AN ANALYSIS OF THE GEOMETRICAL EVOLUTION OF PANHOLES IN THE CITY OF ROCKS, IDAHO

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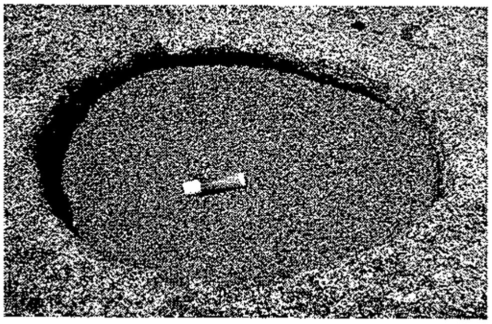
INTRODUCTION

The City of Rocks is located near the town of Almo in the Albion Range of Southern Idaho. It lies within the Oligocene Almo Pluton, which forms the core of one of the four structural domes in the Albion Range metamorphic core complex. Much of the country rock is composed of granite and gneiss of the Archean Green Creek Complex (Armstrong, 1968). The area is a tor and bornhardt landscape, exhibiting a number of major weathering and erosional features, including abundant jointing and sheeting, case hardening and panholes, which are relatively shallow, wide and flat-floored weathering pits (Twidale, 1971).

Earlier studies use a variety of terms to describe panholes, including gnammas, armchair hollows, opferkessel, and weathering or solution pits and pans, depending on the region, the slope of the surface they were found on, their specific size and geometry, and the particular researcher's preference (Ollier, 1969). For the purpose of this paper, panholes will be defined as depressed erosional features found on flat or gently sloping rock (less than 20 degrees). Similar features on steeper slopes will be referred to as armchair hollows. Panholes are usually roughly elliptical or circular in shape. They have flat bottoms, and are generally wide and relatively shallow. Panholes observed in this study area ranged from only a few centimeters across and millimeters deep to 3-4 meters across and 2-3 meters deep. Overhung rims are common. Often panholes breach their sides and multiple holes coalesce, with the larger panholes tending to be of this variety. Almost all of the panholes observed in the study area had moss or lichen covering part or all of their structure.



Picture 1 Example of a shallow, flat-floored panhole. Scale is approximately 5 cm long.

While many researchers have noted the occurrence of panholes throughout the world, and have commented on their varying shapes, there has been little work that focuses specifically on their geometry and its evolution. This project examines the evolving geometry of panholes through time, using their depth to width ratio as a measure of their geometry and volume as a proxy for time.

MODELS

Hypotheses involving the origin and evolution of panholes are plentiful. It has been proposed that they are an example of a two stage erosional feature, in which erosion begins as subsurface weathering, and continues in the second stage as preferential erosion of the weathered rock (Twidale, 1993). It is also possible, however, for these features to form even when exploitable depressions are not initially present. One explanation is that erosion from moss and lichen could differentially weaken the rock and cause a depression in which water could begin to accumulate (Twidale, 1971). In fact, it has been found that algae penetrates 1-2 mm into the walls of the holes (Fairbridge, 1968).

Once a depression is formed it seems that water is the main cause of further erosion. Frost action, salt crystallization, and hydration can all break down the rock within the depression (Twidale, 1971). The addition of biotic material such as leaves and needles can also make the water solution more acidic. Since igneous rock is most soluble in acidic water, this further aids the erosional process (Fairbridge, 1968). The most powerful control, however, is simply the length of time the water is in contact with the rock. Rock that is under water for longer periods should erode more quickly than drier rock. If this were the case however, we would then expect to see pits, with a hemispherical shape in cross-section, instead of the distinctive flat bottoms of pans. The reason they do not usually form in this manner is due largely to structural controls. Panholes often form in rock that is laminated. Although water can percolate through weakened rock faster than unweathered rock, it cannot travel as fast as it does through the numerous partings that run parallel to the surface. Therefore more water travels laterally than vertically in the panhole, and erosion does not occur at the same rate in all directions (Twidale, 1971).

The goal for this study was to determine whether there is a consistent geometry or consistently evolving geometry through time. However, there are no definitive data about the rate at which these features form, and therefore no way to determine absolute ages for the panholes measured. Instead I assumed that these features form at a constant rate through time. Using this assumption, I could then use volume as a proxy for age. I used the depth to width ratio of each axis to analyze the geometry of the panholes. Using the assumption that the length of time under water is the main control on panhole growth, I developed my own model of evolution. My hypothesis was that when the panholes first formed, they would be relatively wide and quite shallow, since they begin only as small scoops or depressions in the rock. During this period their depth to width ratio would be quite low. Then as they enlarged and expanded laterally, a greater amount of surface area on the bottom of the pans would be exposed. Vertical erosion would begin to increase, and as a result their ratio would increase. However, at some point the increased vertical erosion would expose more rock surface on the walls, and lateral erosion would once again increase. As a result, we would expect the depth to width ratio to lower. My goal was to collect data to either verify or disprove this sequence of events.

METHODS

All panholes measured in this study occurred on surfaces with a slope of less than 20°, and none of them had sides that were breached. Cross-sections were measured along both the long and short axes of the panholes. In order to do this, a ruler was laid over the axis that was being measured. A variety of measuring devices were used, from 6-inch rulers to 12-foot poles, depending on the size of the panhole. Depth was then measured vertically down from the pole at regular intervals determined by the size of the hole and the irregularity of the surface. Each rim was noted, as well as distinctive features particular to each hole. The measurements were then plotted in a spreadsheet for each axis of each panhole. Corrections were made for the general hill slope and any discrepancy between the height of the measuring bar and the height of the ground surface. 103 panholes were measured, and 101 were used in the final analysis, with two being omitted due to errors in records of field measurements.

RESULTS AND DISCUSSION

Analyses of the long and short axes of the panholes were done separately. Using the mean depth for each axis, a depth to width ratio was determined, and was plotted against the cube root of the volume of the panhole. I assumed that each dimension enlarged at a steady rate through time. Therefore, the volume should enlarge with the cube of its age. Using the egodic hypothesis it was assumed that a sequence of increasingly large panholes represented the evolution of the individual panhole through time. Therefore taking the cube root of the volume would be an accurate substitute for time. Panholes with volumes over 100,000 cm^3 were excluded from the final analysis because field observations suggested that they were not singular erosional features, but rather composites of two or more coalescent panholes.

In figures 1a and 1b depth to width ratios of all panholes of volumes less than 100,000 cm^3 are plotted against the cube root of the panhole volume, which is being used as a proxy for panhole age. There is considerable scatter in the data. However, when the data is smoothed using a 15-point running mean, a general pattern becomes evident.

The long axis initially begins with an average depth to width ratio of approximately 0.11. This quickly increases to a maximum of about 0.18 in the span of approximately 6 units of time. It then slowly decreases over a period of 22 time units until it reaches a steady state of 0.11. The short axis follows the same general trend. It begins with an average depth to width ratio of 0.13 and increases to 0.20, again in 6 units of time. It then slowly decreases over 22 units of time to 0.15. The beginning and ending depth to width ratios, as well as the high point are very similar for both the long and the short axis. In addition, they occur at the same points in time.

The appearance of the initial rapid increase in depth to width ratio followed by a much slower decline suggests that perhaps these panholes undergo two separate stages of evolution. The initial increase in the ratio represents the first stage of formation, and the subsequent decline represents the secondary stage of evolution. If these two separate sections do indeed represent different evolutionary periods, it follows that these separate periods are influenced by different erosional controls. If this is so, then the period in which the depth to width ratio is the highest likely represents the transition zone in which the panholes are influenced by both stages of evolution and their respective erosional controls.

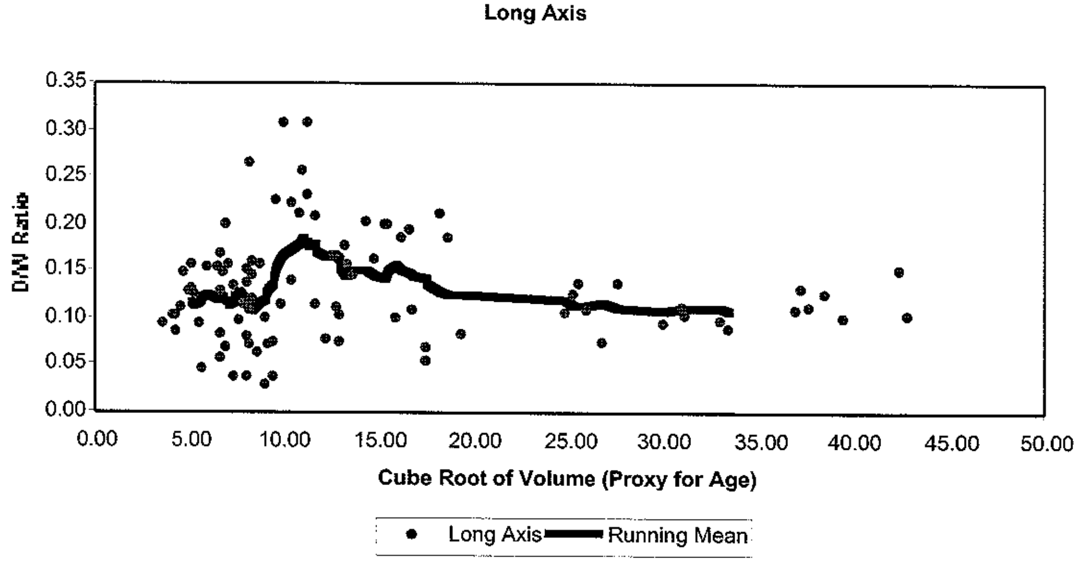
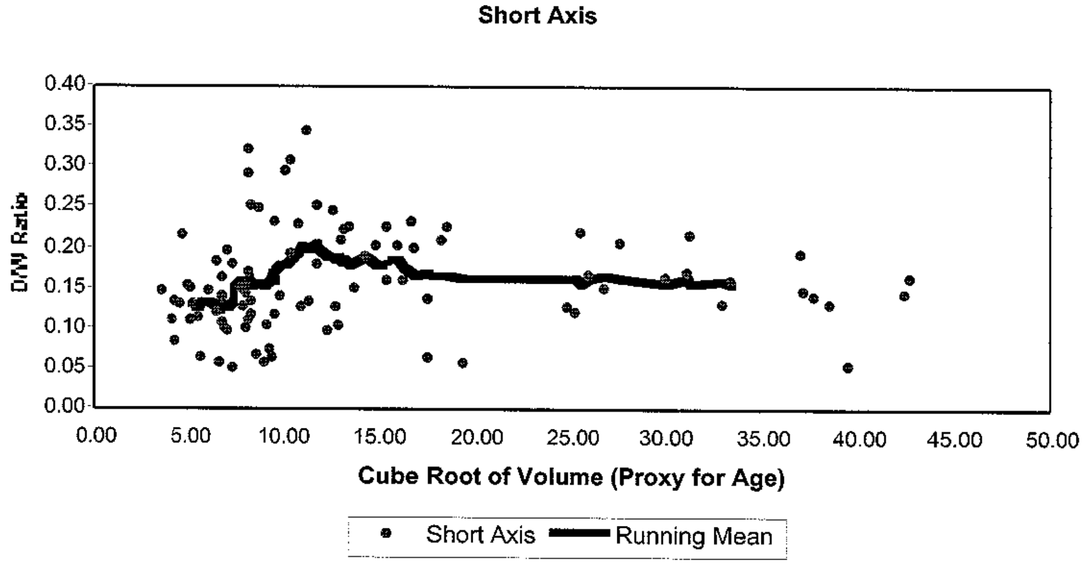


Figure 1a & 1b. Depth to width ratio of measured panholes plotted against the cube root of the volume with a 15 point running mean line for both the long and short axes.



While doing a statistical analysis of the data, linear regression analyses were run for each pan axis for both developmental stages. The two points that made up the high part of the running mean for each axis were considered to define the transition zone for each axis. Since I assume that the transition zone is a period in which both evolutionary stages are operating at the same time, these points were included in the analysis of both the primary and secondary stages of evolution. All four analyses showed a statistical significance at a 99% confidence level between volume (i.e. time) and the aspect ratio. The variance (r^2) ranged from 12-22% for the four analyses. This low level of explained variance reflects the high degree of scatter in figures 1a and 1b.

There is a great deal of scatter in both of the plots. The sample size was fairly large, so the source of the scatter would not be the size of the n. Instead, it most likely results from the great variety of factors and controls that contribute to the creation and evolution of these erosional features. Despite the scatter, the general trend is statistically significant.

CONCLUSION

Weathering pits exhibit a great variety of forms and geometries. This is due in large part to apparent variations in erosional controls. Panholes in particular, however, seem to exhibit a fairly consistent geometry. One of the most powerful controls on the formation of panholes is the amount of time that the rock is covered with water. This affects the rate of erosion, the appearance of overhung rims and their geometry and evolution. However, due to the general pattern of the data it seems likely that there are two different stages of erosion, in which different erosional controls are dominant. The initial stage is marked by a relatively short period in which the increase in depth to width ratio is rapid. This is followed by a much longer period of erosion, which results in a much slower drop in the ratio. What remains to be determined is what processes are most important at each stage of panhole formation.

REFERENCES

Armstrong, Richard Lee, 1968. Mantled Gneiss Domes in the Albion Range, Southern Idaho. Geological Society of America Bulletin, v.79: 1295-1314

Dzulynski, St., and Kotarba, A., Solution pans and their bearing on the development of pediments and tors in granite. Zeitschrift für Geomorphologie N.F., v.23, ed.2: 172-191

Fairbridge, Rhodes, W., 1968. Solution pits and pans.-In: The Encyclopedia of Geomorphology. New York, p. 1033-1036

Ollier, C.D., 1969. Weathering. New York, p. 190-191

Twidale, C.R., 1971. Structural Landforms. Australian National University Press, Canberra. p. 81-89

Twidale, C.R., 1993. The research frontier and beyond: granitic terrains. Geomorphology, v.7:187-223