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A Study of Bedrock Strength Controls on the Erosion of the Colorado Plateau

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Introduction

There has been renewed debate over the mechanisms of uplift and erosion in the Colorado Plateau, and in order to understand the patterns of topography and process in this landscape a third factor of bedrock properties must be considered. Our goal is to compile a dataset of bedrock strength and properties of the river systems. The study area includes the entire Colorado Plateau and the western part of the Central Plateau. There have been complications, however, and the methodology problem must be addressed. Traditional rock strength measures such as Schmidt hammer rebound, Selby rock mass strength (RMS), or tensile strength ignore weak rock types. We need to develop a new methodology that reliably estimates the strength of mud-rocks that are too incompetent to test directly.

Goals

We will complete measurements of the characteristics of rock formations along the Colorado and Green rivers to address the research question of how bedrock strength controls the erosion of these rivers. The Green River Basin can be broken up into 48 reaches dominated by a variety of bedrock compositions including Proterozoic, quartzite, sandstone, shale, limestone, evaporites, and crystalline basement. Compressive strength data from most of the outcropping rock formations have been collected from all reaches, however tensile strength data for these rocks are not well documented. The tensile strength of mud-rocks is a critical test. Our existing data indicate there are strong relations between rock strength and channel valley width and gradient and stream power. Documentation will be done to complete modified Selby rock mass strength evaluations, noting thickness and proportion of beds that are too weak to be tested. From these new data, we aim to back-calculate the compressive and tensile strength of mud-rocks to be measured in the laboratory. We hope to develop a methodology that can be applied to the measured channel widths and known rock strengths, similar to previous numerical modeling in the region.

Methods

Compressive strength is quantified using a Schmidt ( rebound) hammer in the field. Schmidt hammer measurements can be directly converted to a compressive strength value through an empirical relation (C = 2.12 * R-0.25). However, the model value assigned to a Schmidt rock hardness measurement is also an important component of the semi-quantitative modified Selby RMS classification. Other factors sampled into this classification include fracture/joint orientation, bedrock thickness, and width. We propose that some of these factors (such as groundwater and weathering) are major contributors to bedrock erosion. Other, not-considered factors such as the volume of weak rock (i.e., shale) that makes up the rock formation should probably be included in the modified Selby RMS classification. See table of modified Selby RMS measures below.

Tensile strength is determined by the Brazilian splitting test in the lab. This method requires 3 inch thick and 2 inch diameter rock disks, cored from in situ rock samples. The Brazilian test is a standard method that reliably estimates the strength of mud-rocks to estimate the effective tensile strength for mud-rocks.

Neither of these methods currently include a means to quantify the strength of mud-rocks.

Initial Results

Compressive and tensile strength of rocks in the Colorado Plateau are rather poorly correlated with each other. Since rocks are weaker and break in tension, the tensile strength of a rock is a better value to use for the determination of that formation’s reliability. Experimental results from Skir and Dietrich (2001) suggest that tensile strength is good measure of bedrock erosion rate. Our initial results support this hypothesis with a significantly better correlation of unit stream power with tensile strength than either compressive strength or modified Selby rock mass strength.

Planned Work

- Field work will primarily entail collecting samples from formations for which we currently lack tensile strength data.
- Application of the additional proposed factor “proportion of mud rock” to the modified Selby RMS classification will be needed to refine the semi-quantitative dataset.
- Formations of rock too weak to sample will be documented along with their corresponding channel metrics in order to generate a functional relation that we can use to estimate non-active rock strength.