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Upstream facing convex surfaces and the importance of bedload in fluvial bedrock incision: observations from Taiwan.

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Until recently many bedrock bedforms have been little more than ornate curiosities found in many bedrock river channels because few process-form linkages had been established for the myriad of forms recognised in the literature. In addition rates of bedrock bedform development from direct observations in natural channels are rare due to difficulties in confidently linking spatial observations from two monitoring visits using extant methods.

We have documented bedrock bedforms present at 45 river locations in a survey of Taiwanese rivers and monitored erosion at sites on a single river, the Li Wu River, between 2007 and 2008. Taiwan is an ideal location to investigate bedrock bedforms produced by bedload abrasion due to regular high discharge events, high discharge variability, high sediment transport rates of bedload calibre material, and documented high fluvial bedrock erosion rates. In this paper we present surface texture observations (photographs and scanning electron microscope images) of a particularly common variety of bedrock bedform found in Taiwanese rivers: upstream facing convex surfaces (UFCS). A distinct contrast exists in surface textures, on two scales of observation, between the upstream and downstream facing facets. On a millimetre scale, upstream facing convex surfaces have a sugary roughness with centimetre-scale pits superimposed on a larger-scale smoothed convex form. In contrast downstream facing surfaces are often more intricately sculpted on a centimetre scale with millimetre- to micrometre-scale roughness, defined by roughness elements smaller than the rock forming grain, superimposed on an often undulatory concave form. A linear crestline feature marks the change in slope and surface texture of the bedform and is orientated approximately normal to the channel axis.

To complement these qualitative observations we present a novel method to quantify small-magnitude surface changes by using embedded, two-part datums and conventional 3D laser scanning. Using this method the kinematics of ten nascent upstream facing convex surfaces were determined by differencing three-dimensional models acquired in March of 2007 and 2008. A feature common to all sites is an asymmetric pattern of erosion at the scale of the bedform. Erosion was dominantly focused on the upstream facing surfaces whereas the downstream facing surfaces experienced minor erosion. The linear crestline maps the boundary between high and low relative erosion rates, in addition to marking the boundary between changing surface texture and slope characteristics. To a much lesser extent, in some cases, erosion is also spatially variable within each facet of the bedrock bedform.

We argue that the erosion of the upstream facing, or stoss, surface of this variety of bedrock bedform is the work of abrasion by bedload, which by being decoupled from the flow can only impact the stoss surface to any significant extent. If this is the case then the high erosion rates observed indicate that abrasion by bedload is the controlling process in the formation of this variety of bedrock bedform and perhaps the channel at large in this setting. Lee surfaces, which are sculpted more slowly, are the product of suspended load abrasion due to much smaller particles impacting the substrate in the lee of the obstacle where they are ejected from tightly curved flow lines. As bedload accounts for only $\sim$30% of the total river sediment load yet bedload abrasion accounts for virtually all the erosion on UFCSs, the quantity of bedload passing through bedrock rivers has a strong control on channel incision rates.