Journal of Volcanology and Geothermal Research 229–230 (2012) 64–73

Contents lists available at SciVerse ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

K–Ar ages determined for post-caldera volcanic products from Aso volcano, central Kyushu, Japan

Masaya Miyoshi [a,*], Hirochika Sumino [b], Yasuo Miyabuchi [c], Taro Shinmura [d], Yasushi Mori [e], Toshiaki Hasenaka [f], Kuniyuki Furukawa [g], Koji Uno [h], Keisuke Nagao [b]

[a] *Earthquake Research Institute, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan*
[b] *Geochemical Research Center, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[c] *Faculty of Education, Kumamoto University, 2-40-1 Kurokami, Kumamoto-shi, Kumamoto 860-8555, Japan*
[d] *Faculty of Economics, Kumamoto Gakuen University, 2-5-1 Oe, Kumamoto-shi, Kumamoto 862-8680, Japan*
[e] *Kitakyushu Museum of Natural History and Human History, 2-4-1 Yahatahigashi-ku Higashida, Kitakyushu-shi, Fukuoka 805-0071, Japan*
[f] *Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto-shi, Kumamoto 860-8555, Japan*
[g] *Faculty of Business Administration, Aichi University, 4-60-6 Hiraike, Nakamura-ku, Nagoya-shi, Aichi 453-8777, Japan*
[h] *Graduate School of Education, Okayama University, 3-1-1 Tsushimanaka, Kita-ku, Okayama-shi, Okayama 700-8530, Japan*

A R T I C L E   I N F O

Article history:
Received 6 July 2011
Accepted 2 April 2012
Available online 10 April 2012

Keywords:
K–Ar dating
Sensitivity method
Post-caldera volcanism
Aso volcano

A B S T R A C T

We determined the K–Ar ages for post-caldera lavas from Aso volcano in central Kyushu, Japan using the unspiked sensitivity method. The following three peaks of highly-frequent volcanism are recognized in the post-caldera stage: 70–50 ka, 40–20 ka and later than 10 ka. The two peaks of 70–50 ka and 40–20 ka are characterized by activities of compositionally diverse magmas from basalt to rhyolite. The volumes of silicic magmas are significantly larger than those of basalt magmas in these peaks. On the other hand, the peak later than 10 ka is characterized by predominantly basaltic eruptions without silicic magma activities. The active center of the silicic magma production (= crustal assimilation of injected basalt) had presumably migrated northeastward from the southwestern part of the caldera between the peaks of 70–50 ka and 40–20 ka. The predominant basaltic activity in the peak later than 10 ka represents that the production rate of silicic magma decreased, and does not indicate the accumulation of voluminous silicic magma beneath the recent Aso caldera.

1. Introduction

Large-scale caldera-forming eruptions are one of the most catastrophic geological events on Earth; hence, understanding the processes of the formation and evolution of the huge magma systems related to caldera volcanism is of great importance. Geochronological and geochemical data pertaining to post-caldera volcanic products are expected to provide key information about magmatic succession and the magma-plumbing system after caldera formation.

The Aso volcano, situated in central Kyushu, southwestern Japan, is characterized by two different types of volcanisms: caldera-forming pyroclastic-flow eruptions (Aso-1 to Aso-4, from 270 ka to 89 ka) and post-caldera extrusive volcanic activities (<89 ka) (Ono and Watanabe, 1985). Ono and Watanabe (1983, 1985) carried out detailed geological studies and pointed out that the compositional cycles (rhyolitic to basaltic or vice versa) recognized in the caldera-forming pyroclastic products reflect the presence of a single compositionally stratified magma chamber. On the basis of detailed petrological and isotopic data, Hunter (1998) and Kaneko et al. (2007) argued that the compositional diversity of caldera-forming products was due to several intracrustal processes (magma-mixing, crustal assimilation, and fractional crystallization) occurring in a huge single-zoned magma chamber. In the post-caldera stage (after 89 ka), various types of magmas were extruded from several vents in the caldera (Watanabe, 2001; Miyoshi et al., 2005), and formed the central cones (Fig. 1). Ono and Watanabe (1983) presumed that the collapse of the large single magma chamber in the caldera-forming stage resulted in the formation of multiple small discrete magma chambers in the post-caldera stage, with each post-caldera vent releasing magmas of different compositions. Miyoshi et al. (2005) supported this multiple-magma-chamber hypothesis on the basis of the results of simple model-calculations using petrological data of the post-caldera volcanic products. The significantly heterogeneous Sr isotope ratios of post-caldera lavas are also consistent with the multiple-magma-chamber hypothesis (Miyoshi et al., 2011). Miyabuchi et al. (2003, 2004a) and Miyabuchi (2009) established the stratigraphy of more than 30 units of fallout tephra layers from central cones on the basis of detailed geological data and several ^{14}C age data, and estimated the total volume of the post-caldera tephra-fall-deposits and their

* Corresponding author at: Geological Laboratory, Faculty of Education and Regional Studies, University of Fukui, 3-9-1 Bunkyo, Fukui-shi, Fukui 910-8507, Japan.
E-mail address: miyoshim@f-edu.u-fukui.ac.jp (M. Miyoshi).

0377-0273/$ – see front matter
doi:10.1016/j.jvolgeores.2012.04.003

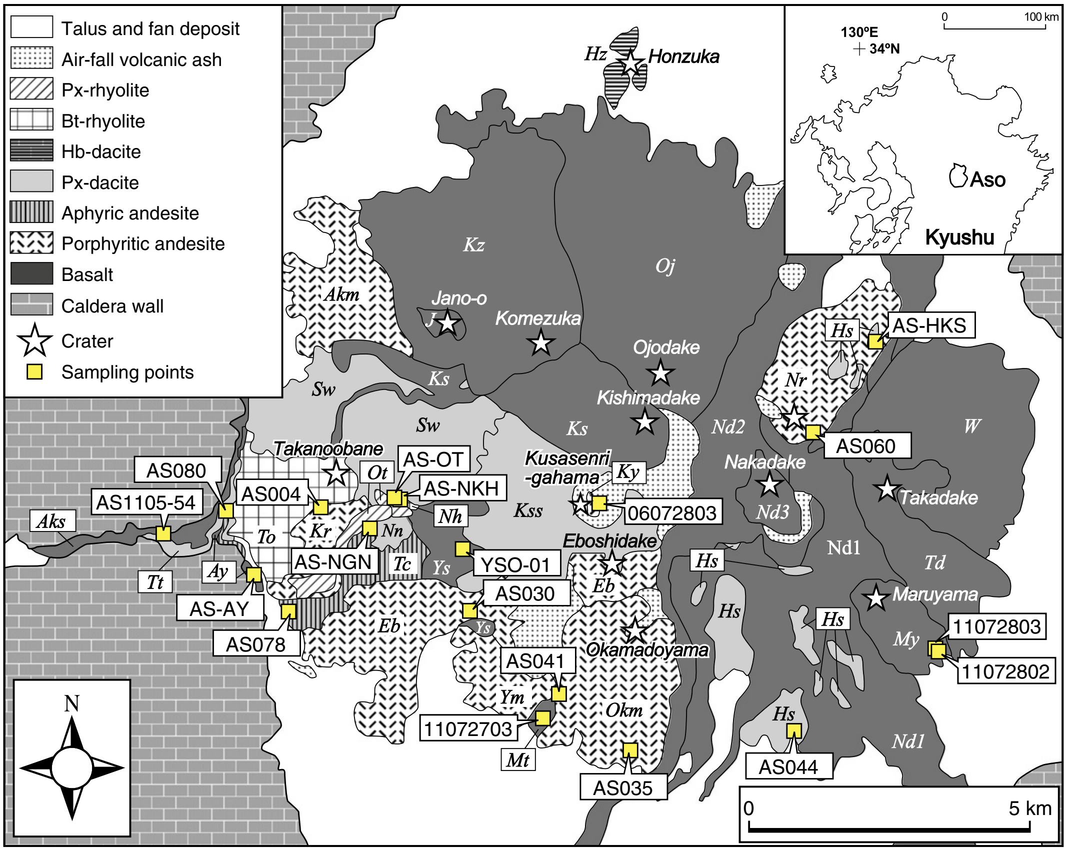

Fig. 1. Simplified distribution map of the post-caldera volcanic products of Aso volcano. Stars show the locations of the main observable craters in Takanoobane, Jano-o, Komezuka, Ojodake, Kishimadake, Nakadake, Eboshidake, Kusasenrigahama, Okamadoyama, Maruyama, Takadake, Naraodake, and Honzuka. Abbreviations for the unit names: Aks = Akase lava; Tt = Tateno lava; Ay = Ayugaerinotaki lava; To = Takanoobane lava; Kr = Karisako lava; Sw = Sawatsuno lava; Tc = Tochinoki lava; Nn = Nagano lava; Ot = Otogase lava; Nh = Nakahono lava; Ys = Yoshioka lava; Eb = Eboshidake lava; Kss = Kusasenrigahama pyroclastic products; Ky = Komatateyama; Ym = Yomineyama lava; Mt = Matsunoki lava; Hs = Hakusui lava; Ks = Kishimadake lava; Akm = Akamizu lava; J = Janoo scoria; Kz = Komezuka lava; Oj = Ojodake lava; Hz = Honzuka lava; Nr = Naraodake lava; W = Washigamine lava; Td = Takadake lava; My = Maruyama lava; Nd1 = Nakadake old lava; Nd2 = Nakadake young lava; Nd3 = Nakadake youngest pyroclastic products.
Adapted from the Geological Survey of Japan Map Series 1:500,000 (Ono and Watanabe, 1985; Masuda et al., 2004 and Miyabuchi et al., 2004a).

magma discharge rate as 18.1 km^3 corresponding to 1.5 km^3/ky, respectively.

Although our understanding of the magma plumbing system and tephrostratigraphy in the post-caldera stage has progressed due to the abovementioned studies, the ages of most of the lava units are yet to be determined. The radiometric ages of the post-caldera lavas are essential to clarify magmatic succession after caldera formation. Therefore, in this paper, we present new K–Ar age data for sixteen post-caldera lava units from the Aso central cones.

2. Geological setting of Aso volcano

The Aso volcano, located on the volcanic front in Kyushu Island in the southwest Japan–Ryukyu arc, is the second largest caldera volcano in Japan (25 km × 18 km). The caldera was formed by four pyroclastic-flow eruptions: Aso-1 (270 ka), Aso-2 (140 ka), Aso-3 (120 ka), and Aso-4 (89 ka) (Ono and Watanabe, 1985; Matsumoto et al., 1991). The basement of the caldera wall consists of pre-Aso volcanic rocks that were active until just before the caldera-forming Aso-1 eruption and have various chemical compositions (rhyolitic to basaltic) (Ono, 1965; Ono and Watanabe, 1985; Miyoshi et al., 2009). The Aso-1 to Aso-4 pyroclastic flow deposits are spread widely on the surface of the pre-existing pre-Aso volcanic rocks. The post-caldera volcanism started soon after the last caldera formation (89 ka). The post-caldera volcanic products were ejected from several vents in the caldera, and formed the central cones. Komazawa (1995) and Miyabuchi (2009) pointed out that the voluminous post-caldera volcanic rocks are buried under the present central cones. There are 27 observable units of post-caldera lavas (Fig. 1) that show diverse chemical compositions (rhyolitic to basaltic) (Ono and Watanabe, 1985; Masuda et al., 2004; Miyabuchi et al., 2004a; Miyoshi et al., 2005). Matsumoto et al. (1991) reported the K–Ar ages of five post-caldera lava units and they are as follows: Tochinoki lava (73 ka); Takanoobane lava (51 ka); Hakusui lava (30 ka); Honzuka lava (46 ka); Sawatsuno lava (27 ka). Nakadake, the only active crater in the present Aso volcano, is situated in the eastern part of the central cones. Geophysical studies showed that two possible magma chambers were detected as low-velocity anomalies in the middle-to-shallow crust beneath the Aso caldera (Sudo and Kong, 2001; Abe et al., 2010).

3. Petrologic characteristics of post-caldera volcanic products

The post-caldera volcanic products are divided into the following seven rock-types on the basis of their petrography and whole-rock geochemistry (Miyoshi et al., 2005). The petrographic characteristics of the seven rock-types are summarized in Table 1.

(1) Pyroxene-rhyolite (SiO_2: >69 wt.%): Otogase lava applies to this type. The sample is fresh obsidian lava, and includes 5–10 vol.% crystal content as plagioclase (4–9 vol.%; <0.6 mm) plus minor (<1 vol.%) orthopyroxene (<0.2 mm), clinopyroxene (<0.3 mm) and opaque minerals. The groundmass is clear and glassy with few microlites (Fig. 2a); (2) biotite-rhyolite (SiO_2: >69 wt.%): Nakahono and Takanoobane lavas apply to this rock type. All the samples are aphyric obsidian lavas, with 10–12 vol.% crystal content as plagioclase (5–10 vol.%; <0.5 mm), biotite (1–2 vol.%; <0.3 mm) plus minor