The forming process of the Nakanoumi caldera based on component analysis for deposits of Eruptive Episode C (Chuseri tephra), Towada volcano, NE Japan

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The Towada volcano is a double caldera volcano. The outer caldera, Towada caldera, was formed during three large pyroclastic eruptions before 13 ka. The inner caldera, Nakanoumi caldera, is a summit crater of the Goshikiiwa volcano, which is a basaltic post-caldera volcano. The Nakanoumi caldera was formed by the explosive activities from felsic magma.
The products of Eruptive Episode C (6.2 ka) consist of the following three units in ascending order: Chuseri pumice (CP), Kanegasawa pumice (KP), and Utarube ash (UA); the total eruptive volume was 3.0 km^3. CP is a Plinian pumice deposit, KP is stratified lithic-rich pumice fall deposits, and UA is phreatomagmatic ash deposits. Although Hayakawa (1985) considered that the Nakanoumi caldera was formed in this episode from both lithic-rich features in KP and an eruptive sequence from magmatic (CP) to phreatomagmatic (UA), the details are still not clear.
The change of the amounts and components of the lithic fragments in pyroclasts are indicative of vent enlargement or the opening of new vents. Their temporal variation has been examined in connection with the change in eruptive style and caldera forming processes. Therefore, to discuss the formation process of the Nakanoumi caldera, we investigated the temporal variation of lithic fragments in CP and KP deposits, by a component analysis on both deposits.
CP is an almost homogeneous coarse pumice deposit except for the finer part at the bottom and uppermost, and this indicates that the eruption rate of the main part was constant. KP consists of alternating pyroclastic fall deposits and fine ash layers with short dormancy. Each pyroclastic fall deposit gradually changes from a lithic-rich layer to a pumice-rich one without clear boundaries, and the contained lithics are accessory or accidental materials.
Lithic contents in CP are under 10 wt% through most of the main part. However, in the top of the main part, the content increases up to 40 wt% with increases in the maximum pumice size (MP). The amounts in KP show pronounced contrast. While lithic-rich layers have over 80 wt% lithics, pumice-rich layers have 40–50 wt%, which are the same as the contents at the top of the main part of CP.
The Goshikiiwa volcano is composed of basaltic lava, agglutinate and a little silicic welded pumice. Dacitic lava dome exists on the northeast slope. Beneath the Goshikiiwa volcano, there are lavas and welded tuffs that were produced during the pre-Towada caldera stage, and basement rocks like slates and charts are present in deeper areas. Lithic components in the main part of CP are mainly mafic rocks derived from the Goshikiiwa volcano. At the top of the main part of CP with increases in lithic contents, brown altered and silicified lithics come into the deposit. Components of KP deposits are similar to the top of the main part of CP but with small quantities of obsidian. Both deposits do not contain the lithics from deeper depths.
The increasing amounts of lithics are not related to the timing of the shift in eruptive units, but occur at the top of the main part of CP. Although MP in CP increases with this change, it is difficult to explain this feature by only the amplification of volcanic intensity given the lack of change in the median grain size.
The lithics in CP and KP are mainly shallow components from the Goshikiiwa volcano, so all of the lithic clasts were produced by the destruction of the Goshikiiwa volcano around the surface. The total lithic contents, which are estimated to be 0.16 km^3, are deficient to fill up the Nakanoumi

caldera; however, Episode A, the latest eruption, contained 0.6 km^3 of lithics. Moreover, because Nakanoumi is over 200 m deeper than the floor of the Towada caldera, the rocks under the Goshikiiwa volcano need to be eroded. Hence, the Nakanoumi caldera may be formed stepwise by multiple eruptions after Episode C and not only during this episode.

Keywords: Towada volcano, Chuseri tephra, lithic fragment, component analysis

