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Optically stimulated luminescence dating of Late Pleistocene tephric loess intercalated with Towada tephra layers in northeastern Japan

Kazumi Ito [a, *], Toru Tamura [a], Takashi Kudo [a], Sumiko Tsukamoto [b]

[a] Geological Survey of Japan, AIST, Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki, 305-8567, Japan
[b] Leibniz Institute for Applied Geophysics (LIAG), Section S3: Geochronology and Isotope Hydrology, Stilleweg 2, 30655, Hannover, Germany

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ABSTRACT

To investigate the pre-50 ka eruption history of Towada volcano, northeastern Japan, optically stimulated luminescence (OSL) dating was applied to fine-grained quartz extracted from Late Pleistocene tephric loess intercalated with Towada tephra layers in a sediment core from the Kamikita Plain. The bulk OSL signal was found to be unsuitable for dating, because the medium and slow-1 components were thermally unstable. After a deconvolution of the bulk OSL signal to extract the fast component, the equivalent dose was estimated by using the single-aliquot regenerative-dose protocol. The OSL ages obtained for the tephric loess were generally in agreement with the stratigraphic sequence in the interval from 2.10 to 7.45 m depth, where they ranged from 156 ± 12 ka to 49 ± 3 ka, in ascending order. We calculated the ages of CP, SP, RP, and KbP tephras by interpolating OSL ages; these are 111 ± 6 ka, 89 ± 6 ka, 61 ± 4 ka, and 58 ± 4 ka, respectively; these ages are broadly concordant with previous estimates. The age of the RP tephra is of particular importance because its eruption marked the beginning of the caldera-forming stage of Towada volcano. Our results show that this eruption occurred about 20 ka younger than previously thought (ca. 80 ka). Our results demonstrate that OSL dating of quartz grains in tephric loess can be used to estimate the ages of intercalated tephra layers and contribute to our understanding of the eruption histories of volcanoes.

1. Introduction

Towada volcano in northeastern Japan is an active volcano, which erupted several times during the Late Pleistocene and formed Towada caldera (Hayakawa, 1985). The many tephra layers deposited in the vicinity of Towada volcano have been key to understand its eruptive history (Oike and Nakagawa, 1979; Hayakawa, 1985; Nakagawa et al., 1986; Matsuyama and Oike, 1986). However, the ages of tephra layers deposited before 50 ka are still not determined precisely because of less of suitable dating methods, despite these tephra layers are important to understand the history of the caldera-forming of Towada volcano.

Numerical ages of tephra layers in Japan have been estimated by various methods (e.g., Machida and Arai, 1983, 2003; Okuno and Nakamura, 2003; Miyairi et al., 2004), among which radiocarbon dating has been particularly effective for ages up to 50 ka that is the practical limit of its application. By using optically stimulated luminescence (OSL) dating, it should be possible to determine the ages of tephra layers older than 50 ka. Several studies studied the applicability of luminescence dating to volcanic quartz grains in Japan (e.g., Ganzawa et al., 2005; Tsukamoto et al., 2003, 2007). They concluded that red thermoluminescence dating of quartz phenocrysts (Fattahi and Stokes, 2003) was most suitable, whilst the age determinations of volcanic quartz grains by OSL are hampered by the lack of fast component signal (Jain et al., 2003; Tsukamoto et al., 2003, 2007).

Many studies have confirmed that quartz OSL dating works well for Chinese loess (Roberts and Wintle, 2001; Stokes et al., 2003; Buylaert et al., 2007; Lai, 2010). Watanuki et al. (2005) tested the application of OSL dating to Japanese loess in eastern Japan, which was a mixture of local volcanic ash and aeolian dusts transported from the Asian continent and neighbourhood of sampling site. They deconvoluted the bulk OSL signal to extract the fast component (suitable for dating), which they considered to represent the distant-transported aeolian dust, and determined ages that were concordant with those of widespread Late Pleistocene tephra layers in Japan (Watanuki et al., 2005). Although not yet applied

* Corresponding author. Tel.: +81 29 861 4164.
E-mail address: kazumi-itou@aist.go.jp (K. Ito).

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elsewhere in Japan, this modified OSL dating protocol has the potential to improve our understanding of Late Pleistocene tephrochronology.

In this paper, we report on our new application of quartz OSL dating to Late Pleistocene tephric loess recovered from a core drilled in the Kamikita coastal plain, northeastern Japan. In the tephric loess, there are intercalated tephra layers erupted from Towada volcano. We determined the ages of the tephra layers, which were previously not well constrained, by interpolating two OSL ages of the tephric loess. The new tephra ages provide improved understanding of the Late Pleistocene eruptive history of Towada volcano.

2. Overview of towada volcano

Towada volcano is located on the border between Aomori and Akita prefectures, northeastern Japan (Fig. 1a), holding Lake Towada within its caldera (Fig. 1b). The eruptive history of Towada volcano has been divided into three stages: the pre-caldera (200–55 ka), caldera-forming (55–15 ka), and post-caldera (15–0 ka) stages (Hayakawa, 1985). Of these ages, those before 50 ka are not based on numerical dating and are not well constrained, as described below. Hayakawa (1985) assigned alphabetic codes to the major eruptive episodes in order of their ages.

Towada caldera (11 km diameter) was formed by eruptive episodes Q, N, and L during the caldera-forming stage (Hayakawa, 1985). The chronology of the post-caldera stage is well constrained by radiocarbon dating (Hayakawa, 1985; Kudo and Sasaki, 2007; Kudo, 2008), but the pre-caldera stage and the first half of the caldera-forming stage are beyond the age limit of effective radiocarbon dating and are thus not well constrained.

Previous estimates of the ages of the major tephra layers from Towada volcano derived by zircon fission-track dating and other indirect methods (e.g., oxygen isotope stratigraphy; assumption of constant accumulation of loess) are listed in Table 1. For example, the ages of the Ofudo pyroclastic flow and the Toya pyroclastic fall deposits were estimated with accuracy by using several dating methods. On the other hands, the age of the Towada-Okuse pyroclastic flow deposits and associated Red pumice (RP) tephra was estimated to be 82–50 ka (Kudo and Kobayashi, 2013); the uncertainties of these results are too large to allow an understanding of the detailed history of volcanic activity.

3. Kamikita Plain and core sampling

The Kamikita coastal plain is located 40 km east-southeast of Towada volcano and is characterized by a series of Middle and Late Pleistocene marine terraces (Miyauchi, 1987) composed of shallow-marine deposits overlain by terrestrial sediments. The shallow-marine deposits accumulated during the interglacial sea-level highstands of marine isotope stages (MIS) 5a, 5c, 5e, 7, and 9 (Kuwabara, 2009). The terrestrial sediments consist of alternating of layers of tephra and tephric loess.

A 30-m-long sediment core (core GSRH) was obtained on the Shichihyaku terrace (MIS 9; Kuwabara, 2009) in Rokunohe Town, Aomori Prefecture (lat 40.64203°N, long 141.30136°E; 69.4 m above sea level; Fig. 1). The core was covered by a light-tight acryl pipe when sampled and later halved vertically in a dark room under subdued red light. One half was used for OSL dating and the other half was used for description under natural light outside the dark room. The lower 15.5 m of the core consists of shallow-marine deposits, and the upper 14.5 m interval is an alternation of layers

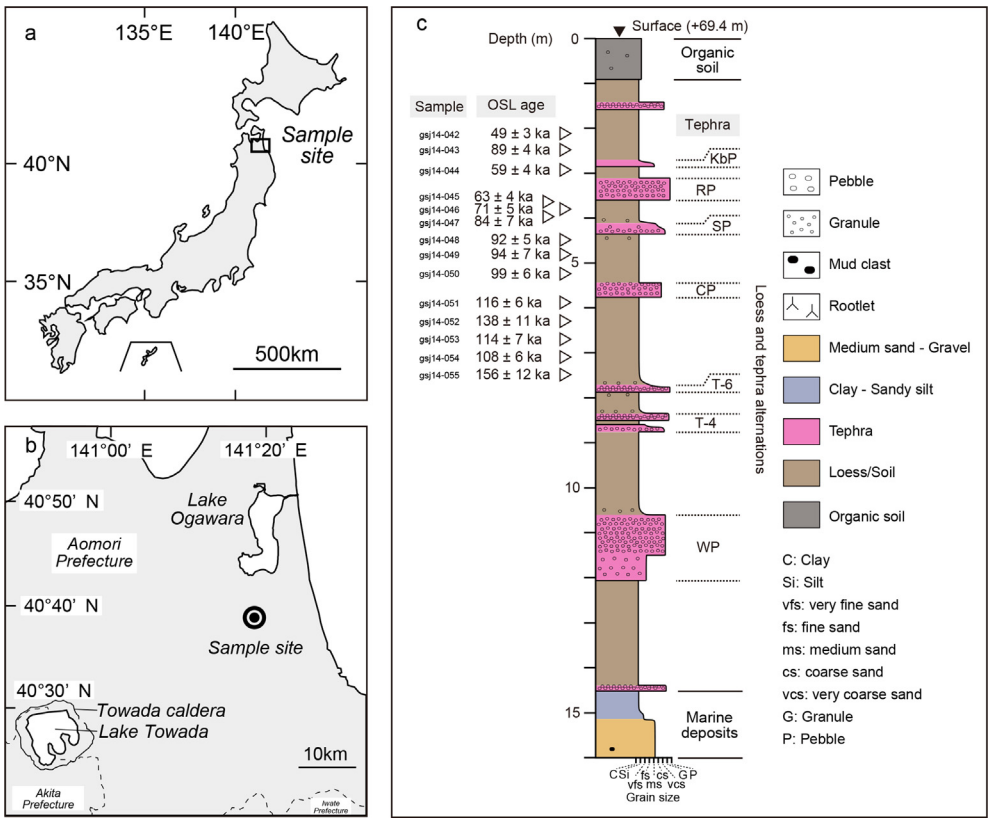

Fig. 1. (a) Regional map of Japan showing the location of Kamikita coastal plain. (b) Map showing locations of sampling site and Lake Towada. (c) Columnar section and OSL ages of the upper part of core GSRH.

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