

Eruption types determined by the mass flux and volatile component content of ascending magma flow

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Volcanic eruptions include the effusive ones that erupt fluid lava and the explosive ones that emit magma fragments in gassy flows or other forms. Traditionally, explosive eruptions are further classified into Plinian eruptions accompanied by high eruption columns, Pelean eruptions involving abundant pyroclastic flows, Vulcanian eruptions with strong instantaneous explosions, Strombolian eruptions involving periodic lava fountains and so on. Effusive and explosive eruptions are clearly controlled by the efficiency of degassing, but what produces various types of explosive eruptions has not yet been explained quite clearly. In this paper I propose a simple idea about how various explosive eruptions arise depending on the natures of ascending deep magma flow based on a stationary conduit flow model.

The state of erupting magma may be represented by exit velocity and the volatile content that determines the vesicularity of volcanic products. The volatile content is specified by its mass ratio to the fluid magma (including solidified part). On the other hand, it is convenient to represent the deep state of magma flow by the mass flux of fluid magma and the volatile contents before degassing takes place. When the magma flow is in a stationary state the mass flux of fluid magma is constant so that it defines the deep state of magma flow with the initial volatile content independently of the specific depth at which magma ascent starts.

The relation between the surface and deep states of ascending magma is calculated using a stationary conduit flow model. In this calculation the volatile component is assumed to move at the same speed as the fluid magma neglecting relative motions. In bubbly magma horizontal permeable flow of volatile gas is assumed to control the rate of degassing. In this treatment, the pressure gradient that drives the permeable flow is considered to arise from the ascent velocity change from center to side and the resulting difference of relaxation of gas expansion due to decompression (Ida, JVGR, 162, 172-184, 2007). The wall friction is assumed to be proportional to ascent velocity in bubbly flow and to the square of ascent velocity in gassy flow with suitable friction coefficients. The relation for water steam in magma is used for solubility of volatiles in magma.

The integration of conduit flow is executed from the surface to a deep conduit. Namely, the deep state of magma flux and volatile content are calculated for various sets of the exit velocity and volatile content at the surface prescribed with the magma pressure equal to the atmospheric pressure. Compiling the calculation results shows that some groups characterize the relation between the surface and deep conditions. Each group can be interpreted in connection with eruption types in the following way.

Firstly, high-speed gassy flow erupts violently when the deep magma contains sufficiently abundant volatile component. This case may produce a Plinian eruption. In this case the exit velocity and gas content are determined by the deep magma flux alone independently of deep gas content because of adjustment by degassing during the ascent process. Secondly, a stationary conduit flow disappears below the critical value of fluid magma flux with high gas content in a deep conduit. In this case magma flow should be non-stationary and may produce Vulcanian or Strombolian eruptions. Thirdly, a relatively slow magma flow with low vesicularity flows out when volatile component is poor. This case likely results in Pelean eruptions because of difficult acceleration of gassy flow in the air.

Our analysis and interpretation suggest that various eruption types arise from different combinations of ascending magma flux and degassing efficiency. It is non-linearity involved in ascending magma flow with vesiculation and degassing that produces separate groups characterizing eruption types.

Keywords: volcanic eruption type, ascending magma flow, conduit flow model, volatile component content, degassing, computer simulation