Rolling, Rolling, Rolling Down the River: What Impact do Harder Rocks have on a River's Foundation as they Travel Downstream?

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Motivation

When you compare the renditions of "Proud Mary" by CCR and Tina Turner, Turner's harder, rock'n'roll version is faster, grittier, and more impactful – some might even call it more *abrasive* – than the gentle sway CCR's soft rock sound evokes. The same contrast between softness and abrasiveness can be found in gravel-sized rocks that are rolling down real-world river systems. In this project we explore the relationship between the relative hardness of different rock types found in the gravel load of a small river, and their ability to breakdown, or *abrade*, as they travel downstream. We expect to find that harder rocks will remain larger in size for longer distances downstream, causing them to have a greater impact on the geometry of the river. Improving our ability to predict the evolution of river hydraulic geometry (which includes metrics such as channel width, slope, and water depth) has many relevant implications for humans, including knowing when and where the land between the waterway and your waterfront property will wash away.

Background

$$E = KA^m S^n$$

E= Vertical Erosion Rate $[LT^{-1}]$
K=Erodibility Coefficient $[LT^{1-2m}T^{-1}]$
A=Upstream Drainage Area $[L^2]$
S=Streamwise Channel Bed Gradient

What's Missing? Sediment.

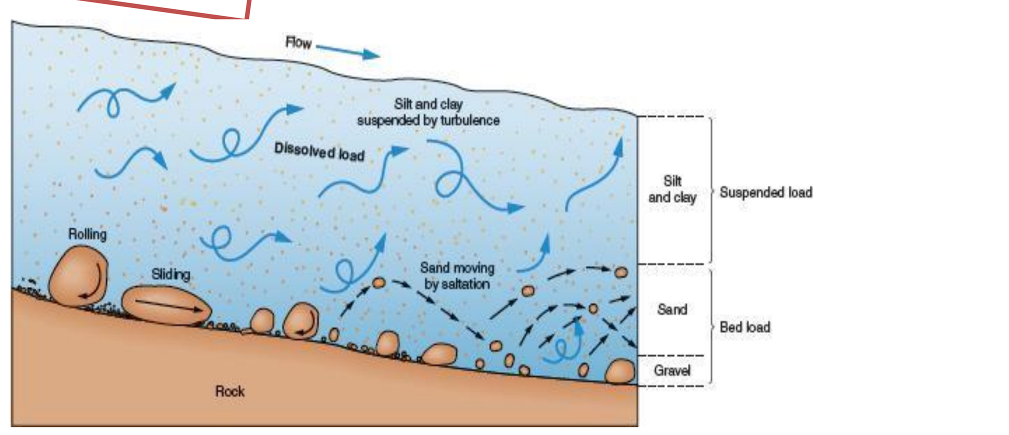

Figure 1. Diagram showing how a stream transports sediment. For this study we focused on the bedload gravel.
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Methods

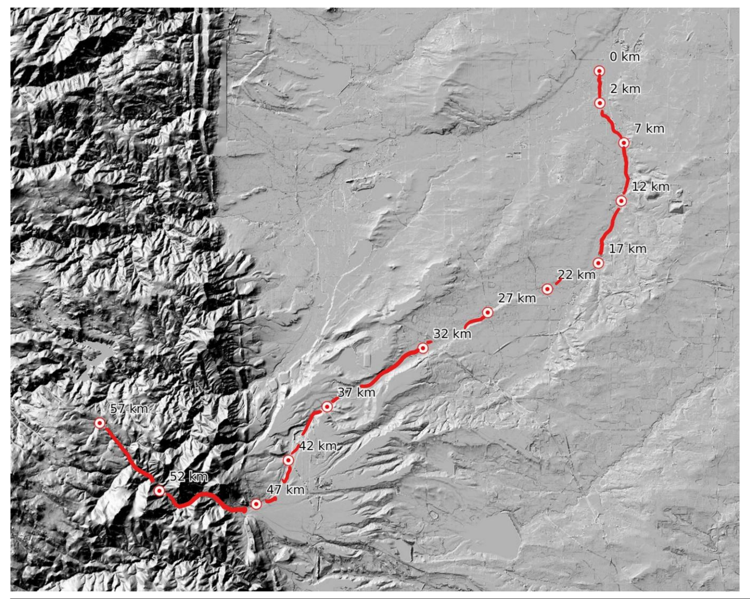


Figure 2. Map of Coal Creek with sampling sites labeled.

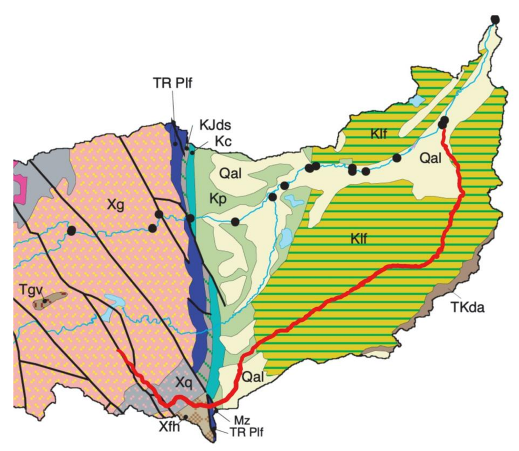


Figure 3. Geologic Map of rock types in the Eastern section of Boulder Creek Watershed Adjacent to Coal Creek (shaded red on the map above)[1].

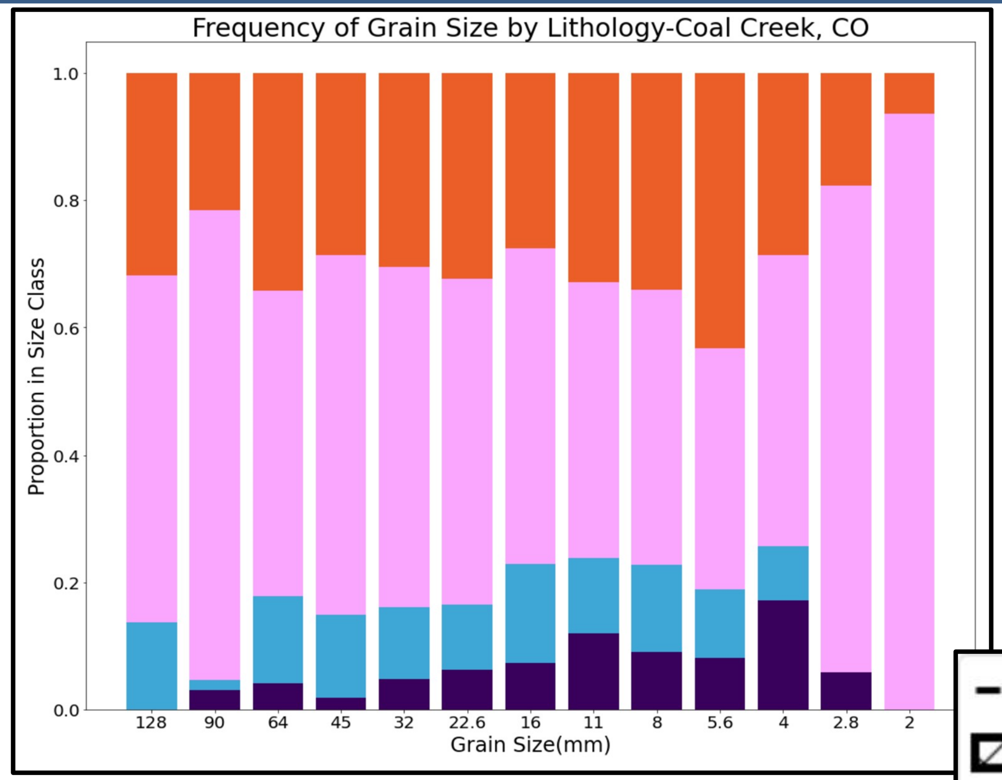
Period	Code	Description	Study Classification
Quaternary	Qal	Alluvium, Gravel, and Eolian Deposits	N/A
Tertiary	Tkda	Denver and Arapahoe Formations: sandstone, mudstone, claystone, and conglomerate	Sedimentary
Cretaceous	Klf	Laramie Formation and Fox Hills Sandstone: shale, claystone, sandstone, and major coal beds	Sedimentary
Cretaceous	Kp	Pierre Shale	Sedimentary
Triassic/Permian /Pennsylvanian	TR Plf	Lykins, Lyons, and Fountain Formations: red siltstone, sandstone, and conglomerate	Sedimentary
Mesozoic	Mz	Mesozoic Sedimentary Rocks	Sedimentary
Pre-Cambrian	Xg	Grantitic Rocks of 1700-M.Y. Age Group (Includes Boulder Creek Granodiorite)	Igneous
Pre-Cambrian	Xfh	Felsic and Hornblendic Gneisses, either separate or interlayered	Metamorphic
Pre-Cambrian	Xq	Quartzite, conglomerate, and interlayered mica schist	Quartzite

Table 1. Coal Creek Watershed Rocks with lithologies and descriptions. The group we assigned each rock type to is also included [1].

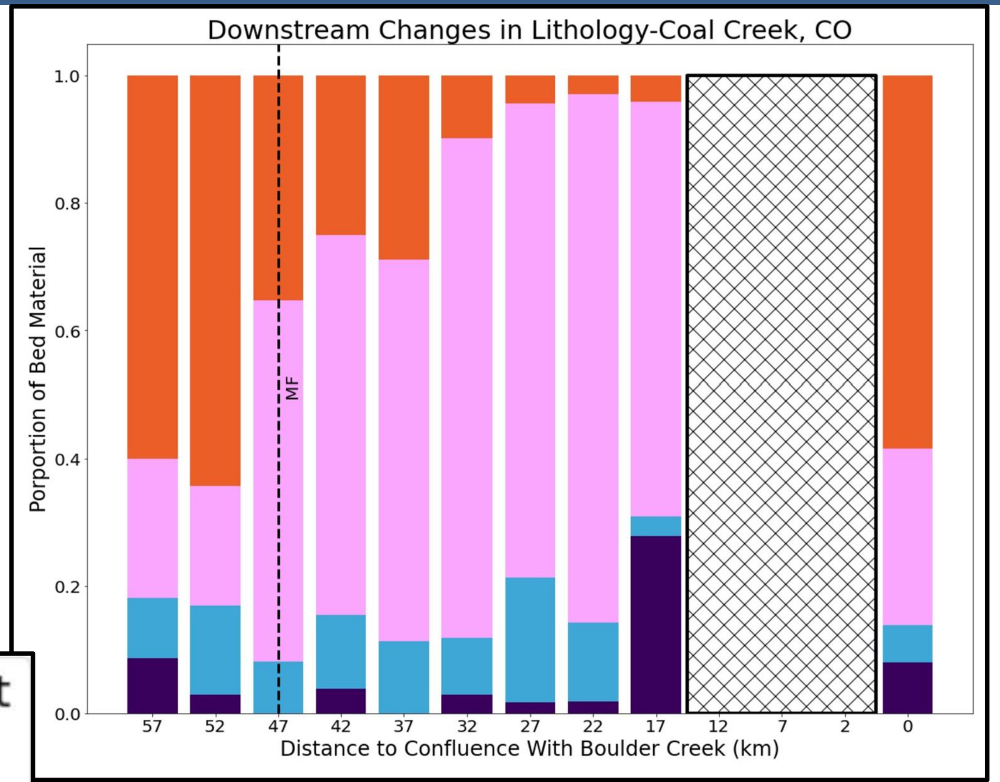
This study used surface pebble counts along Coal Creek to investigate changes in gravel size and lithology with downstream distance. Sampling sites were mapped out every 5 km starting at the headwaters. At each station, we:

- Randomly selected ≥100 grains of sediment from the stream bed
- Determined the size class of each sampled grain based on a measurement of its intermediate axis ("b-axis")
- Identified the lithology of each grain

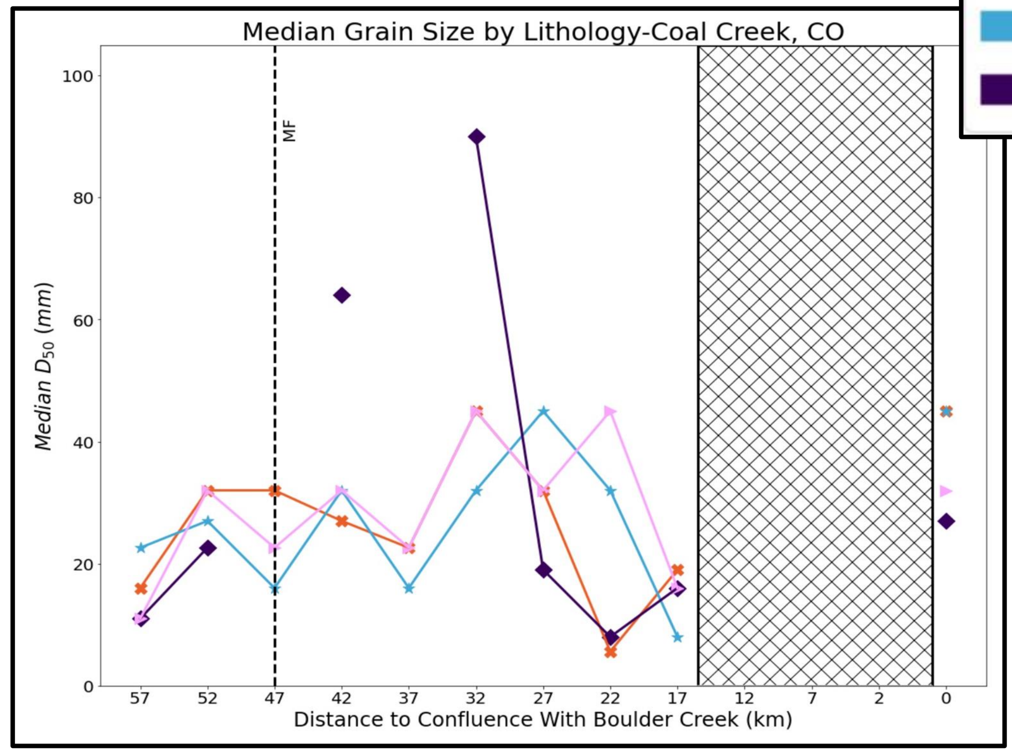
Results



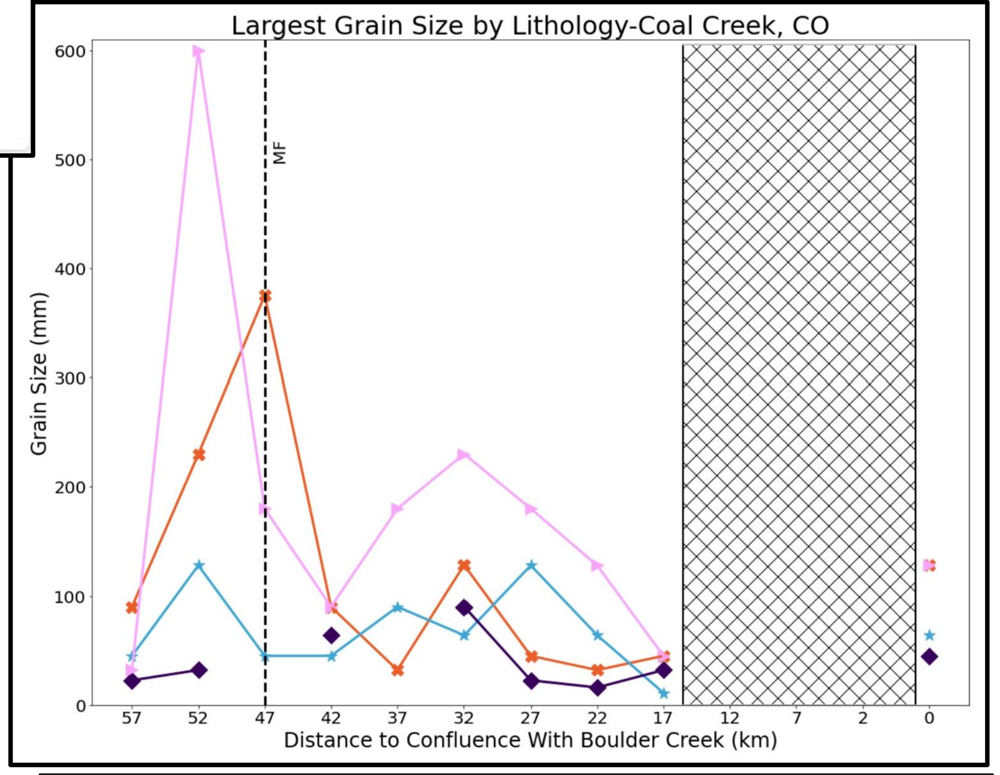
Graph A. The relative proportion of each lithology for the entire sample group, sorted by its intermediate axis.



Graph B. The relative changes in lithology from the headwaters of Coal Creek, to its confluence with Boulder Creek.



Graph C. Median Grain size for each lithology from the headwaters of Coal Creek to its confluence with Boulder Creek



Graph D. The largest grain size for each lithology from the Headwaters of Coal Creek to its confluence with Boulder Creek.

Conclusions

- The durable composition of quartzite allows these grains to maintain their size for longer distances compared to the softer sedimentary rocks and the fragile components of igneous and metamorphic rocks.
- Large sedimentary clasts are rare but do occur; these are likely from local hillslope inputs and do not appear to persist very far downstream
- We should consider the lithology of the bedrock that supplies stream sediment because this exerts a control on median grain size

Future Work

This project has enabled us to develop two hypotheses concerning the potential effects of a quartz-rich bedload being carried across sedimentary bedrock:

1. The harder, more resistant bedrock, abrades the bedrock below more efficiently leading to further erosion of the bedrock.
2. More resistant rock can preserve the bedrock during periods of lower discharge. The river is strong enough to carry away the finer, less dense sediment within the gravel bed, also called *winnowing*. This allows the harder rocks to shield the finer sediment below the gravel surface and preserve the subsurface, *armoring*.

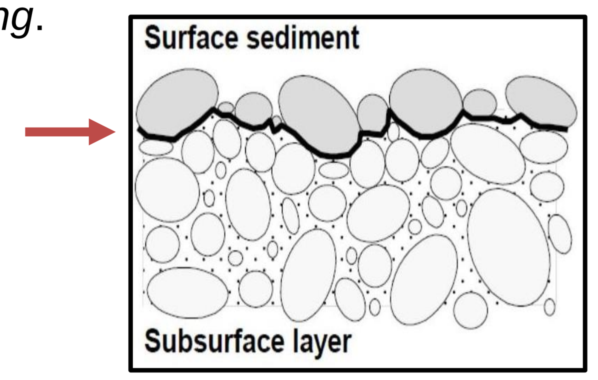


Figure 4. Example showing how the coarser rocks on the surface of the gravel bed can protect the sediment below from erosion and abrasion, *armoring*. The transition between the surface and subsurface is marked with a bold black line and a red arrow [3].

Testing these hypotheses will require additional data. The results from this study can be expanded upon by doing the following:

- Collect missing data from 2 sites on Coal Creek
- Replicate this study on a similar stream nearby and compare results
- Increase the precision of rock identification to specific units.

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