‘Earth’s Interior: subduction zones & volcanic arcs’

Drilling submarine pyroclastic deposits emplaced during gigantic caldera-forming eruptions

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Abstract

Gigantic caldera-forming eruptions have repeatedly occurred in areas of deep/shallow oceans, with the production of voluminous pyroclastic flows. Such eruptions are a crucial part of the record of silicic magmatism along subduction plate boundaries. In order to contribute exploring ‘subduction zones and volcanic arcs’, gigantic caldera-forming events must be a target in the next phase of IODP. Ocean drilling provides vital information on controversial issues; (1) dynamics of huge pyroclastic flows entering sea or traveling over sea and their depositional/welding processes, (2) the caldera-collapse and resurgent processes of the recent caldera-forming eruptions, (3) nature of large silicic magmatic system belong to subduction zones, and (4) assessments of hazards caused by huge pyroclastic flows, ash-cloud, volcanic gases, and tsunamis, which will devastatively impact on very wide areas. For approaching these issues, systematic/multiple drilling inside and outside caldera will be necessary to obtain non-disturbed cores of submarine volcaniclastic deposits. Sedimentary records and structure of collapsed caldera detected by ocean drilling will allow us to extend fundamental knowledge on ‘gigantic caldera-forming eruptions’ and their origins.

[Introduction]

Caldera-forming eruptions, which may erupt up to a few thousands of km^3 of magma, are catastrophic volcanic events that pose one of the great natural hazards on earth. Such eruptions are low frequent events, but their impacts are very severe. Even relatively small caldera-forming eruptions may result in several thousands deaths, and alter the global climate (e.g. Newhall and Punongbayan, 1996). While most recent work on recent eruptions is focused on on-land events, many Quaternary caldera-forming eruptions have occurred in areas of deep/shallow seas, with the production of voluminous pyroclastic flows (Allen and Cas, 2001, Tani et al., 2008). Such eruptions are a crucial part of the record of silicic magmatism in subduction zones.

The 1883 eruption of Krakatau in Indonesia and the 3.6 ka Minoan eruption of Santorini in Greece are the most famous examples of recent marine caldera-forming eruptions. Other Quaternary marine silicic calderas have been also discovered on subduction zones and near ocean islands; the Shichito-Iwojima Ridge, Izu-Ogasawara (or Izu-Bonin) Arc, the Kermadec Ridge north of Taupo volcanic zone, New Zealand, Papua New Guinea, Vanuatu, and the Hellenic Island Arc in Greece. Although these eruptions must have significantly and devastatingly affected the development of coastal human activities and environments around the volcanoes, they still remain speculative and controversial, especially with respect to the effects of seawater on dynamics and evolution of such large-scale silicic marine eruptions. The reasons for this include the rare occurrence and violent nature of this type of eruption, the lack of direct observations, and difficulties arising from global variations in sea levels and local tectonic or volcano-tectonic effects.

The 7.3 ka eruption at Kikai caldera, Japan, occurred in a shallow sea. The volcanic explosivity index (VEI) is 7, based on total volume of products (150-170 km^3), which was larger in scale than the celebrated Santorini and Krakatau eruptions (VEI is 6), and this eruption was the largest in the last 10 ka in Japan (Machida and Arai, 2003). Previous researchers characterized a major sequence of the deposits in the 7.3 ka Kikai eruption (e.g. Maeno and Taniguchi, 2007). They showed that the eruption produced a climactic pyroclastic flow that traveled over the sea and resulted in devastating damage to prehistoric human activities in southern Kyushu (Fig. 1). However, they did not carry out a precise analysis of the lithofacies in the eruptive deposits especially in the sea.

[Potential works]

The detail of submarine deposits in and around the Kikai caldera is not well known. So, IODP should challenge to drill the intra- and outer- deposits from caldera-forming eruptions at Kikai caldera (Fig. 1). The deposits may include welded or non-welded thick pyroclastic flow deposits and lava flows. Total thickness of deposits outside caldera is probably less than a few hundred meters.

(1): Detail survey of submarine deposits around the Kikai caldera will enable us to reconstruct the 7.3 ka caldera-forming eruption; especially, depositional processes of pyroclasts in proximal area, dynamics of huge pyroclastic flows entering sea or traveling over sea and their depositional/welding processes, and so on.

We can discuss eruption dynamics and magma-water interaction based on analyses of the stratigraphy, textural, and lithofacies characteristics, and components of the deposits. How are the distribution, thickness, degree of welding, and internal structures of huge marine pyroclastic flow deposits? There are no such detail descriptions in previous researches for any calderas; so, it will be very important part of ongoing studies of marine silicic eruptions.

(2): Detail survey of intra-caldera deposits and inner structure of the Kikai caldera will enable us to evaluate the caldera-collapse and resurgent processes of the recent caldera-forming eruption. The formation processes of ring-fault and intra-deposits are not well known, which is classic problems on volcanology. The timing of resurgent domes and their characteristics are also important for understanding the recent volcanic activities of Kikai caldera.

(3): Petrological and geochemical data of submarine rock samples in and around Kikai caldera will be keys for understanding large silicic magmatic systems (LSMSs) belong to Kyushu-Ryukyu Arc.

(4): Above three works will be linked with assessments of hazards caused by huge pyroclastic flows, ash-cloud, volcanic gases, and tsunamis, which will devastatively impact on very wide areas. Such studies can provide constraints on predicted patterns for future volcanic activity.

[Strategy]

For approaching these issues, systematic/multiple drilling inside and outside caldera will be necessary in order to obtain non-disturbed and high resolution sedimentary cores of submarine volcaniclastic deposits. Riser drilling system of Chikyu will be a strong tool to recover cores of heterogeneous pyroclastic flow deposits consisting of soft, unconsolidated ashes and densely welded tuff. Sedimentary records and inner structure of collapsed caldera detected by ocean drilling will allow us to extend fundamental knowledge on 'gigantic caldera-forming eruptions' and its origin.

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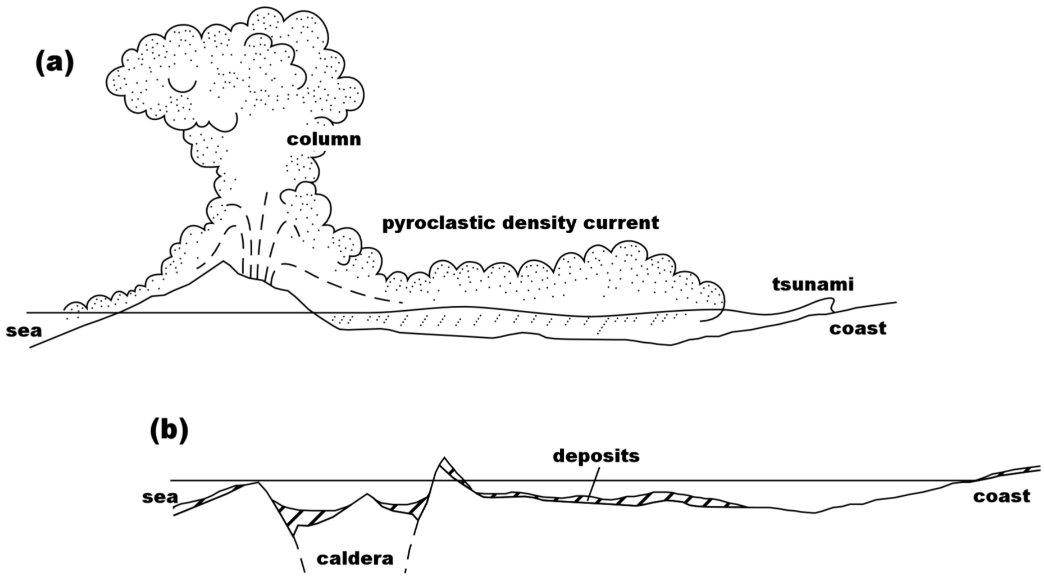

Figure 1. Idealized processes during a marine caldera-forming eruption. (a) Pyroclastic density currents are generated from column collapsing, and they enter or travel over sea. Tsunamis may be generated during these processes. (b) Resultant major deposits are distributed on submarine fields near the volcano. These are clues for understanding the evolution and dynamics of the caldera-forming eruption.