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Understanding Subduction Erosion Through Scaled Sandbox Analogue Experiments

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The removal of material by tectonic erosion at ∼60% of the Earth's convergent margins is a significant but still poorly understood process. We explored mass transfer processes and the structural evolution of erosive systems in a series of 2D sandbox experiments. A wedge-shaped sand body with an initial wedge geometry of 125 cm (length) x 30 cm (height) x 20 cm (width) represented the forearc in a sandbox 3 m long. A conveyor belt with a rough surface at the base simulated subducting oceanic crust. The initial slope angle α was set to 13.5º, the basal angle β to zero. For the system to develop dynamics similar to those observed in nature, the mechanical properties of the materials were properly scaled.

Our study explored the role of a controlled volume of sediment leaving the sand wedge on its mechanics and dynamics by varying the width of the subduction window (Global Capacity GC) at the base of the back wall. We quantified our results, including frontal erosion (removing material from the tip of the slope), basal erosion (detachments from the base of the forearc, causing surface subsidence), subsidence, accretion and tip retreat, and compared them to natural examples of erosive convergent margins. Basal erosion, subsidence and frontal prism evolution are related to subduction channel (SC) characteristics. Volumes of frontal and basal erosion decrease as GC decreases. Basal erosion can amount to up to twice the frontal erosion in case of a sufficiently wide subduction window. As a consequence, wedges with large GCs produced erosion ratios (basal erosion/frontal erosion) > 1, in agreement with estimates from natural forearcs. Total erosion (i.e., frontal plus basal erosion) was favored by wide GCs. Commonly, the size of the frontal prism varied in size with the GC. "Accretionary" systems evolved in erosive systems by varying the GC, without adding sediment to the toe. Thinner GCs developed a higher number of backthrusts at the frontal slope. We identified three segments along the wedge and the SC, related to the mass transfer modes. At the toe, the total sediment entering the channel is restricted by the inlet capacity (IC). Volumes of eroded material correlate with the IC/GC-ratio. If IC $\leq$ GC, frontal erosion is controlled by GC; if IC $>$ GC, by IC. In addition, the IC/GC-ratio also controlled basal erosion: when IC/GC$>>$1, basal erosion was very low; in contrast, when IC/GC$<$1, basal erosion dominated.