Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SVC52-P02 Room:Convention Hall Time:May 21 17:15-18:15

Comparing long-term variation of pre-caldera volcanic activity in Bali and in Tengger caldera region, East Java

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Large-scale, caldera-forming eruptions cause significant effects on both regional and global scale. Large amount of magma need to accumulate over long period of time before large-scale eruption takes place. In order to find the characteristics on the long-term variation of volcanic activity prior to caldera-forming eruptions, we observe stratigraphy and topography, and conduct comprehensive sample collection of volcanic rocks in Bali and Tengger caldera region, East Java. Modal abundance analysis, as well as on-going analysis on whole-rock chemistry and K-Ar dating, are preformed at CRIEPI. Mass fractionation correction method is used for the K-Ar dating. Lava samples having pilotaxitic or intergranular groundmass texture are selected for dating analysis in order to obtain accurate and precise ages.

We have identified three periods of volcanic activity in Bali. They are 1.6 m.y. BP, 0.7-0.5 m.y. BP, and 0.2 m.y. BP to present. Large somma of both Batur and Bratan caldera volcanoes are constructed by 0.2-0.1 Ma activity, and partly covers 0.6-0.5 Ma volcano to form large shield volcano. Both Batur and Bratan systems have produced caldera-forming eruptions multiple times in the past 30 ky. The calderas have formed between the aprons of volcanoes from different ages.

For andesites, some mafic phenocryst assemblages are limited to particular period. Hornblende phenocryst is mostly limited to early Quaternary andesites, and orthopyroxene phenocyst is limited to 0.5 Ma andesite. Clinopyroxene phenocrysts are common to andesites of all periods, except for aphyric andesites of 0.2 Ma activity. They are light-colored in thin sections, indicating their high Mg# and relatively high temperature of magma. The large shield volcanoes of 0.2 Ma consist of aphyric andesite lava layers. The aphyric andesite lavas have relatively higher K2O, TiO2 content and FeO∗/MgO ratio. The 0.2 Ma aphyric andesite has also erupted outside of somma at the small volcano located 10 km to the NW of Batur caldera rim.

We have identified at least four active periods in Tengger, East Java; they are 1.7 m.y. BP, 0.5 m.y. BP, 0.3 m.y. BP, and 0.1 m.y. BP to present. The start of volcanic activity is similar to Bali, but the two caldera-forming eruptions (Ngadisari and Sand Sea) are much older than Bali. The age of the basalt lava erupted during the second (Sand Sea) caldera eruption is 0.3 Ma. The somma of Sand Sea caldera consists of volcanoes formed at 0.5-0.45 Ma (basalts of the north wall) and 0.3 Ma (basaltic andesites of the south wall). Based on our K-Ar ages, the first (Ngadisari) caldera and the intra-caldera units have formed between 0.45-0.3 m.y. BP.

Long-term variations similar to Bali are found in Tengger region. (a) Large shield volcano is constructed prior to caldera-forming eruption as a result of overlapping volcanoes formed in multiple periods. (b) Clinopyroxene is common phenocryst of basaltic andesite to andesite, and occurence of orthopyroxene andesite is limited to pre-caldera active periods. (c) The clinopyroxene phenocrysts are light-colored in thin sections which indicate their high Mg# and high temperature of magma. (d) Activity of aphyric andesite started during the intra-caldera period. (e) The younger aphyric andesites have relatively higher K2O, TiO2 content and FeO∗/MgO ratio.

During the intra-caldera activity, temporal transition from heterogenous basaltic andesite to homogeneous, aphyric andesite is observed, suggesting accumulation of andesite magma. The lava and spatter bomb of the central cones, including the present vent (Bromo), are andesites which have similar whole-rock chemistry to the andesites of intra-caldera period and caldera-forming eruptions, although they have heterogenous texture.

Field surveys of this study are conducted as a part of the FY 2009-2011 project ”Multi-disciplinary Hazard Reduction from Earthquakes and Volcanoes in Indonesia”, supported by SATREPS from JST, JICA, RISTEK and LIPI.

Keywords: caldera, phenocryst modal abundance, K-Ar dating, Quaternary, Sunda arc, Indonesia