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Experimental Study on Spontaneous Stratification by Piling of Granular Mixtures

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Introduction

Spontaneous stratification is well known in the field of granular material physics. When heterogeneous granular mixture in size and/or shape of grain is poured from a hopper onto a heap and makes a mountain, layer structure of striped pattern in parallel with the mountain slope is formed inside the mountain because separation by different features of grains takes place in the granular flow on the slope. On the other hand, in scoria cones, which grow with volcanic clasts rolling down on slope, we can often find a striped pattern due to size of scoria. Probably it is formed by spontaneous stratification. In order to understand physical processes of spontaneous stratification to obtain information on eruption of scoria cone (i.e., eruption rate) from the layer structure, carried out 2-dimensional laboratory experiments using a thin Perspex cell. We report determination processes of cyclic thickness of striped pattern.

Experimental apparatus and conditions

Granular mixture consists of two kinds of grains (grains #1 and #2) with the same volumes. We always used spherical glass beads (diameter 0.2mm, density 2.6 g/cm^3) as grain#1. As grain#2, we used three kinds of irregular shaped grains with ~1 mm diameter and various density: sugar (density 1.6 g/cm^3), basalt sand (2.8 g/cm^3), or magnetite sand (5.2 g/cm^3). We dropped the granular mixture near the wall of an experimental cell (300x400mm) of a 15mm gap with a hopper (nozzle diameter 5mm) from 300mm high from base. Flux from the hopper is constant (9-10 ml/s) during each run.

Results and discussion

As grains fall in the cell continuously, the formation of alternating layers consisting of small grain#1 as lower layer and large grain#2 as upper occurs cyclically regardless of kind of grain#2. We present manner of the layer formation during one cycle.

In the beginning of a cycle, grains are stagnant. The mountain has slope with constant angle (initial slope of cycle) and a flat top with about ~20 mm wide. The grains fall on the top from the hopper and then flow down along the initial slope of cycle. At the early stage of the cycle, the outflow rate collapsing from the top region down to the slope is smaller than the inflow rate supplied from the hopper; grains pile up at the top and the height of the top rises. Fluidal part of the grains exists on the initial slope of cycle. Its tip moves down along the initial slope of cycle. During this, grains #1 and #2 separate at lower and upper parts within the fluidal part, respectively, resulting in formation of a pair of the layers. At the top region, the higher the top becomes, the larger the outflow rate is. The outflow rate balances with the inflow rate, then the top stops growing. After this, the top level does not change until the end of the cycle. After the tip of the fluidal part reaches the base of the cell, grains roll a bit (~25 mm) on the base and then deposit, which extends the base of the mountain. The grains flowing down successively accumulate, become stagnant, and form new slope that is parallel to the initial slope of cycle. The new slope grows up to the top and reaches it. At this time, this one cycle ends.

The experiments show us that flow rate of granular mixture that flows down on the slope (Ff) is given as an increasing function of the relative top height from that in the initial condition of cycle (d). In addition, the cyclic thickness of layers is equal to d determined by Ff (d) =Fh, where Fh is the flow rate supplied from the hopper. Therefore, Fh can be obtained from d if we know Ff (d). Because Fh is approximately equal to the eruption rate of a scoria cone, we could estimate eruption rate of scoria cone from its layering structure. Ff (d) is affected by some parameters such as density, size, and shape of grains in granular mixtures. We will carry out experiments controlling these parameter and flow rate to determine Ff (d) in future work.