

The Tephra Layers Distributed around the Eastern Foot of the Zao Volcano —Ages and Volumes of the Za-To 1 to 4 Tephra—

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Ages of four scoriaceous volcanic sand layers (Za-To 1 to 4) distributed around the eastern foot of the Zao volcano are determined to be ca. 33–32, 30.7, 27.1, and 12.9 cal kyr BP, respectively, based on four newly obtained radiocarbon dates and loess chronometry. Besides, we detect To-H (To-HP) glasses from the loess below the Za-To 4 tephra. The estimated age of the loess horizon is consistent with the previously reported one for To-H (To-HP). Volumes of Za-To 1 to 4 tephras are estimated to be ca. 3×10^{-2} , 3×10^{-1} , 1×10^{-1} and 1×10^{-1} DRE km³, respectively, and the averaged discharge rate from Za-To 1 to 4 is calculated to be ca. 0.02–0.03 km³/ky.

Key words: Zao volcano, tephra layers, radiocarbon dating, volcanic glass, discharge rate

1. Introduction

The Zao volcano is a stratovolcano which is located in the central part of the volcanic front of the northeast Japan arc (Fig. 1). This volcano started its activity at about 1 Ma (Takaoka, *et al.*, 1989), and has continued to the present day. Geologic and petrologic studies of the whole of the eruptive products were performed by various authors (e.g. Chiba, 1961; Oba and Konda, 1989; Sakayori, 1992), and according to these studies, the newest stage of the Zao volcano began at ca. 30 ka, and numerous small to medium sized eruptions have continued for the past 30-ky. At about 30 ka, the horse shoe-shaped Umanose caldera (1.7 km in diameter), which is located in the central part of the Zao, was formed by explosive eruptions (Sakayori, 1992). The newest cone Goshikidake is situated in the inner part of the Umanose caldera and the newest crater lake Okama is located in the western part of the Goshikidake.

Tephro-stratigraphy is very useful to establish the detailed eruptive history of volcanoes (e.g. Thorarinsson, 1981). In the case of the Zao newest stage, the tephro-stratigraphic studies were performed by various authors (e.g., Imura, 1996, 1999; Itagaki *et al.*, 1981; Saigusa and Shoji, 1984). Imura (1999) recognized ten volcanic sand layers (Za-To 1 to 10). Za-To 1 to 4 tephras are mostly distributed around the eastern foot of the Zao volcano, while Za-To 5 to 10 are mainly near the summit

area. Imura (1999) also estimated that the ages of Za-To 1 to 4 tephras are older than ca. 20 ka, based on a radiocarbon age (Itagaki *et al.*, 1981), and the estimated AT (Aira-Tn tephra) horizon. AT is a widespread tephra ejected from the Aira caldera about 29 cal kyr BP (Okuno, 2002), widely distributed in Japan. In the Zao, AT volcanic glasses which is the bubble wall type (Machida and Arai, 2003) are found in the upper part of the loess below the Za-To 4 tephra (Imura, 1996). In this study, we determined the ages of Za-To 1 to 4 tephra layers based on newly obtained four radiocarbon dates, coupled with the loess chronometry (Hayakawa, 1995) and tephrochronology. Using this new age data and the magma discharge volume estimated from the isopach maps, we have calculated the magma discharge rates during the Za-To 1 to 4 activities.

2. Stratigraphic description of the Za-To 1 to 4 tephra layers

Za-To 1 to 4 tephra layers consist of scoriaceous volcanic sand, and are well sorted and laminated. In an outcrop at Haraobi (Loc. 7; Fig. 1), all of the Za-To 1 to 4 tephra layers can be observed and they are intercalated in the brown colored loess (partly reddish-dark brown colored paleosol), observed at the eastern foot of Zao.

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