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Regolith, Rock and Fluid Distributions at the Upper Colorado River Basin via a Multicomponent Seismic Imaging Approach

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Surface geophysical measurements can link geologic, geomorphic and hydrologic processes. Characterizing subsurface properties at sufficient resolution, yet over a large enough spatial extent to make statistically relevant correlations between subsurface structure and surface observations (topographic attributes, vegetation, etc.), is currently not standard practice because ground-based geophysical campaigns are limited by acquisition rates. The seismic land streamer is a semi-autonomous vehicle-mounted acquisition system designed to pull geophone arrays and a seismic source to rapidly acquire large data volumes compared to traditional planted geophone surveys. Acquisition geometry is well suited for obtaining first arrivals to constrain p-wave velocities (Vp), Rayleigh waves to constrain shear-wave (Vs) velocities and reflections to map significant subsurface stratigraphy. Joint and/or independent analysis of these semi-independent data sources reduce uncertainties in data interpretation.

In October 2018, we conducted an exploratory seismic survey of the East River Watershed Function Science Focus Area, near Crested Butte, CO. Our survey goals were to map seismic bedrock, regolith and sediment properties and relate them to geomorphic and hydrologic processes. Bedrock in the watershed is composed of Mancos Shale and younger crystalline intrusions. Hillslopes are mantled with weathered bedrock, moraines, landslides and colluvium. The watershed is roughly divided into an upper and lower flood plain separated by a locally steeper stream gradient with bedrock exposures in the river. We acquired ~12 km of seismic data along roads with a 72-channel, 1.25m spaced streamer and an average shot spacing of 2.5m and an average acquisition rate of 3 km/day. We also obtained ~3km of planted geophone data with geophone and shot spacings between 2.5 and 5 meters and an acquisition rate of 0.5 km/day.

Preliminary Vp results show a sharp transition between regolith and bedrock along hillslopes suggesting a similarly abrupt change in porosity. Vp anisotropy in the Mancos Shale suggests geologic structure drives bedrock groundwater flow. We note changes in Vp and Vs with elevation and slope, reflecting contact metamorphism away from intrusive rocks and the influence of sediment transport on seismic velocity. We show that the Upper Flood Plain contains about 20 meters of alluvium compared to <10 meters in the Lower Flood Plain, reflecting slope-dependent variations sediment transport along the watershed. Reflection images suggest channel morphology is controlled, in part by geologic structure.