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Zircon U–Pb dating using LA-ICP-MS: Quaternary tephras in Boso Peninsula, Japan

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A B S T R A C T

Zircon U–Pb dating using LA-ICP-MS was applied to six Quaternary tephras in Boso Peninsula, central Japan: J1, Ks4, Ks5, Ks10, Ks11, and Ch2 in descending order. Accurate age determination of these tephras is of critical importance because they are widespread tephras in Japan and also relevant to a candidate site for the global boundary stratotype section and point of the early–middle Pleistocene boundary. Twenty grains were dated for each tephra and the following results were obtained. The J1 tephra had only 5 grains that yielded <2 Ma. The obtained age was ~0.2 m.y. older than the stratigraphic age. No Quaternary ages were obtained from the Ks4 tephra. The Ks5 and Ks10 tephras had 10–12 grains that were ~0.1–0.3 m.y. older than the stratigraphic age. The Ks11 tephra had 14 grains that yielded a weighted mean age of 0.52 ± 0.04 Ma (error reported as 95% confidence level), which was in agreement with the stratigraphic age. The Ch2 tephra had 16 grains that yielded a weighted mean age of 0.61 ± 0.02 Ma, which was also in agreement with the stratigraphic age. The good agreement between zircon U–Pb ages and the stratigraphy for Ks11 and Ch2 tephras validates the reliability of the established stratigraphy and our dating approach. The other tephras that yielded ~0.1–0.3 m.y. older ages than the stratigraphy may indicate that the analyzed zircons were antecrysts that crystallized before eruption or they were detrital zircons incorporated during deposition.

1. Introduction

In-situ zircon U–Pb dating using secondary ion mass spectrometry (SIMS) and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) is now widely used for Quaternary tephrochronology (e.g., Lanphere et al., 2004; Bachmann et al., 2007; Cocherie et al., 2009; Guillong et al., 2014; Ito, 2014; Suganuma et al., 2015). Among them, Ito (2014) demonstrated that U–Pb dating using LA-ICP-MS can yield reliable ages as young as ~0.1 Ma using Toya tephra, widely distributed in northern Japan. Here, we follow Ito (2014)'s U–Pb dating approach for six Quaternary tephras distributed in Boso Peninsula, central Japan (Fig. 1).

In Boso Peninsula, thick Pleistocene marine sediments, the Kazusa Group and the overlying Shimosa Group, were deposited (Figs. 1B and 2). The Kazusa Group is well exposed and contains a remarkably continuous stratigraphic succession with well-preserved marine microfossils, pollen, paleomagnetic reversal events, and a large number of tephra layers, allowing a robust chronological and stratigraphic framework. It contains the Matuyama–Brunhes (MB) boundary and is considered as an excellent candidate for the global boundary stratotype section and point of the early–middle Pleistocene boundary (Kazaoka et al., 2015; Hyodo et al., 2016). Suganuma et al. (2015) reported a SIMS U–Pb zircon age of 0.773 ± 0.007 Ma from a tephra (Byakubi-E or Byk-E) just below the MB boundary in Boso Peninsula. This study reports new LA-ICP-MS U–Pb zircon ages from some of important tephras above the Byakubi-E tephra in Boso Peninsula, which will contribute to further establish Japanese and worldwide Pleistocene chronostratigraphy.

2. Geology and samples

Thick marine sediments were deposited in response to the west-north-westward subduction of the Pacific plate beneath the Philippine Sea and North American Sea plates during the Pleistocene (Fig. 1A). In Boso Peninsula, the Kazusa Group of ~3000 thick deep-

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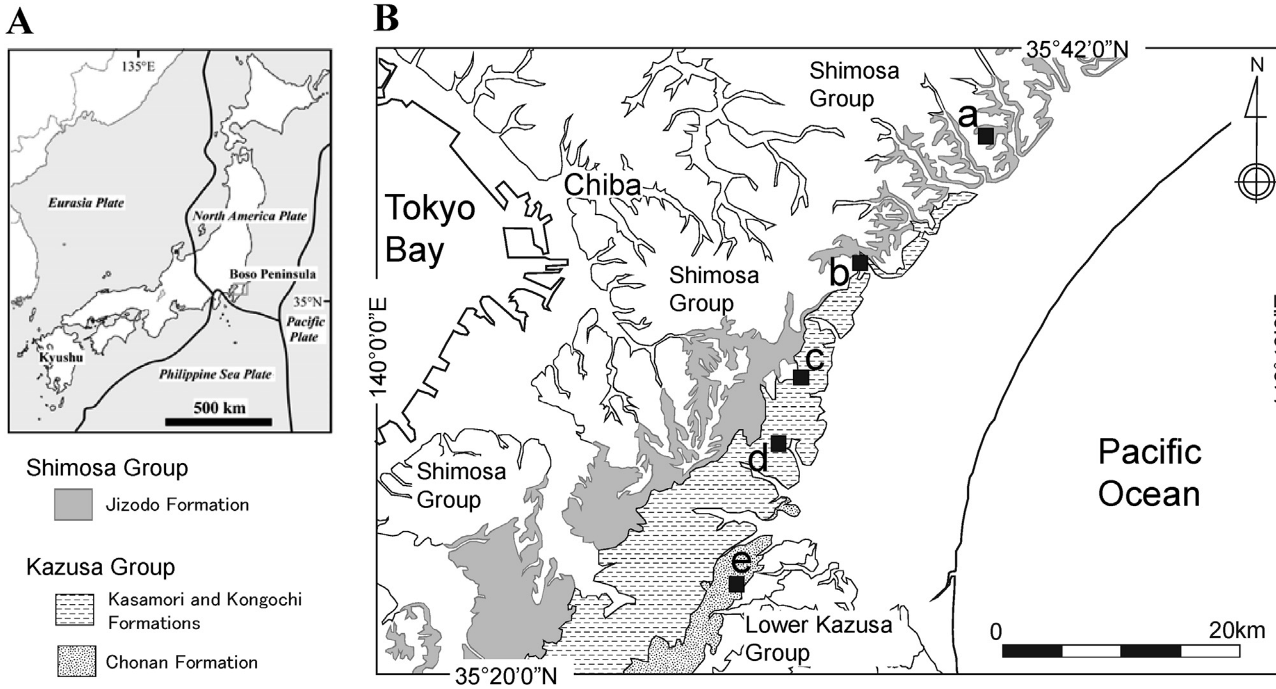

Fig. 1. Location of study site, Japan. A: Tectonic setting, B: Distribution of the Shimosa and Kazusa Groups (Boso Peninsula) and sampling points. a: J1 tephra, b: Ks4 tephra, c: Ks5 tephra, d: Ks10 and Ks11 tephras, e: Ch2 tephra.

and shallow-water marine succession was deposited in the early and middle Pleistocene time. Evidence based on calcareous nannofossils (Sato et al., 1988), planktonic foraminifera (Oda, 1977), diatoms (Cherepanova et al., 2002), magnetostratigraphy (Niitsuma, 1976), and oxygen isotope stratigraphy (Okada and Niitsuma, 1989; Pickering et al., 1999; Tsuji et al., 2005) has provided estimated depositional ages of ca. 2.4 to 0.5 Ma for the Kazusa Group. Furthermore numerous tephra beds facilitate detailed stratigraphic correlation and the compilation of different types of age data (Machida et al., 1980; Satoguchi and Nagahashi, 2012). So far many zircon fission-track (ZFT) ages were reported on tephras in the Kazusa Group (e.g., Tokuhashi et al., 1983; Kasuya, 1990; Watanabe and Danhara, 1996; Suzuki et al., 1998) but these have >10% uncertainties (2 σ) (Fig. 2).

The stratigraphy of the Kazusa Group is well summarized in Kazaoka et al. (2015). It is subdivided into 14 formations: in stratigraphically ascending order, these are the Kurotaki, Katsuura, Namihana, Ohara, Kiwada, Otadai, Umegase, Kokumoto, Kakinokidai, Ichijiku, Chonan, Mandano, Kasamori, and Kongochi Formations. The MB boundary is observed in the Kokumoto Formation. In this study, five tephras were sampled in the Chonan and Kasamori Formations from the upper part of the Kazusa Group in and around the Mobara district, Chiba Prefecture, Japan (Figs. 1B and 2). These tephras were selected because they are widespread tephras or candidates of marker tephras and it was known that they contain abundant zircons.

The Chonan Formation is 65–110 m thick and composed of sand-dominated alternating thin (up to a few cm) sands and siltstones. Several sandstone beds up to 4 m thick are intercalated in the upper part of the formation. Three tephra beds (Ch1–3) are recognized. The Ch2, a 10–13 cm thick white fine-sand to silt tephra in the middle of the Chonan Formation, was sampled (Figs. 1B and 2). A detailed sampling locality and an outcrop photograph are shown in Supplementary Figs. S1 and S2. This tephra is correlated to the Seiganji-Toga (Se-Tg) tephra of Kyushu Island (Fig. 1A) origin. Based on a comparison of oxygen isotope curves between central and northernmost Boso Peninsula (Kameo et al., 2006), the Ch2 tephra was deposited during the marine isotope stage (MIS) 16.2 which is at ~0.63 Ma (Bassinot et al., 1994) (Fig. 2).

The Kasamori Formation is approximately 300 m thick and is mainly composed of silty sandstone interbedded with sandstones (5–30 m). The depositional environments of the Kasamori Formation have been interpreted as representing a storm-influenced shelf (Ito, 1998). Numerous tephra beds are recognized. Ks11, 10, 5, and 4 tephras in ascending order were sampled in this study (Fig. 2). The Ks11 is a ~10 cm thick pale pink silt tephra of Kyushu Island origin and also referred to as Kobayashi-Kasamori (Kb-Ks) tephra or as Kamiogi I (Kmg 1) tephra, which corresponds to MIS 14.2 or 0.53–0.54 Ma (Kameo et al., 2006; Nakazawa et al., 2009). Machida and Arai (2011) estimated its age as 0.52–0.53 Ma based on compilation of ZFT age data. The Ks10 is a ~10 cm thick pale gray silt tephra of Kyushu Island origin and also referred to as Kamiogi II (Kmg 2) tephra. It also corresponds to MIS 14.2. The Ks5 is a ~20 cm white silt tephra of Kyushu Island origin and also referred to as Ikadachi II tephra (Satoguchi and Hattori, 2008). It corresponds to MIS 13 or ~0.50 Ma (Nanayama et al., 2016). On the contrary, Machida (2002) estimated a younger age of 0.43–0.45 Ma based on ZFT age data and stratigraphy. The Ks4 is a ~30 cm thick white fine-sand to silt tephra which lies at the boundary between Kasamori and Kongochi Formations at MIS 13 (Nakazato and Sato, 2010).

The Kazusa Group is overlain by the middle and late Pleistocene Shimosa Group which comprises shallow marine to coastal sediments that represent the infilling of the paleo-Tokyo Bay (Ito, 1995; Ito et al., 1999). The Shimosa Group is subdivided into 7 formations and a ~10 cm white silt tephra (J1) was sampled from the lowest Jizodo Formation (Fig. 2). The Jizodo Formation is approximately 50 m thick and unconformably overlies the Kongochi Formation of the Kazusa Group. It is mainly composed of mudstone in the lower part and sandstone in the upper part, deposited in the shallow marine environment mainly during the MIS 11.3 transgression

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