Geophysical Research Abstracts
Vol. 20, EGU2018-11399, 2018
EGU General Assembly 2018

Beyond the threshold for motion: river channel geometry and grain size reflect sediment supply

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In many gravel-bedded rivers, floods that fill the channel banks create just enough shear stress to move the median-sized gravel particles on the bed surface (D50). Because these ‘threshold channels’ are common, and theoretical work nicely explains the coincidence of bankfull flow and the incipient motion of D50, some have argued that all self-formed gravel-bedded rivers in equilibrium must be ‘threshold channels’. However, not all natural gravel channels actually conform to this simple relationship; some channels maintain bankfull stresses far in excess of the critical stress required to initiate sediment transport. We use a database of >300 gravel-bedded rivers and >600 10Be-derived erosion rates from across North America to explore the hypothesis that sediment supply drives the magnitude of bankfull shear stress relative to the critical stress required to mobilize the median bed surface grain size (τ*bf/τ*c). We find that τ*bf/τ*c is significantly higher in West Coast river reaches (2.35, n=96) than in river reaches elsewhere on the continent (1.03, n=245). This pattern parallels trends in erosion rates (and hence sediment supplies). Supporting our hypothesis, we find a significant correlation between upstream erosion rate and local τ*bf/τ*c at sites where this comparison is possible. Our analysis reveals a decrease in bed surface armoring with increasing τ*bf/τ*c, suggesting channels accommodate changes in sediment supply through adjustments in bed surface grain size. The observed relationship between sediment supply, armoring, and τ*bf/τ*c is supported by a numerical model for sediment transport. Our findings demonstrate that sediment supply is encoded in the bankfull hydraulic geometry of gravel bedded channels through its control on bed surface grain size.