Mechanism of density and size segregation in deposits of pyroclastic flow

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The main portion of pyroclastic flow shows various characteristic features. One of the features is density and size segregation of large fragments in the vertical direction; light pumice and dense rock fragments are enriched towards the top and the bottom, respectively, and the fragment size increases with height (reverse grading) for light pumice while it decreases (normal grading) for dense rock. Both gradings are often observed simultaneously (`type 2' in C. J. N. Wilson, J. Volcanol. Geotherm. Res., vol.8, 231, 1980). Another important feature is that, pumice and rock fragments are concentrated at the top and the bottom, respectively, regardless of their size (`type 3' in Wilson (1980)).

To understand the mechanism which produces these features, we studied numerically granular flows without gas on an inclined rough surface with impurities that are different in density and size from the surrounding matrix particles.

We used a two-dimensional Discrete Element Method with soft particle model. The simulations show that the matrix particles are fluidized because some parts of the gravitational energy are converted into random energy. We found the impurities rise or sink according to their density in the fluidized matrix particles. As the density difference between the impurity and the matrix particles increases and the impurity size increases, the speed for rising or sinking increases. This indicates the simultaneous occurrence of the reverse grading of the light impurities and the normal grading of heavy impurities, which corresponds to `type 2'. After enough time, the light/heavy impurities concentrate at the top and the bottom. This corresponds to `type 3'. These results suggest that our granular flow without gas can produce the density- and size-segregation seen in pyroclastic flow. Furthermore, our results indicate that the degree of size segregation increases with time, in other words, the distance from the vent.

Next, we discuss the mechanism of the segregation. Our numerical results indicate that the granular pressure monotonously decreases with height. The negative gradient of the pressure generates a buoyant force. Hence, since light impurities are subjected to a force from the granular pressure which is larger than the gravitational force, they rise, while heavy ones sink. Furthermore, when impurities move relative to matrix particles, the impurities are subjected to the granular viscous force from randomly moving matrix particles. Our results indicate that the behavior of the impurities obeys the law for the liquid viscous force on a cylinder (Oseen's equation). The viscous force is a function of the impurity size and hence the rising- and sinking-speeds would depend on the size.