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Development of experimental landform with uplift and erosion— Does the dynamic equilibrium appear? —

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Uplift and erosion are the principal driving forces shaping the sub-aerial surface of the earth. Their interaction had been a major concern to geomorphologists in the old days when speculative theories of landform evolution dominated. In those days, the cycle of erosion advocated by Davis (1889) had so overwhelming influences that modern geomorphology had to start from the denial of this theory. Landform evolution (and the interaction between uplift and erosion), which usually did not leave enough evidence for scientific studies, has never been the main subject of modern geomorphology. Modern geomorphology, in other words, has hardly succeeded in explaining the development of landform through a long period. The application of dynamic equilibrium by Hack (1960) sounded plausible, but it could hardly replace the cycle of erosion theory due to the same lack in evidences. Recent computer simulations also have no solid ground on the real landform. The landform evolution, however, is still an important and attractive subject of geomorphology, to which we are required to provide some rational explanation. Observing the development of experimental landform with artificial rainfall and uplift, both of which are processes physically possible on the earth, can probably be a way that would provide ideas to explain the landform evolution, although experimental landform is not a scale-model of real landform.

Miniature erosion landform formed by artificial rainfall on the square mound of a mixture of fine sand and kaolinite (90x90x12cm) was slowly uplifted after a low-relief surface developed. Two runs of this type with different uplift rates and one run without uplift, each of which lasted for 1759 hours, are reported here. Erosion started with the rapid development of valley system, and the average height decreased exponentially without uplift. The decrease in average height became much slower with the uplift of 0.1mm/3hours. Subtracting the amount of uplift, the average height shows a rather straight decrease, and the rate of lowering indicates that erosion occurred a little more than compensating the uplift. The development of alluvial fans around the mound, activated and prolonged by the uplift, worked to keep the local base level (and the average height) high, and their dissection, which slightly accelerated surface lowering, occurred with the integration of drainage basins to a dominant one. The alluvial fan development was activated and prolonged more by the uplift of higher rate (0.2mm/3hours). The average height stayed at nearly the same level through the experiment. The dynamic equilibrium (or flux steady state) may have achieved; however, as indicated by the experiment with lower uplift rate, this quasi-equilibrium may possibly result from a mere coincidence of experimental setting. On the other hand, the standard deviation of height within a 10 x10cm square, which showed an exponential decrease without uplift after reaching the maximum value around 30 hours, stayed at certain levels according to the rate of uplift. This seems to indicate that the equilibrium was reached between uplift rate and local relief. The two types of erosion observed during the experiments, (1) erosion accompanied by knick points migrating upstream and (2) erosion detected by the flow of heavy minerals, can explain the process achieving the equilibrium. The knick point of erosion (1), which starts from the upper part of alluvial fans and often associated with the stream avulsion, decreases its height while migrating upstream, and this type of erosion tends to increase the relief. Erosion (2), on the other hand, decreases the relief. The uplift of higher rate, which activates the development of alluvial fans more, increases the occurrence frequency of erosion (1); and therefore, keeps the local relief higher, while the stable average height seems to be determined by the condition of alluvial fan development around the mound.