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Paleo-basin hydrology and sediment transport in the Pisco Valley, Peru

toufik bekaddour and fritz schlunegger
Bern University, Earth Sciences, Geology, Bern, Switzerland (toufik.bekaddour@geo.unibe.ch)

Quantitative data on sediment transport and climatic changes allow the understanding of alluvial river processes such as aggradation, degradation, vertical and lateral incision and valley widening. Here, we focus on the ca. 4.5*10ˆ3 kmˆ2-large Pisco drainage basin on the western Pacific side of the Andes, central Peru, which is currently a desert with precipitation rates decreasing form 800 mm/yr on the Altiplano, to 10 mm/yr at the coast. While higher precipitation rates than at present have been inferred from lake level highstands on the Altiplano between 48 and 36 Ka PB (Minchin period), no quantitative estimates about water budgets for that time have been presented so far. Here we use the stratigraphic archives from the Pisco Valley and explore relationships between: (i) the particle size of bedload and the shear stress conditions needed for their entrainment, and (ii) the basin hydrology and channel adjustment for the present time and the Minchin pluvial period between 48 to 36 ka BP when sediment aggradation resulting in the build-up of ca. 50 km-thick terrace sequences. We find that the bedload material is generally more coarse-grained in the terrace deposits than in modern longitudinal bars. In particular, grain size measurements reveal that the mean D50 and D84 of the modern deposits are about 100 and 170 mm, respectively. Meanwhile the mean D50 and D84 inferred from measurements of the terrace deposits are ca. 150 and 310 mm. Our results reveal that the current mean annual discharge Q=60 mˆ3/s of the Pisco River is just refreshing the flat middle reaches and transporting the coarse particles in the steep higher reaches at near critical threshold. On the other hand, the hydraulic analyses based on the D50 of the Pisco River reveal that a critical discharge of Q=300 mˆ3/s is required to transport the D84 along the entire channel, and a discharge of this magnitude could rearrange the entire channel morphology except for the downstream reaches where the coarse bed particles remain immobile. For the terrace deposits, however, the critical discharge inferred from grain size data yield strong prevailing hydraulic conditions during the Minchin and more powerful formative discharge (Q=900 mˆ3/s) that exceeded the threshold of motion of the D84 along the entire Pisco River. Our results first underscore the importance of the channel geometry in general, and gradients in particular, as one of the most important controlling parameter for sediment transport (i.e. where erosion, by-pass and sediment accumulation occurs). Most important, the data presented here suggest that in the Pisco Valley, the channel forming discharge was at least 3 times higher between 48-36 Ka PB than at present. For the Minchin period, we anticipate similar changes for the Altiplano, and potentially also for other regions in South America.