G226-P005 **Room: Poster Session Hall** **Time: May 17**

Autogenic fluvial grade attained independent of initial conditions: Implications from analog flume experiments

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A river that transports sediment through a reach with neither net deposition nor net erosion in a suitably time-averaged, statistical sense is referred to as graded with respect to that reach of the river. This concept of fluvial grade is typically presented as the long-term, equilibrium state of a river system subject to steady external forcing and stationary sea level. The conventional view of grade claims that, as long as relative sea level remains stationary, rivers will eventually become graded and, further, that the graded state disappears when relative sea level rises or falls. Other workers have suggested that rivers cannot avoid coastal aggradation when they extend basinward during sea-level standstill. This skeptical view of grade arises from the observation that the downstream end of a natural alluvial river is the shoreline or river mouth, which, on geologic time scales, is a moving boundary. Key questions are if and how rivers can be graded in au autogenic manner consistent with the physical behavior of this moving boundary. Here it is shown that rivers ending in prograding deltas and subject to steady sea level fall can be in grade with any constant rates of the fall regardless of initial shoreline positions. Consider an antecedent graded river profile, the upstream end of which consists of a bedrock-alluvial transition, and the downstream end of which is a fixed overfall where constant sea level is maintained. The antecedent graded profile is then drowned by a jump in sea level, after which sea level drops in time. The result is a new river profile ending in a prograding delta that deposits on top of the antecedent profile. If (1) the rate of sea level drop is constant and (2) the length of the antecedent reach is sufficient, the new profile eventually becomes perfectly parallel to the antecedent profile, so maintaining grade as it progrades. In the experiments reported here a series of graded profiles with prograding deltas are stacked. The first such profile is stacked on the antecedent profile. Each subsequent graded profile is stacked on its immediate predecessor. A graded profile is eventually reached regardless of the rate of sea level fall, as long as it is constant, and as long as the antecedent profile is of sufficient length, and also regardless of where the initial position of shoreline was. It is found that the approach to grade is more rapid (and distance the delta progrades before attaining grade is shorter) for higher rates of sea level fall, lower rates of sediment supply, and higher water discharges.