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Threshold of uplift rate in the experiments of landform development with rainfall-erosion and uplift

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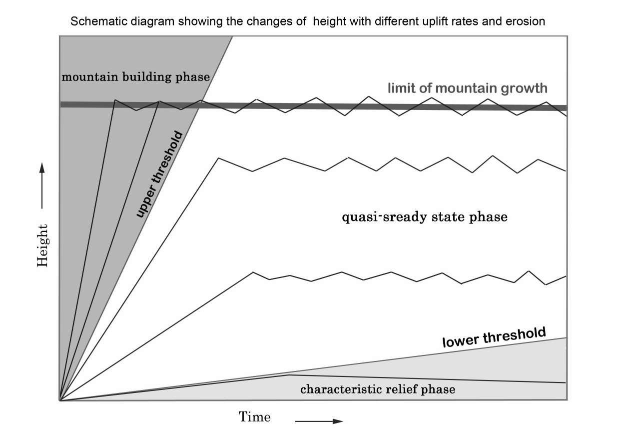
A series of experiments with rainfall-erosion and uplift of various rates suggests the existence of threshold uplift rates, across which experimental landforms show different aspects of development. A mixture of fine sand and kaolinite compacted in a square-prism-shaped container (60x60x40cm) is pushed out at a constant rate from a flat surface under the artificial mist-type rainfall. In the experiment with a low uplift rate below the lower threshold, drainage networks develop as the surface slowly uplifted. The erosion is exclusively fluvial and no slope, on which failures occur, develops. The maximum height of the surface increases with the uplift while a remnant of flat incipient surface remains, but this increase stops when the fluvial erosion becomes effective on the whole surface. The erosion on the top of low hills where the fluvial erosion works least balances with the uplift. The bottom of major valleys, where the fluvial erosion works most, is considered to have become stable at this point and no further downcut is expected. In the area between the bottom of major valleys and the top of hills, on the other hand, the erosion slightly exceeds the uplift, resulting in slow decrease of average height. A certain low characteristic relief determined by the mound erodibility and rainfall intensity develops and lasts for a long period. When the uplift rate becomes higher than the lower threshold, slopes appear at valley sides (and faults) while drainage networks are developing. After drainage networks develop, uplift exceeds erosion in the upstream area where fluvial erosion works less. Hills grow higher and slope processes, especially failures, become significant. Two types of slope failures are observed. One is relatively small failures which occur on the upper part of slopes. Surface material on the upper part of slopes absorbs much water and falls down with its own weight. Another is large scale failures observed after large and high slopes develop with rapid uplift. A whole slope collapses when its base is eroded away. The former small failures occur any time when slopes of a certain height form, and do not affect the average height unless yielded debris are carried out from the uplifted area by fluvial processes. Debris deposited in the uplifted area, however, tend to increase the gradient of streams enhancing the ability of transport. This means that sediment supply from slopes and erosion by streams would balance to form relatively stable relief and height. In the case of the latter large failures, debris from slope failures flow down as debris flows directly out from the uplifted area (even out from the deposition area when its width is narrow), and reduced relief and height significantly. This type of large slope failures occurs intensively at certain intervals depending on the rate of uplift. The surface rises and the relief increases with the uplift between the periods of intensive large slope failures, and the mound height and relief may show oscillating changes around a certain value corresponding to the rate of uplift. However, considering the magnitude of change and the length of interval, it seems difficult to call this condition 'steady state.' 'Quasi steady state' might be an adequate name for this phase of experimental landform development, including the landform development dominantly with small slope failures. If the uplift rate becomes even higher and crosses the possible upper threshold, uplift overwhelms erosion and hills grow into high mountains until the relief (and height) hits the limit determined by the width of deposition (as well as uplift) area and the strength of mound forming material. Whenever the uplift ends, the experimental landform starts decreasing its height and relief exponentially, and a peneplain-like surface appears finally after a very long period of erosion.

Keywords: rainfall-erosion experiment, landform development, threshold uplift rate, slope failures, quasi steady state, limit of mountain growth


Schematic diagram showing the changes of height with different uplift rates and erosion
mountain building phase
limit of mountain growth
upper threshold
quasi-sready state phase
lower threshold
characteristic relief phase
Height
Time