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Major variations in vitrinite reflectance and consolidation characteristics within a post-middle Miocene forearc basin, central Japan: A geodynamical implication for basin evolution

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ABSTRACT

Forearc basin sediments near the ocean-ward margin preserve tectonic information related to plate subduction. The post-middle Miocene Boso forearc basin, central Japan, records major differences in structure, paleo-maximum temperature, and consolidation state between below (Miura Group) and above (Kazusa Group) the Kurotaki Unconformity, which formed at ca. 3 Ma. Many fault systems below the unconformity are characterized by a disaggregation-band-like inner fabric that apparently formed soon after sedimentation, whereas there are few of this type of fault system above the unconformity. Vitrinite reflectance values (R_o) are 0.38%–0.44% and 0.22%–0.25% below and above the unconformity, respectively. The consolidation yield stress (p_c) in the Miura Group (23.7 MPa in the Anno Formation; 31.0 MPa in the Amatsu Formation) is much greater than that in the Kazusa Group (7.5, 7.6 and 9.6 MPa in the Umegase, Ohtadai and Kiwada formations, respectively). These clear differences in vitrinite reflectance and consolidation characteristics above and below the unconformity are attributed to a forearc basin evolution, which resulted in the Miura Group being geothermally matured, tectonically compacted, uplifted, and eroded (500 m in maximum) before sedimentation of the Kazusa Group. The forearc basin, especially near the trench-slope break, records structural and physical properties reflecting the plate-tectonic environment and the development of the trench-slope.

1. Introduction

Forearc basins in subduction zones occur between the magmatic front and the trench-slope break (e.g., Dickinson, 1995). The trench-slope break is a topographic high dividing the forearc basin from the trench slope area, and it marks the arc-ward limit of deformation related to plate subduction (Moore and Karig, 1976). The inner wedge, corresponding to the forearc basin area, generally stays in a stable regime throughout earthquake cycles, acting as an apparent backstop and providing a stable environment for the formation of forearc basins (Wang and Hu, 2006). Therefore, trench slopes are a matter of research interest, because they preserve kinematical or mechanical information on plate-subduction-related tectonics (e.g., Strasser et al., 2009; Chiyonobu et al., submitted to this issue). Recently, however, Moore et al. (2013) suggested that the formation of normal-fault systems in the Kumano basin, SW Japan, occurred in association with plate subduction and accretionary prism formation in the Nankai. The orientations of older fault populations are controlled by uplift of the underlying accretionary prism, implying that the forearc basin region is not as stable as previously believed. In contrast, the observation that active normal faults occur throughout the basin supports the idea that the horizontal stress parallel to the plate convergence direction does not achieve the critical stress necessary to activate or form thrust faults and produce horizontal shortening within the shallow portion of the inner wedge (Moore et al., 2013). Therefore, geologic structures such as folds and faults in forearc basins may yield information useful to understanding tectonic processes related to plate subduction, as their characteristics should have formed in association with the development of accretionary prisms and the trench-slope break.

As the development of the Kumano basin was initiated only recently (e.g., Expedition 319 Scientists, 2010; Ramirez et al., 2015), the sensitivity of the structural or mechanical properties of the forearc basin to regional tectonics is unclear. A non-metamorphosed post-middle Miocene to Pleistocene forearc basin is exposed on land in the northern parts of the Miura and Boso peninsulas, central Japan (Fig. 1). Although two short time-gaps (hiatus) are present, the forearc basin preserves a successive geologic record during the past 15 Ma and is a suitable setting for examining how forearc basins record geologic information related to subduction tectonics. We performed structural and paleo-geothermal analyses in the forearc basin of the Boso Peninsula to

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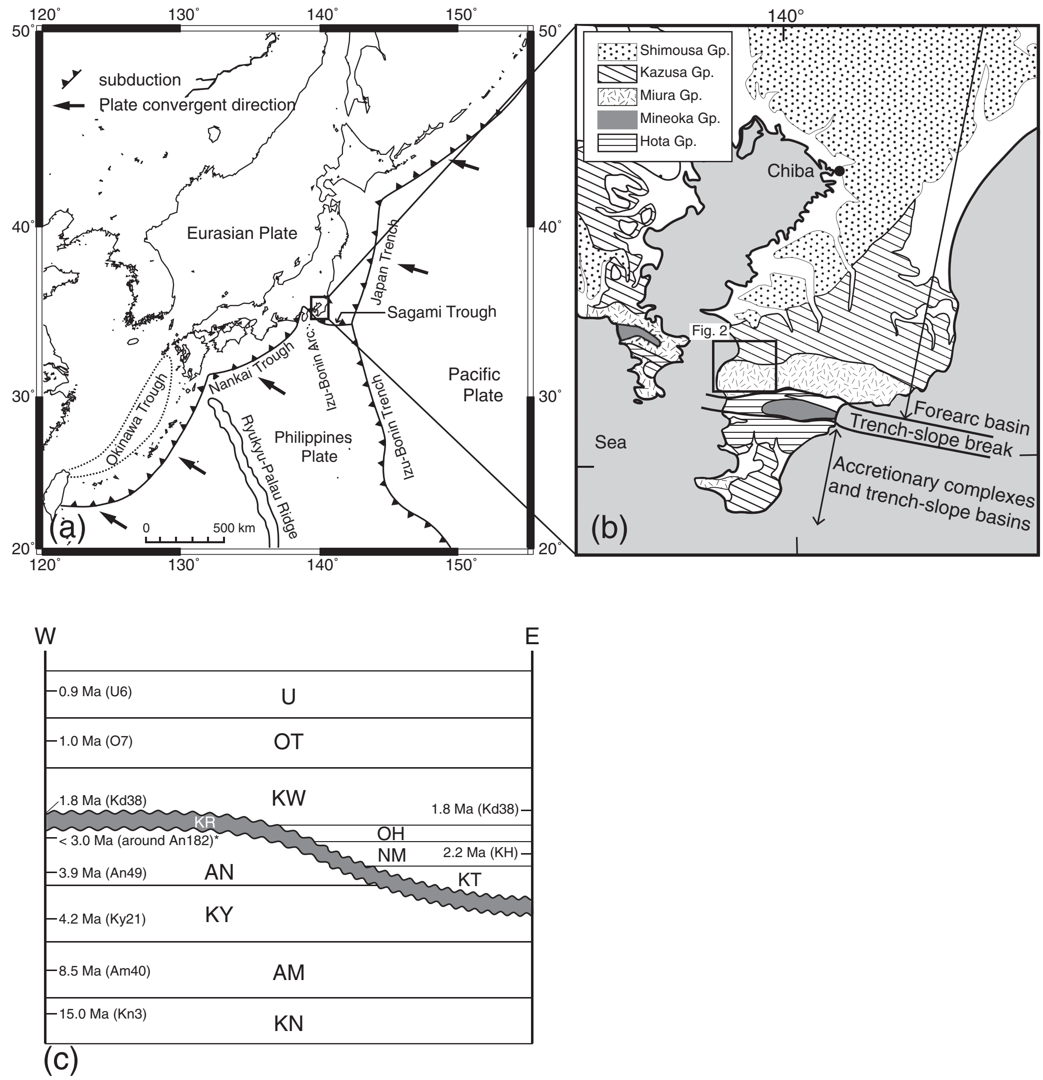

Fig. 1. (a) Plate configuration of the Japanese Islands. The rectangle indicates the area covered by Fig. 1b. (b) Geologic map of the Miura and Boso peninsulas. The geology of the Boso Peninsula is subdivided into three parts: Early Miocene and Late Miocene–Pliocene accretionary complexes and middle Miocene–Pleistocene trench-slope basins in the south, a post-middle Miocene forearc basin in the north, and an intervening trench-slope break comprising an ophiolite complex. (c) Schematic diagram showing stratigraphy of the lower part of the Boso forearc basin (U: Umegase Fm., OT: Ohtadai Fm., KW: Kiwada Fm., OH: O'hara Fm., NM: Namihana Fm., KT: Katsuura Fm., KR: Kurotaki Fm., AN: Anno Fm., KY: Kiyosumi Fm., AM: Amatsu Fm., KN: Kinone Fm.). The marked age data (*) is based on calcareous nannofossil (Kameo and Sekine, 2013) and other data are obtained from zircon fission track (Watanabe and Danhara, 1996; Takahashi and Danhara, 1997; Tokuhashi et al., 2000; Tsuji et al., 2005; Tamura and Yamazaki, 2009). The larger amount of erosion of the Miura Group occurred in the eastern part. The Kazusa Group abuts against the Kurotaki Unconformity and the lower part of the Kazusa Group has overlain it.

examine the relationship between basin evolution and plate-subduction processes. Geo-technical consolidation tests were also performed to examine variations in the consolidation characteristics in the forearc basin.

2. Geologic setting

The Boso Peninsula of central Japan is located north of the Sagami Trough, which is the plate boundary between the Eurasian and Philippine Sea plates (Fig. 1a). The geology of the Boso Peninsula is controlled by plate-subduction phenomena and is divided into three parts (Fig. 1b): 1) early Miocene to Pliocene accretionary complexes and trench-slope basin deposits in the southern part (Saito, 1992; Yamamoto and Kawakami, 2005; Yamamoto et al., 2005; Kawakami and Shishikura, 2006; Chiyonobu et al., submitted to this issue); 2) the Hayama–Mineoka tectonic belt, dominated by ophiolite, in the middle part (e.g., Ogawa and Taniguchi, 1987), corresponding to the trench-slope break (Soh et al., 1991); and 3) a post-middle Miocene forearc basin in the northern part (Mitsunashi et al., 1979; Nakajima et al., 1981; Nakajima and Watanabe, 2005).

The Boso forearc basin consists mainly of the 15–3 Ma Miura Group and the 2.5–0.6 Ma Kazusa Group (e.g., Nakajima and Watanabe, 2005; Kameo and Sekine, 2013; Fig. 1c). The boundary between the two groups is the Kurotaki Unconformity (Koike, 1951), which is actually hiatus formed by submarine erosion at ca. 3 Ma when the convergence direction of the Philippine Sea Plate changed (Takahashi, 2006). Many tuff layers occur in the Boso Peninsula, constituting useful marker beds for correlation (e.g., Urabe et al., 1990; Satoguchi et al., 2000; Takahashi et al., 2005) and for examination of the attitude of the basin and structures.

The Miura Group is divided into the Neogene Kinone, Amatsu, Kiyosumi, and Anno formations (Fig. 2). The Kinone and Amatsu formations are mainly hemipelagic mudstones, and the Kiyosumi and Anno formations are mostly turbidite successions. The Kinone and Amatsu formations are assigned to Calcareous Nannofossil bio-zones (CN; Okada and Bukry, 1980) and Neogene Nannofossil bio-zones (NN; Martini, 1971) CN3–CN4 (NN4–NN5) and CN5b (NN7), respectively on the basis of their calcareous nannofossils (Mita and Takahashi,

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