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Review of Physical Theories of Granular Flow on Slope - For Understanding Piling Structure of Scoria Cone

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Scoria cone grows with volcanic clasts rolling down and piling on the ground. Its growth mechanism should be investigated on the basis of granular physics.

In the field of granular physics, the phenomenon 'spontaneous stratification' is well known. When heterogeneous granular mixture in size and shape of grain is poured from a hopper onto a ground and makes a pile, layer structure of striped pattern in parallel with the pile slope is formed inside the pile because separation of the grains with different features takes place in the granular flow on the slope. Some scoria cones have layer structures, which may be formed by spontaneous stratification.

In order to obtain information on eruption of scoria cone (i.e., eruption rate) from the layer structure, we aim to understand spontaneously stratified granular pile quantitatively. In this presentation we review theoretical and experimental studies on dynamics of granular flow on inclined surface in granular physics and discuss some problems for our study on scoria cone.

The relation between supply flux and layer thickness

We reported at JGU 2007 that the granular flow on the surface of the pile occurs periodically on 2-dimensional laboratory experiments. During some time of the runs, the flow was almost steady and has the thickness of the flow, h. At this time, the mass flux in the flow layer, F, is equal to the mass flux falling from the hopper, and can be described as F = DUh, where U and D is the mean velocity and the mean mass density of the flow, respectively. According to the experimental study by Makse et al. (1998), the thickness of the fixed layer in the pile after settling, L, is proportional to h. Thus we get F = DUkL, where k is the proportionality constant. When U can be described as a function of F and h in a granular media with some parameters such as frictional coefficient and grain diameter, the above equation gives a relationship between F and L. Then we can estimate F from the layer structure of a pile.

The review of studies on granular flow velocity

In order to evaluate the mean velocity U, we need to know the vertical velocity profile in the flow layer. The motion of a grain is determined by gravity force and stress resulting from interaction with other grains. Therefore, evaluation of the stress is necessary. Previous workers approximately consider granular media with homogenous grains as continua and theoretically investigated formulations of stress in the flow on the basis of experiments and numerical calculations. However, the unified expression of the stress has not been established because the features of the flows are different due to the conditions of the flow such as slope angle and physical parameters of grains.

Bagnold (1954) concluded that both of the frequency of collision and momentum loss by each collision are proportional to the shear rate so that the shear stress is proportional to the square of the shear rate. On the other hand, Silbert et al. (2002) reported that Bagnold's law is not correct in the case of the small slope angle. In recent works, stress by effects of friction between grains and existence of force networks spanning throughout granular media as well as Bagnold's stress were evaluated (e.g., Mills et al., 1999). These different expressions on stress give different velocity profiles.

Future work

We need to know the stress expression and velocity profiles appropriate to the granular media and conditions in our experiments. In addition, we use granular mixture with two kinds of grains. Granular mixture is divided into two layers on the slope. Dynamics of each flow layer can be expressed by that of single layer flow with appropriate boundary condition. The lower layer has not free surface but finite stress at the upper boundary and the upper layer is dragged by surface motion of the lower layer. We should develop a proper physical model to describe spontaneous stratification in future work.