Time-scale leading to the climactic pyroclastic flow phase in the 7.3 ka caldera-forming eruption at Kikai caldera, Japan

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Many explosive caldera-forming eruptions are represented by two major eruptive phases, the initial plinian and the following climactic pyroclastic flow phases (e.g., Druitt and Sparks, 1984). A time-scale between the two phases is a key to understand how caldera-forming eruptions evolve. The 7.3 ka eruption at Kikai caldera, Japan, was such the case with four major depositional units; the early plinian (fallout deposit, Unit A) and its column collapse phase (intraplinian pyroclastic density current (PDC) deposit, Unit B), the climactic caldera-forming phase (large-scale PDC deposits, Unit C; co-ignimbrite ash fall deposit, Unit D). In this study, we describe the deposit features of Units B and C and their boundary structures then discuss the time-scale between these units.

Unit B shows various degree of welding due to high-temperature emplacement condition (Maeno and Taniguchi, 2007; 2009). At some locations near the caldera, fragments of welded tuff of Unit B (m-sized blocks) are entrained into Unit C. The field observation suggests that the uppermost part (at least 1 meter thick or more) of Unit B was sufficiently cooled before the climactic phase and eroded by the following energetic PDCs. In fact, Unit C is not a single massive ignimbrite unit, but consists of multiple PDC units with alternate lithic-rich and pumice/ash-rich subunits in proximal area. Other erosional features such as U-shaped channels are also recognized on the deposits immediately below Unit C. The deposit facies and structure indicate stepwise deposition from flows but also highly erosive nature of flows in the beginning of climactic phase. The relationship between Units B and C indicates that there was a time-break between these units, and the thermal history (welding and cooling process) of Unit B is important to constrain the time-scale between the end of plinian phase and the onset of the climactic phases.

The thermal history of Unit B can be evaluated using the one-dimensional heat transfer and deformation model that includes the effect of changes of viscosity and pore fraction due to compaction with time (e.g., Riehle et al. 1995; Quane et al. 2009). As the initial condition, three layers were assumed; the uppermost layer (Unit B) with temperature T_a, which overlays the middle layer Unit A, and the lowermost layer (pre-eruptive ground). Given the possible ranges of emplacement temperature (T_a), initial thickness, and physicochemical properties of pyroclasts, parameter studies were carried out. Finally, we obtain thickness changes with time, density profiles (degree of welding) of the deposit, and time-scale to achieve glass transition temperature that may cause failure of welded tuff for various initial conditions. The results suggest that the order of days or weeks (at least a few days), rather than hours, is required to explain the deposit features such as thickness, degree of welding (deposit density), etc. Therefore it might be a time-break with days or more between plinian and climactic phases in the 7.3 ka eruption at Kikai caldera. This discontinuous sequence of the eruption is different from historical smaller-scale caldera-forming eruptions at Krakatau in 1883 and at Tambora in 1815 in which two major eruptive phases were continuous.

Keywords: caldera, Kikai, pyroclastic density currents, welding, time-scale

