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Chronostratigraphy of the Pliocene–Pleistocene boundary in forearc basin fill on the Pacific side of central Japan: Constraints on the spatial distribution of an unconformity resulting from a widespread tectonic event

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A B S T R A C T

The upper Ikego Formation (Pliocene) and the Urago Formation (Pliocene to Lower Pleistocene) have been examined for their lithostratigraphy, calcareous nannofossil biostratigraphy, and magnetostratigraphy. Both formations are forearc basin fills exposed on the Miura Peninsula on the Pacific side of central Japan. The boundary between these formations has been previously treated as the western extension of the Kurotaki Unconformity, which was considered to be related to widespread tectonic change at ca. 3 Ma in the Japanese forearc region. However, the presence of the unconformity on the Miura Peninsula remains unclear due to sparse lithostratigraphic and chronostratigraphic data around the boundary between the both formations. In the study area, the Ikego Formation consists mainly of sandy mudstone and the Urago Formation of sandstone and muddy sandstone; both formations contain numerous tuff beds. Key tuff beds and the last appearance of *Discoaster tamalis* have been identified in the upper Ikego Formation and the lower Urago Formation, allowing these formations to be considered conformable. The following continuous stratigraphic markers were identified (in ascending order): top of the Mammoth Subchronozone (3.21 Ma); base (3.13 Ma) and top (3.05 Ma) of the Kaena Subchronozone; last appearance of *Discoaster tamalis* (2.76 Ma); the widespread tuff bed KGP (ca. 2.5 Ma); and the last appearance of *Discoaster pentaradiatus* (2.41 Ma). Sedimentation rates are almost constant among these age-controlled horizons, which indicates continuous sedimentation from 3.2 to 2.4 Ma. The results indicate that the Kazusa Group conformably overlies the Miura Group on the Miura Peninsula, which provides a well-established continuous stratigraphic section for analyses of regional paleoenvironmental and tectonic evolution in the Japanese forearc region.

1. Introduction

Recent stratigraphic studies have recognized remarkable unconformities near the Pliocene–Pleistocene boundary in major successions on the Japanese islands, and considered such unconformities to have been caused by widespread tectonic change (Takahashi, 2006; Tamura and Yamazaki, 2010; Oda et al., 2011). The ages and formation processes of these unconformities would provide significant implications for basin evolution during the Pliocene–Pleistocene tectonic transition. The Miura and Kazusa groups, which are Neogene–Quaternary forearc basin fills forming the basement of the Kanto Plain, are well exposed on the Miura and Boso peninsulas on the Pacific side of central Japan (Fig. 1). The boundary between the Miura and Kazusa groups is known as the Kurotaki Unconformity (Koike, 1951), which was considered to be a

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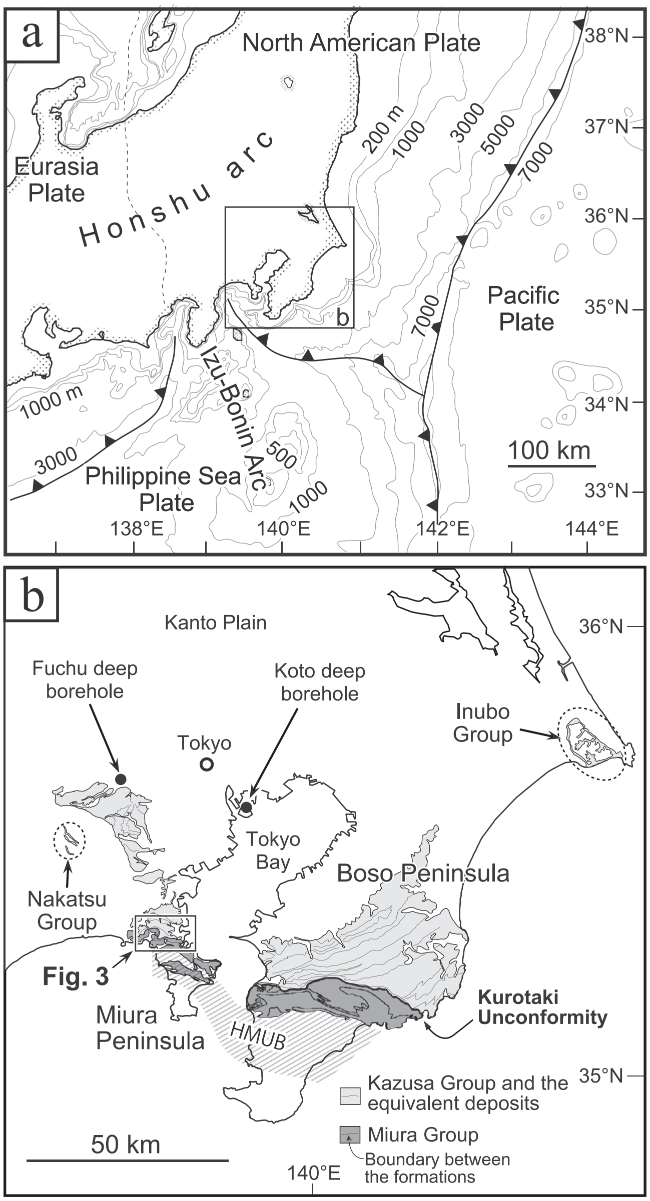

Fig. 1. Maps illustrating the geotectonic setting of the Miura and Kazusa groups in the southern Kanto region on the Pacific side of central Japan. **a**, Plate boundaries near the Japanese islands. **b**, Surface distributions of the Miura and Kazusa groups on the Miura and Boso peninsulas, based on Mitsunashi et al. (1980), Mitsunashi and Suda (1980), Unozawa et al. (1983), Eto (1986a), and Sakamoto et al. (1987). HMUB: Hayama–Mineoka uplift belt.

result of conditions associated with a change in the motion of the Philippine Sea Plate (Honda and Seno, 1988; Takahashi, 2006). The distribution of this unconformity based on high-resolution stratigraphy in each individual section should constrain the age and formation process of this unconformity.

However, the distribution of the Kurotaki Unconformity remains controversial. In the Boso Peninsula, the Kurotaki Unconformity is recognized as an apparent angular unconformity (Fig. 1b), and is characterized by a temporal gap of ca. 3–2.4 Ma (e.g., Kameo and Sekine, 2013). Conversely, the western extension of the Kurotaki Unconformity on the Miura Peninsula has long been debated (e.g., Akamine et al., 1956). This is due to the difficulty in locating the boundary, which is the result of lithologic similarity between the uppermost Miura Group and the lowermost Kazusa Group on the peninsula. In addition, a shortage of chronostratigraphic data from near the Pliocene–Pleistocene boundary has contributed to the controversy surrounding the presence of the Kurotaki Unconformity on the Miura Peninsula. The lack of reference stratigraphy on the Miura Peninsula also causes uncertainty in recognizing the unconformity in subsurface strata beneath the western shores of Tokyo Bay.

The main objectives of this study are to reveal the stratigraphic relationship between the Miura and Kazusa groups, and to establish the chronostratigraphy from the uppermost Pliocene through the lowermost Pleistocene in both groups on the Miura Peninsula. Magnetostratigraphy was employed because paleomagnetic polarity reversals provide high-resolution depositional ages that have been calibrated astronomically (e.g., Lisiecki and Raymo, 2005). Calcareous nannofossil biohorizons are well suited for precise positioning and verification of paleomagnetic polarity data because of their small diachroneity, as confirmed by correlations with marine isotope stages (Wei, 1993; Raffi et al., 2006; Kameo and Okada, 2016).

2. Geotectonic setting

2.1. Tectonic setting and general stratigraphy

The Kanto region is located at the center of the Honshu arc (Fig. 1), near a trench–trench–trench-type triple junction off the Boso Peninsula. At the triple junction, the Philippine Sea Plate is subducting beneath the North American Plate, and the Pacific Plate is subducting beneath both the North American and Philippine Sea plates (McKenzie and Morgan, 1969). In this tectonic setting, the Hayama-Mineoka uplift belt comprises an ophiolitic complex that acted as an outer forearc high (Takahashi, 2008), which created accommodation space for the deposition of the forearc basin fill. The Miura and Kazusa groups represent forearc basin fill that consists of shallow- and deep-marine deposits (Mitsunashi and Kikuchi, 1982; Ito and Katsura, 1992), and have approximate thicknesses of 2000 m and 3000 m, respectively (Suzuki et al., 1995). The uplift rate, caused by late Quaternary tectonic activity, is up to 3.3 m/kyr (Naruse, 1968), which has enabled us to directly observe these deposits in outcrop. These groups contain numerous key tuff beds and abundant microfossils, which have facilitated lateral stratigraphic correlations and the reliable determination of depositional ages. As a result, the depositional ages of these groups have been estimated based on sequence stratigraphy (Ito and Katsura, 1992), microbiostratigraphy (Oda, 1977; Sato and Takayama, 1988), magnetostratigraphy (Niitsuma, 1976; Okada and Niitsuma, 1989), tephrochronology (Suzuki et al., 2011; Satoguchi and Nagahashi, 2012), and oxygen isotope stratigraphy (Okada and Niitsuma, 1989; Pickering et al., 1999; Tsuji et al., 2005; Nozaki et al., 2014). The age estimates reveal that the Miura and Kazusa groups are characterized by high sedimentation rates, ranging from tens of centimeters to several meters per kyr (Takahashi, 2008; Kazaoka et al., 2015; Ito et al., 2016), thereby providing a high-resolution stratigraphic framework.

2.2. Kurotaki Unconformity on the Boso Peninsula

The Kurotaki Unconformity on the eastern Boso Peninsula is characterized by westward abutting of the Kazusa Group over the Miura Group (Fig. 1b). This unconformity is considered to have formed in a deep-marine environment because there is no evidence of terrestrial deposition, and the strata above the unconformity contain deep-marine molluscan assemblages (e.g., Asaga et al., 1991). Fig. 2 summarizes the stratigraphy and depositional ages of these groups on the Miura and Boso peninsulas, based on the

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