Experimental study of liquefaction and fluid transport: implication for triggered eruptions

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Liquefaction is a phenomenon in which the inter-particle contact of a liquid-saturated granular matter is loosened by vibration and as a result, the bulk behaves like a fluid. It is widely known that earthquakes can cause soil liquefaction which can manifest in the form of sand boils and mud volcanoes. Liquefaction can also occur in a more viscous fluid (e.g, Sumita and Manga, 2008, EPSL), one example of which is a magma chamber. Magmatic liquefaction may also be caused by earthquakes, and may even trigger a volcanic eruption. There have been a number of experimental studies using water saturated soil and sand in the field of soil mechanics or civil engineering. However the details of the critical condition to cause the liquefaction, and how the consequences of the liquefaction differ with the changeable parameters, are still insufficiently known. Here we conduct an experimental study of liquefaction under a vertical vibration to understand the elementary process of liquefaction and fluid transport. We aim to explore the variety of phenomena which may occur, and to better constrain the conditions which cause these results.

An experimental cell (cross section 22.0mm x 99.4mm, height 107.6mm) is filled with a granular matter and liquid (water or glycerin solution). The lower 33.7mm is a two-layered granular medium; the upper layer and lower layer consist of packed glass beads with a size of 0.05 and 0.2 mm, respectively, such that the upper layer becomes a low-permeability layer. The cell is placed on a vertical shaker which vibrates sinusoidally with an acceleration of 2.0-41.1m/s^2 and a frequency of 10-40 Hz.

Here we describe the results for a water-saturated case. From a series of experiments, we find that as we increase the acceleration there are 4 styles of pore water discharge; No-change, Percolation, Transitional, and Flame (i.e., Rayleigh-Taylor type instability). Under a small acceleration, there is no apparent change in the thickness of the granular medium and the two-layer boundary (No-change). As we increase the acceleration, the two-layered granular medium compacts by expelling the pore-water. First there is no apparent change in the form of the two-layer boundary (Percolation), but as acceleration increases, an instability appears (Transition) whose amplitude grows and a flame structure forms (Flame).

In a two-layered water-saturated granular medium, we find that the pore water which originated from the bottom layer temporary accumulates at the interface of the two layers, and then ascend through the upper layer in the form of vertical channels. We find that the critical acceleration for the formation of the flame structure is of the order of $(\Delta\rho/\rho)$g, where $\Delta\rho$ is the particle-water density difference, ρ is the particle density, and g is the gravitational acceleration.