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14. ABSTRACT The major goal of this project is to provide insight to why and how rock strength influences bedrock erosion processes and morphology to quantitatively predict how channel morphology reflects rock strength in our study area and beyond. The project is divided into three parts: (1) quantify channel morphology and characteristics, (2) quantify geotechnical properties of the rock, and (3) perform controlled experiments of bedrock erosion processes. DEM analysis showed significant changes in channel morphology across different rock types. The geotechnical analysis performed provided targets for future work.

15. SUBJECT TERMS river morphology, rock strength, surface processes, material properties
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a. REPORT UU	UU		Brian Yanites
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c. THIS PAGE UU			

Report Title

Final Report: Quantifying Rock Strength from River Channel Morphology

ABSTRACT

The major goal of this project is to provide insight to why and how rock strength influences bedrock erosion processes and morphology to quantitatively predict how channel morphology reflects rock strength in our study area and beyond. The project is divided into three parts: (1) quantify channel morphology and characteristics, (2) quantify geotechnical properties of the rock, and (3) perform controlled experiments of bedrock erosion processes. DEM analysis showed significant changes in channel morphology across different rock types. The geotechnical analysis performed provided targets for future work.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

<u>Received</u>	<u>Paper</u>
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TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Larimer, J.E. and Yanites, B.J. 2016, "Quantitative Relationships Linking Rock Strength to Channel Morphology: A Case Study in Central Arizona", AGU Fall Meeting, San Francisco, CA.

Mitchell, N and Yanites, B.J. 2016. "EXPLORING THE LITHOLOGIC INFLUENCE ON BEDROCK RIVER MORPHOLOGY THROUGH THE SALMON RIVER WATERSHED OF CENTRAL IDAHO." GSA Annual Meeting, Denver, CO. DOI: 10.1130/abs/2016AM-280191

Number of Presentations: 2.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received

Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	<u>Discipline</u>
Jeffrey Larimer	0.50	
FTE Equivalent:	0.50	
Total Number:	1	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	<u>National Academy Member</u>
Brian J. Yanites	0.10	
S.J. Jung	0.10	
FTE Equivalent:	0.20	
Total Number:	2	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	<u>Discipline</u>
Hailey Couture	0.10	Geosciences
FTE Equivalent:	0.10	
Total Number:	1	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 1.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 1.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 1.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME PERCENT SUPPORTED
FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

See Attachment

Major Goals

The major goal of this project is to provide insight to why and how rock strength influences bedrock erosion processes and morphology to quantitatively predict how channel morphology reflects rock strength in our study area and beyond. The project is divided into three parts: (1) quantify channel morphology and characteristics, (2) quantify geotechnical properties of the rock, and (3) perform controlled experiments of bedrock erosion processes.

Quantifying channel morphology and characteristics requires both remote sensing and fieldwork to measure channel slope, channel width, sediment grain size distribution, sediment cover of the riverbed, and sub-meter roughness of the bedrock. Channel slope and width, when normalized by contributing drainage area, allows us to compare the morphology of different segments of rivers in spite of their size. Grain size measurements will be used to scale flume experiments and inform stress magnitudes in fatigue strength tests. Sediment cover/exposed bedrock will allow an assessment of the erosion process operating at different sites as well as the potential influence of sediment cover enhancing or inhibiting erosion at each site. Sub-meter scale roughness will allow us to determine whether the erosion process at specific sites in the field are undergoing grain-by-grain abrasion or wholesale plucking of jointed rock.

Quantifying geotechnical properties of the rock involves both field work and laboratory experiments. Samples collected from the field will be prepared and tested for their tensile strength and fatigue strength. Slake durability tests will assess the rock's susceptibility to weathering through cycles of wetting and drying. Fracture spacing will be calculated using 3D models produced from digital photos of the riverbed at the different sites and will allow us to investigate the critical fracture spacing at which wholesale plucking of jointed rock become dominant. Results from these tests will allow us to develop a comprehensive understanding of the relative rock strength among the different samples.

Laboratory experiments of bedrock erosion utilize both the fatigue tests and measuring erosion in a flume. These experiments are designed to gain further insight into how bedrock erosion processes, and thereby channel morphology, are influenced by the strength of bedrock. The fatigue tests will measure a rock's susceptibility to damage accumulation from impacting grains on the riverbed, while flume experiments will measure the rock's susceptibility to grain-by-grain abrasion. The results from these experiments will answer questions such as: do relative differences in geotechnical properties such as tensile strength predict the rock's susceptibility to abrasion or fatigue?

Accomplishments

Major Activities

During the Fall of 2015 we generated steepness profiles of streams draining the Verde and Aqua Fria Rivers. In October of 2015 the PI and grad student traveled to the Verde and Aqua Fria basins to finalize sampling locations and collect preliminary data. We conducted the first field season in March of 2016. The PI and research group of four students spent two weeks in the Prescott National Forest,

Arizona. Within each field area, the rivers crossed into different lithologies. We recorded exact locations of lithologic boundaries along the rivers and collected numerous bedrock samples from the riverbed using a 6" barrel coring drill. Within each lithologic site (a stretch of a single lithology) we set up several transects across the stream where we measured channel geometry, surveyed bedload sediment size distribution and sediment cover of the riverbed, qualitatively characterized bed roughness, measured P-wave velocities at sub-meter spacings, measured the rebound value of the bedrock using a Schmidt Hammer, and took hundreds of digital photos that will help create 3D models of the river channel.

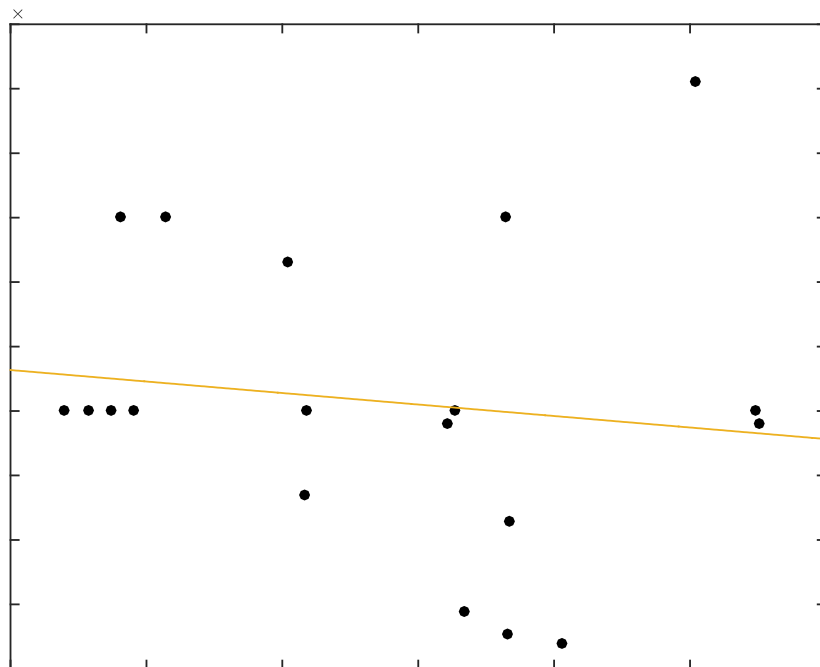
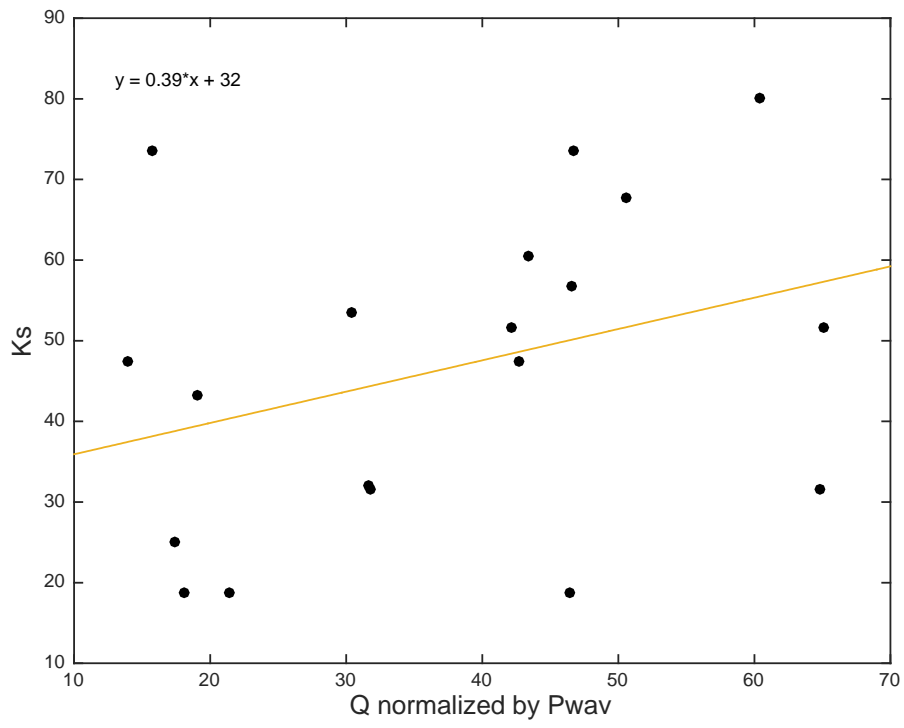
Objectives

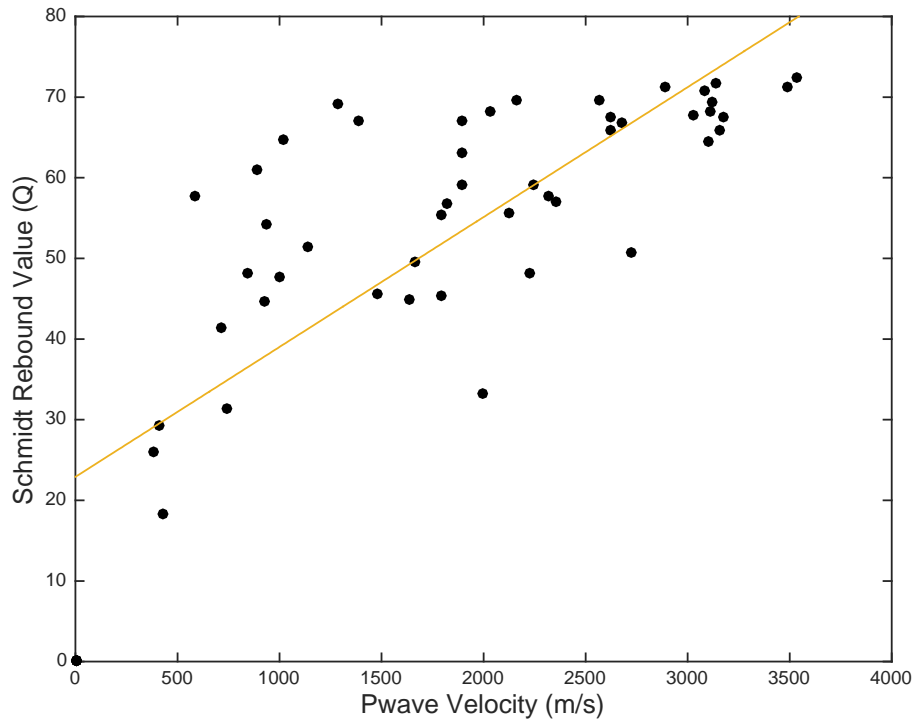
The quantification of channel morphology and characteristics is going according to plan. Channel steepness has been measured along all study reaches using remote sensing. We have completed the first field season in which measurements of channel width and sediment grain size distribution were gathered at 3-5 intervals along the river channel for 17 different sites. We will use these ground verified width measurements to begin remote measurement of channel width along continuous reaches using satellite imagery on Google Earth later this Fall of 2016. Quantification of bed roughness is underway. We have generated 3D models on half of the study sites, and we continue to refine our roughness algorithm to improve sensitivity and validity throughout the different length scales of fracture spacing of the different rock types.

The quantification of geotechnical properties of the rock is also going according to plan. P-wave velocities were recorded in the field at several transects within each study site as well as in the laboratory on core samples that will be strength tested. Tensile strength, fatigue strength, and slake durability tests will begin September 2016, and should be completed by November 2016. The bed roughness algorithm is also being utilized to detect fractures in the rock that will provide an objective and efficient way to measure fracture spacing, which plays a key role in a rock's susceptibility to erosion process.

Results

Using our preliminary data we have compared morphological metrics with P-wave velocity (a proxy for fracture density within the rock) and Schmidt rebound value (a proxy for compressive strength). While these metrics don't fully quantify a rock's strength as it pertains to resistance to erosion, linear models relating morphology to P-wave velocity (m/s) and Schmidt Hammer rebound value (Q) do show slight trends consistent with theoretical models and have improved r^2 values when Q is normalized by the corresponding P-wave velocity measured at the site (Figures 1-2). Q vs. P-wave velocity (Figure 3) shows a strong relationship suggesting that P-wave velocity at the sub-meter scale can be a good indicator of rock strength.





Goals Not Met

Tensile strength, fatigue strength, and slake durability tests will begin during the Fall of 2016 and we expect the results will allow us to derive a more robust quantification of rock strength as it pertains to resistance to erosion. A second field season will take place during Winter of 2017. This field season will fill in any gaps in the dataset and investigate several new sites. Flume experiments will begin Spring 2017 and with results from fatigue strength tests will enable us to consider how other geotechnical properties of rock control the susceptibility to different erosion processes. Quantification of river roughness from structure from motion as well as generating frequency distributions of high intensity flood events for each field location will occur in Fall 2017-Spring 2018. Final analysis and write up will occur in Spring-Summer 2018.

Training

An undergraduate student was given an introduction to integrating GIS software with MATLAB to perform remote sensing of landscape features. During the initial field season, the research team of three graduate students and one undergraduate student were lead by the PI. Students were shown different techniques of stream channel survey and given instruction on measuring sub-meter P-wave velocity and Schmidt Hammer rebound value. The work is supporting a PhD student.

Dissemination

A graduate student will present the first test of the hypothesis that channel morphology reflects rock strength at the American Geophysical Union annual meeting in December of 2016.

Plans

Nothing to report