Effect of wedge geometry and internal friction on subduction erosion processes: Insights from 2D analog models

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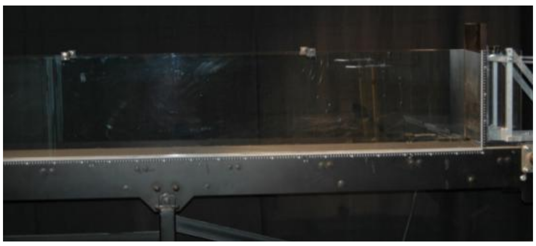
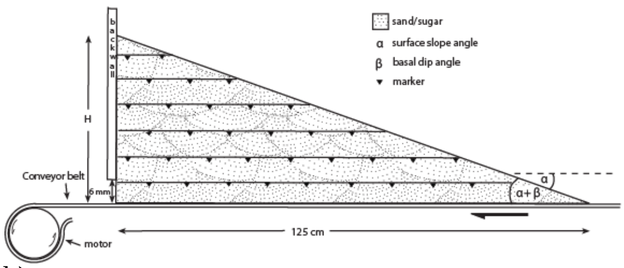
Convergent margins can be classified into two main groups: those with a long-term consumption of the seaward edge and those where sediments from the overriding plate are accreted, called erosive and accretionary margins, respectively. Margins undergoing tectonic erosion remove material from the frontal slope (i.e. frontal erosion), and upper plate base (i.e.basal erosion) [1] transporting sediments and rock into the mantle.

Half of the world's margins have been described as erosive, among them we can mention North Chile, Japan, Costa Rica and Izu/Mariana [2]. However, as subduction erosion technically truncates and destroys the continental margin, the identification and study of tectonic erosion is more difficult than that of accretive processes [3]. In this context, the motivation of this study is to gain insight into the processes related to subduction erosion exploring the influence of the surface slope and forearc strengths on frontal and basal erosion, accretion, and tip retreat. To address these key problems, we use 2D sandbox experiments and monitoring with Particle Image Velocimetry, which allow to directly follow the structural evolution and particle displacement within the wedge. The sandbox apparatus consists of a 3 m long and 20 cm wide glass box (Figure 1a). A conveyor belt with a high friction surface moves backward converging a sand wedge-shaped body toward a rigid backwall, (Figure 1b). We introduce a gap at the base of the backwall allowing the output of material from the system, thus the deep material transport is simulated as in nature. In these experiments, the sand wedge represents the crustal wedge, whereas the conveyor belt simulates the subducting plate. The scale factor corresponds to 10^5, where 125 cm are equivalent to 125 km in a natural forearc (Figure 1b).



a)



b)

Figure 1. a) Picture shows the box used for the all experiments. b) Diagram of model configuration used in this study. Basal angle is set up to zero in all experiments of these series.

In the experiments the tested configurations were: A) pure sand wedge bodies with variable slopes and heights; B) wedges made of different compositions of sand and sugar. In the latter, the properties of the sugar are used to vary the internal friction of the wedge. Higher internal friction generates a stronger wedge. The first results of our experiments show faster tip retreat as the initial angle of the slope is lower. The smaller normal load at the frontal slope allows a faster accretion of material, making the tip retreat easier. On the other hand, the increase of strength should decrease both tip retreat and accretion. Both, frontal and basal erosion show an increment with a small lower slope angle, whereas basal erosion was increased and frontal erosion decreased with a higher internal friction. As a consequence, wedges with higher internal friction produced erosion ratios (basal erosion/frontal erosion) greater than 1, which agree with values estimated in natural wedges [1]. On the other hand, total erosion (i.e. frontal- plus basal-erosion) was favored with lower slope angles and stronger wedges showed lower amounts of erosion.

Structural style was influenced mainly by the initial slope angle and not by changes in strength. Wedges with the same initial lower angle but different strengths developed backthrusting at the frontal slope (Figure 2a, b and c) whereas those with smaller initial lower angles showed normal thrust localized at the rear zone of the wedge (Figure 2d, e and f). Subsidence and middle slope evolution were similar among wedges with different strengths; however those with different initial lower slope angles were characterized by different middle slopes (Figure 2)

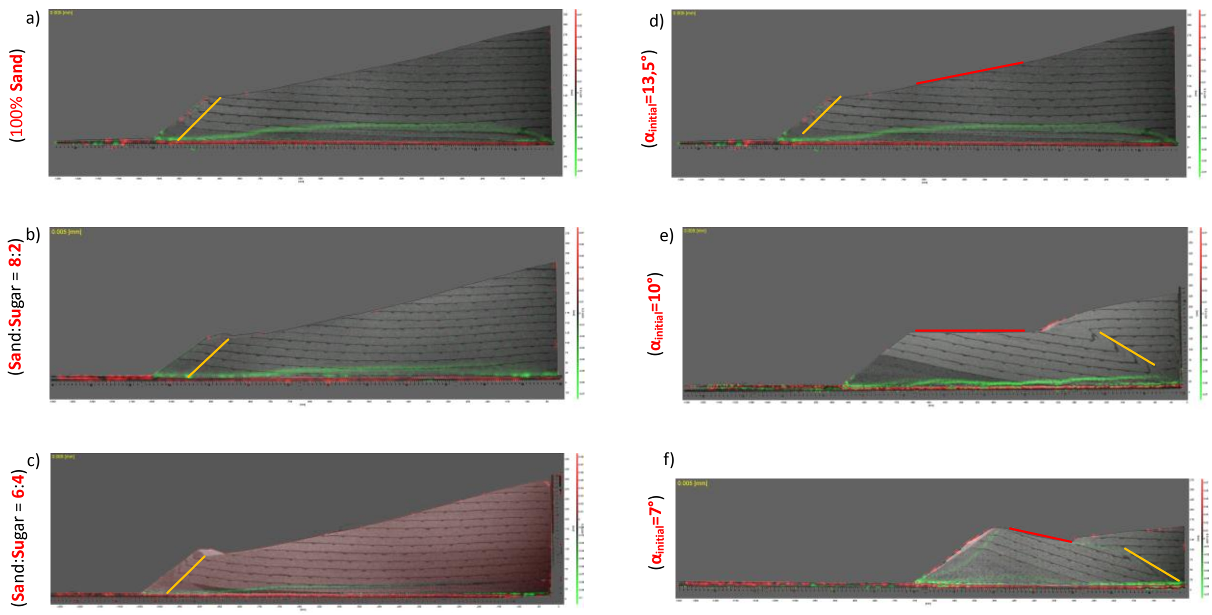


Figure 2. The pictures show the last stage at 500 cm of convergence. Right column compares experiments with different strengths (sugar contents) and the left side different initial slope surfaces. Slopes and faults are shown with red and oranges lines, respectively. Red and green paths on the pictures show the particles movement. The green and the red paths indicate counterclockwise and clockwise displacements, respectively.

Our study suggests that at convergent margins undergoing tectonic erosion, the steepness and strength of the forearc influence its deformation, as well as the landward migration velocity of the trench and the mass transfer of the eroded material. A shallowly inclined continental surface results in a smaller normal force, which permits easier compressional uplift at the frontal slope and accelerates the tip retreat. Additionally, stronger forearcs would develop lower total erosion but higher basal erosion. Our experiment results provide information for the evolution features of forearcs with specific rheological or geometrical configuration (long-term ~10^7 yr) and will allow the comparison with observed characteristics of worldwide erosive margins.

References:

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