# 3-D numerical simulations of eruption clouds: The critical condition for column collapse

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During an explosive volcanic eruption, an eruption cloud forms a buoyant eruption column or a pyroclastic flow. We investigated the critical condition that separates these two eruption styles (column collapse condition) by performing a series of three-dimensional numerical simulations. We identified two types of column collapse in the simulations: collapse from a turbulent jet which efficiently entrains ambient air (jet-type collapse) and that from a fountain with a high concentration of ejected materials (fountain-type collapse). Which type of collapse occurs depends on whether the critical mass discharge rate for column collapse ($MDR_{CC}$) is larger or smaller than that for the potential core near the flow axis to be eroded by shear ($MDR_{JF}$). When the magma temperature is low, $MDR_{CC}$ is smaller than $MDR_{JF}$ for a given exit velocity; therefore, the jet-type collapse occurs before the fountain develops with increasing mass discharge rate. In this case, the column collapse condition depends only on the Richardson number. When the magma temperature is high, on the other hand, $MDR_{CC}$ is larger than $MDR_{JF}$; the fountain develops when the column collapse occurs (i.e. fountain-type collapse). In this case, the collapse condition depends not only on the Richardson number but also on the Mach number. When the flow is supersonic (the Mach number is larger than 1.0), the standing shock waves developing in a fountain inhibit the entrainment of ambient air, which enhances column collapse.