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Limit of mountain growth in the rainfall-erosion and uplift experiment

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The experiments with rainfall-erosion and uplift of various rates suggested the existence of two threshold uplift rates, across which experimental landforms show different aspects of development. When the uplift rate is below the lower threshold, a certain characteristic relief determined by mound erodibility and rainfall intensity dominates. When the uplift rate exceeds the lower threshold, the uplift starts to exceed the erosion from the upstream area where fluvial erosion works less. Hills grow until slope failures occur. Slope failures and creep inside the uplifted area do not change average height unless the sediments are carried away from the uplifted area by fluvial processes. When the uplift rate becomes higher, hills grow more and sediment supply from slopes increases, but the resultant increase in gradients helps fluvial processes carry more sediments. Uplift and erosion become balanced to keep average height roughly constant, and similar landscapes exist for a long time. If the uplift rate becomes even higher and crosses the upper threshold, the uplift will overwhelm the erosion and hills will grow into high mountains. Two runs of the experiment (runs 25 and 26) reported here are the runs performed to examine this upper threshold of uplift rate.

A mixture of fine sand and kaolinite compacted in a square-prism-shaped container (c.a., 60 x 60 x 40 cm) was pushed out by a stepping motor and worm gears set beneath the bottom plate. Artificial rainfall of about 40 mm/h was applied on the square sand mound rising from a flat surface. Different from previous experiments, the width of deposition area was reduced to 10 cm, and mist type rainfall was generated from two spray nozzles. The uplift rate was 5 mm/h (run 25) and 0.4 mm/h (run 26). In run 25, average and maximum heights went up with the uplift, but the rise slowed down after 40 h and 56 h, respectively. After the average height went up above 100 mm (56 h), it started to decrease while the mound was still uplifted, and then decreased rapidly after the uplift stopped (72 h). The maximum height reached the peak (240 mm) at 72 h and then decreased rapidly. Both heights decreased only slightly after 150 h to the end (1000 h) with almost no change in topography. In run 26, the increase in average height with uplift started to slow down around 200 h. After it reached 100 mm at around 600 h, relatively rapid decrease and slow increase occurred repeatedly to keep roughly constant height around 80 mm. The maximum height also increased with the uplift until about 680 h (220 mm), but it showed changes similar to the average height after 680 h around the height of 200 mm.

Two runs showed similar limits of average and maximum heights despite their very deferent uplift rates, indicating the existence of a limit of mountain growth. This limit is considered to be determined by the width of deposition area and the mound material. The narrow deposition area probably worked to lower the limit of mountain growth significantly from the previous experiments, which had the deposition area 60 cm wide. The mound seemed to reach the limit before it attained the quasi-steady state height. The decrease in the rate of rise occurred when the sediments produced by large slope failures moved directly out from the deposition area around the mound. Judging from the maximum height, slopes seem to have a limit around 0.6 (30 degree), above which slope failures actively occur. The roughly constant height after 680 h in run 26 probably does not indicate the quasi-steady state but the limit of mountain growth. However, both average and maximum heights are higher than estimated from the previous experiments. The mist type rainfall could generate less surface water flow and therefore fluvial erosion. The decrease in erosion probably causes the decrease of the threshold uplift rate, and the mound could easily reach the limit of mountain growth lowered by the narrow deposition area.

Keywords: rainfall-erosion experiment, threshold uplift rate, limit of mountain growth, deposition area, slope processes, fluvial erosion