising out of the fans. These cobbles were commonly a few meters above the fan surface, but in some cases were as high as 30 meters. Cobbles were also found at similar heights in panholes on larger spires.

Many of the spires rising through the fans were noted to have trenches in the fan on the up-slope sides. These trenches are 1-2 m deep and 4-5 m wide. Where spires are grouped together, the trenches converge down slope, forming streambeds. As a result, there is up to 20 m of incision into the abandoned fan surface around Castle Rock.

INTERPRETATION

Weathering Features

Assuming a constant rate of spire exhumation and a constant rate of panhole size increase, panhole size should vary as a function of panhole surface height. As this was found to not be the case, one or both of the assumptions does not hold. From the surface in which two stages of panhole development were observed (Figure 2), it can be seen that panhole size does vary with time exposed. Although this does not indicate a constant rate of panhole development, it may alternatively indicate that exhumation does not occur at a constant rate, but rather in episodic exhumation interspersed with periods of inactivity. Part of a spire may be exhumed and left exposed long enough for panholes to form, while areas only a few centimeters lower remain covered.

The flare height histogram shows multiple flare height peaks, which are interpreted to be the result of periodic exhumation. The flares form during periods of little or no net erosion, and are exhumed during periods of high erosion, which would then be followed by

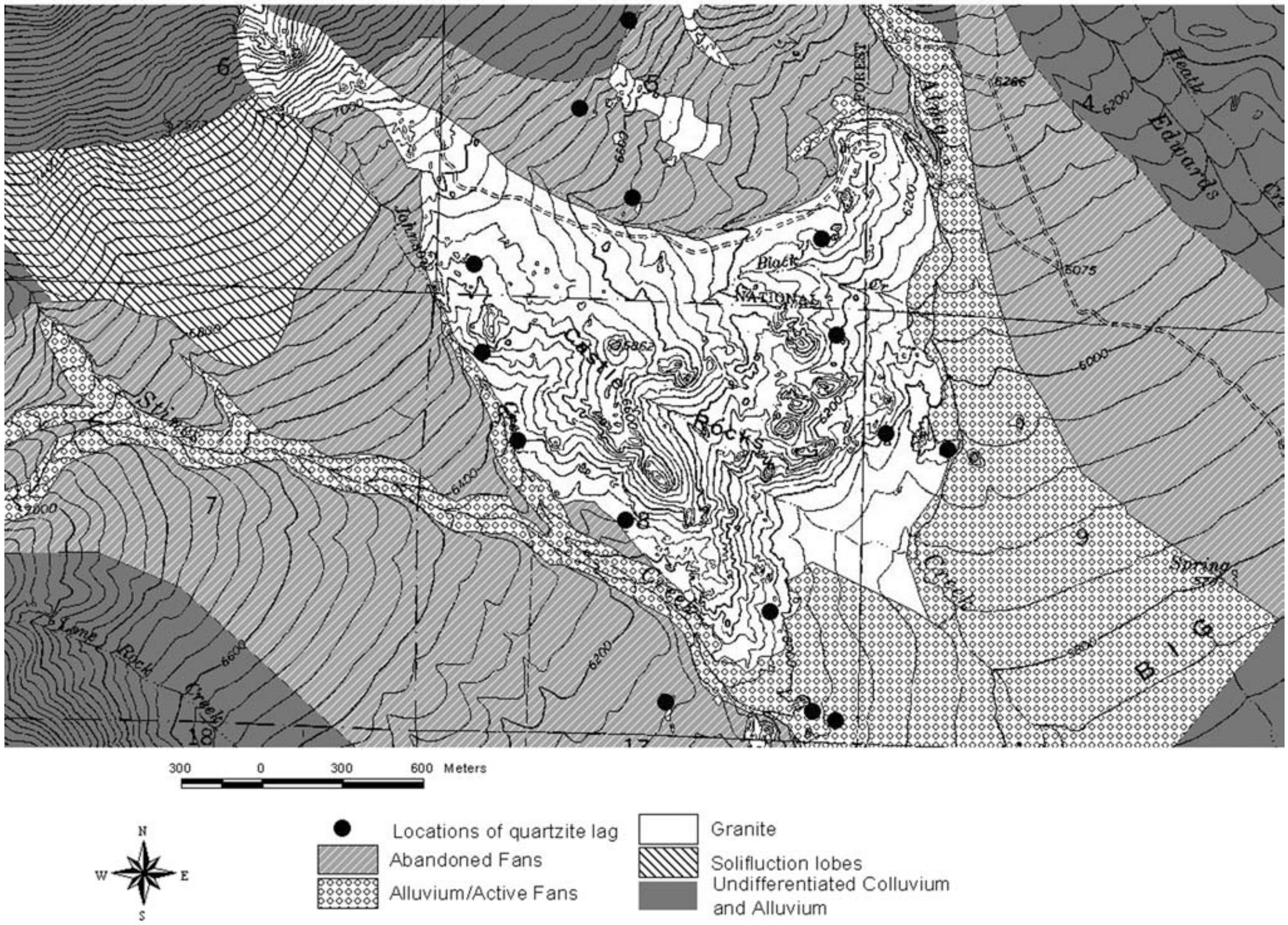

Figure 3: Geomorphic map of Castle Rocks. Black circles mark locations of quartzite cobbles found above the fan surfaces.

another period of slow erosion. Over time, the exposed flares weather away, resulting in a decrease in the number of flares with height, as was observed.

Alluvial Fans

Large-scale exhumation appears to be controlled primarily by stream incision. This process reworks and removes fan deposits, as shown by fan remnant cobbles in the main group of spires and cobbles wedged in cracks in spires. Tens of meters of exhumation may occur as the result of one episode of stream incision, such as along Stines Creek. The flare heights observed indicate that exhumation does not occur in one rapid episode, but rather in smaller episodes as the fans surfaces are reworked. Groundwater sapping due to shallow bedrock and increased run-off from exposed bedrock in the fans is a likely cause of the trenches around the spires. These effects are also responsible for the incision of streams into the fans.

DISCUSSION

Stream incision and fan reworking is likely the result of climate change. Solifluction lobes covering the upslope ends of the larger, abandoned fan surfaces, indicate a periglacial origin and colder climate. The streams may have incised due to decreased sediment supply following the end of the last glacial epoch and during former climate oscillations. Lake cores in the area show that glaciers retreated to their cirques ~15.6ka and disappeared entirely ~13.8ka, and that sedimentation fluctuated on centennial-to-millennial time scales (Bovet, et al). These fluctuations may be responsible for the development of flares of multiple heights. Stream incision and exhumation are also affected by stream capture, which may also be a result of climate fluctuations.

The presence of quartzite cobbles left in cracks, panholes, and on the tops of spires can be explained two ways. Panholes and cracks are not observed in freshly exhumed surfaces. Joints were observed in freshly exposed surfaces, but in most cases, there was no gap. Cobbles must either be left perched on the spires as the rest of the fan materials are removed and panholes and cracks form in the spires, or the spires are exhumed and later reburied by the fans after cracks and panholes are formed. The amount of material wedged in cracks, especially on smaller spires, seems to be greater than the amount of quartzite observed on freshly exhumed spires, suggesting the spires may have been reburied. Fluctuations in sediment supply resulting from climate change provide a potential mechanism for reburial. However, extensive reburial would result in a substantial quantity of material left in the panholes, as the panholes would act as an effective trap for the fan materials, and this was not observed. Quartzite cobbles were only observed in panholes in three places, and all of the cobbles were substantially smaller than the average observed in the fan surfaces. Given this, extensive reburial of the spires seems unlikely, but it is likely that the spires are at least partially reburied during the formation of the alluvial fans.

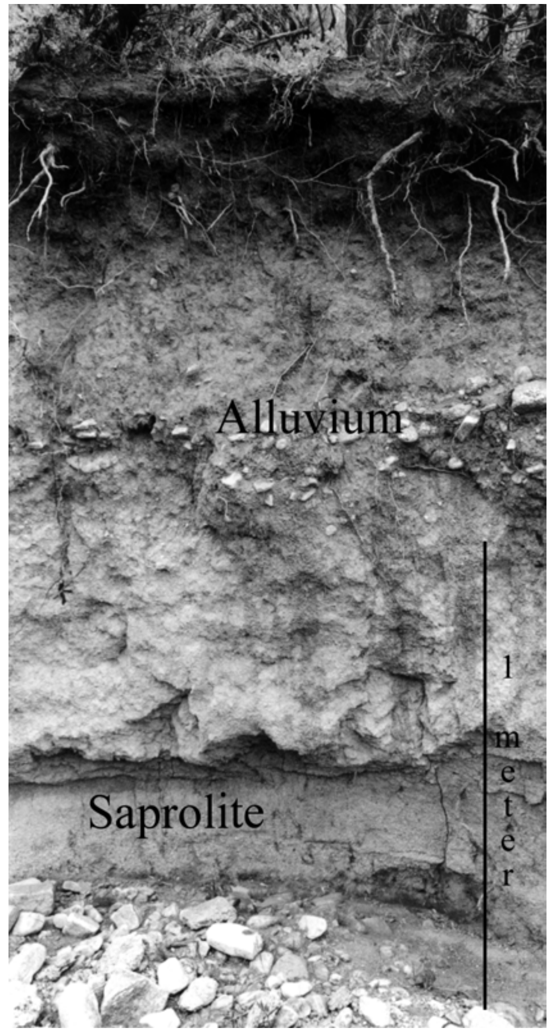

Figure 4: Stream cut exposing weathered granite overlain by alluvium, indicative of two-stage process.

CONCLUSIONS

Observations made in Castle Rocks suggest both episodic exhumation and two-stage development of granitic spires. The presence of alluvium plays crucial role in the formation of the spires by holding moisture responsible for differential subsurface weathering. Granite beneath the alluvium is weathered into saprolite (Figure 4), with differential weathering resulting in the formation of the granitic form observed at the surface. Once the overlying alluvium and saprolyte is stripped away, the exposed granite weathers much more slowly. The presence of quartzite cobble lag indicates that this process has occurred several times, with a partial reburial of the spires in alluvial fans, and thus the process is not simply two-stage, but rather multiple-stage. Likely the cycle of burial, weathering, exhumation, and reburial is closely tied to climatic fluctuations.

REFERENCES CITED

Bovet, Bowerman, and Cadol, this volume.

Twidale, C.R., 20002, The two-stage concept of landform development involving etching: origin, development and implications of an idea, Earth-Science Reviews 57, p. 37-74.