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Crustal characteristic variation in the central Yamato Basin, Japan Sea back-arc basin, deduced from seismic survey results

Takeshi Sato*, Tetsuo No, Seiichi Miura, Shuichi Kodaira

Research and Development Center for Earthquake and Tsunami (CEAT), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan

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ABSTRACT

The crustal structure of the Yamato Bank, the central Yamato Basin, and the continental shelf in the southern Japan Sea back-arc basin is obtained based on a seismic survey using ocean bottom seismographs and seismic shot to elucidate the back-arc basin formation processes. The central Yamato Basin can be divided into three domains based on the crustal structure: the deep basin, the seamount, and the transition domains. In the deep basin domain, the crust without the sedimentary layer is about 12–13 km thick. Very few units have P-wave velocity of 5.4–6.0 km/s, which corresponds to the continental upper crust. In the seamount and transition domains, the crust without the sedimentary layer is about 12–16 km thick. The P-wave velocities of the upper and lower crusts differs among the deep basin, the seamount, and the transition domains. These results indicate that the central Yamato Basin displays crustal variability in different domains. The crust of the deep basin domain is oceanic in nature and suggests advanced back-arc basin development. The seamount domain might have been affected by volcanic activity after basin opening. In the transition domain, the crust comprises mixed characters of continental and oceanic crust. This crustal variation might represent the influence of different processes in the central Yamato Basin, suggesting that crustal development was influenced not only by back-arc opening processes but also by later volcanic activity. In the Yamato Bank and continental shelf, the upper crust has thickness of about 17–18 km and P-wave velocities of 3.3–4.1 to 6.6 km/s. The Yamato Bank and the continental shelf suggest a continental crustal character.

1. Introduction

The Japan Sea, located between the Asian continent and the northeastern and southwestern Japan Island Arcs, is a back-arc basin in the northwestern Pacific comprising three major sub-basins: the Japan Basin located in the north to northwest region, the Yamato Basin located in the southeast region, and the Tsushima Basin located in the southwest region (Fig. 1). The central region in the Japan Sea includes the Yamato Rise composed of the Yamato Bank, Kita-Yamato Bank, and Takuyo Bank (Fig. 1).

For the Japan Sea, it has been inferred from geophysical, geological, and petrological data that back-arc opening of the sea was initiated by crustal rifting in the Asian continental margin in the Early Oligocene, with subsequent ocean floor spreading (e.g., Tamaki et al., 1992). The opening occurred around the middle Miocene (e.g., Kano et al., 2007; Otofuji et al., 1985; Sato, 1994). After this opening stopped, the tectonics in the eastern margin of the Japan Sea was characterized by weak or mild compression between 10 and 3.5 Ma (Sato, 1994; Tamaki, 1988). However, the southern margin of the Japan Sea experienced the compression from the north and from the south directions, or from the northwestern and southeastern directions during the late Miocene (8–5 Ma) (Itoh and Nagasaki, 1996; Itoh et al., 1997; Yamamoto, 1993). After 3.5 Ma, in the eastern margin of this sea and the back-arc side of the northeastern Japan Island Arc, crustal shortening occurred by a strong E-W compression (Sato, 1994; Tamaki, 1988). Along this margin, fault-fold belts developed as a result of deformation caused by extension associated with the opening of the Japan Sea and by the later compression (e.g., Okamura et al., 1995; Sato, 1994). Along the southern margin of the Japan Sea, strike-faults caused by E–W compression have been mainly distributed (e.g., Itoh et al., 2002; Okamura, 2016). The framework of the opening of the Japan Sea is clarified as described above, but, the details remain unknown. Van Horne et al. (2017) reviewed unsolved issues related to the opening of the Japan Sea. To be more specific, three opinions exist in relation to the opening phase of the Japan Sea. One supposition is that by the paleomagnetic study, the age of the opening of the Japan Sea was estimated between 21 and 12 Ma in northeastern Japan side with counterclockwise rotation, and between 16 and 14 Ma in southwestern Japan side with

* Corresponding author at: Research and Development Center for Earthquake and Tsunami (CEAT), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3173-25, Showa-machi, Kanazawa-ku, Yokohama 236-0001, Japan.
E-mail address: tsato@jamstec.go.jp (T. Sato).

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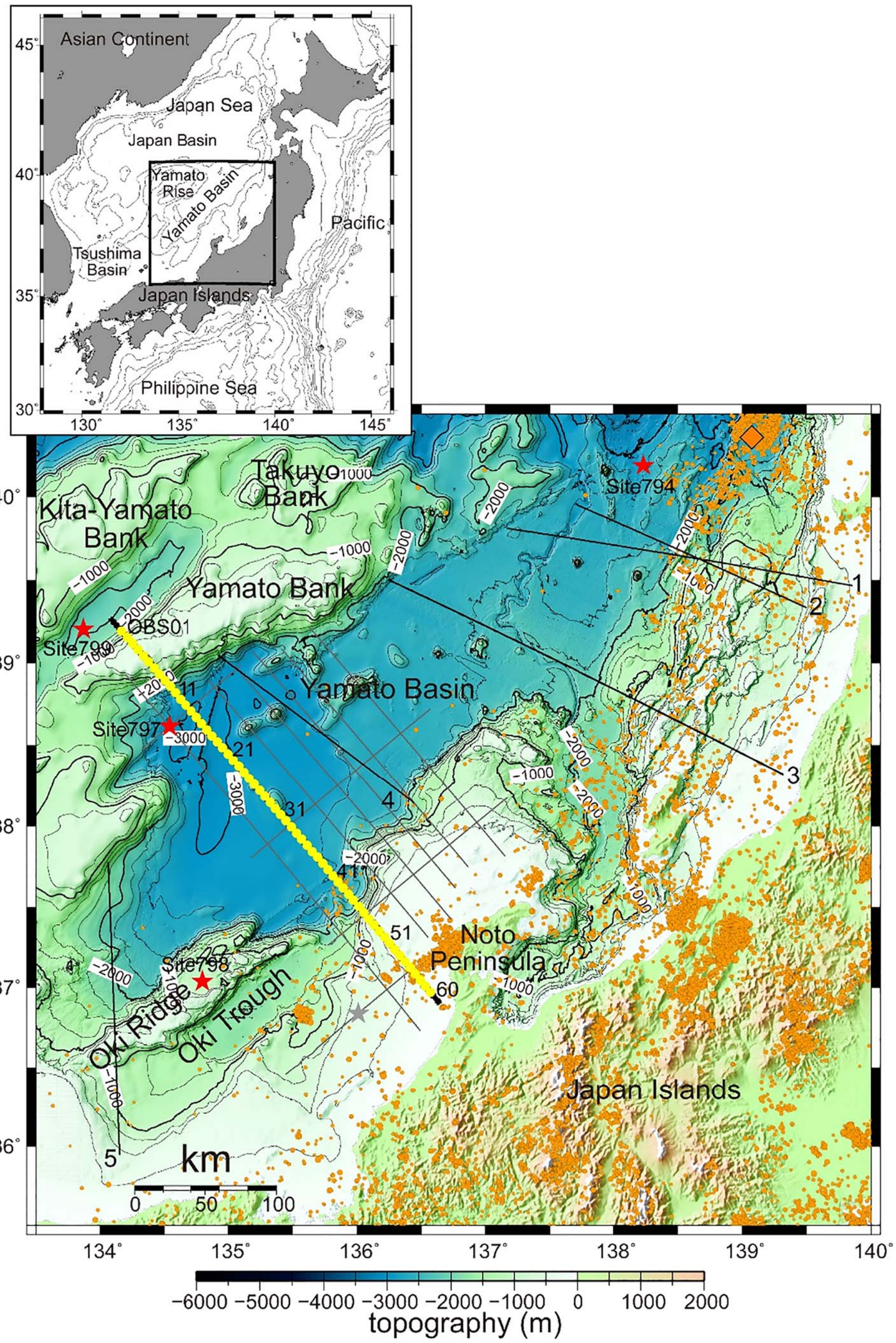

Fig. 1. Map of the local bathymetry around the Yamato Basin and this survey area from the Yamato Bank, the central Yamato Basin, and the continental shelf to the coast of the southwestern Japan Island Arc off the Noto Peninsula in the Japan Sea. The black thick line shows the seismic refraction/wide-angle reflection survey line on air-gun shooting. Positions of deployed OBSs are shown as yellow circles. Grey lines show the MCS survey lines using multi-channel streamer and air-gun (No et al., 2015). Red and grey stars represent positions of ODP drilling sites (Sites 794, 797, 798, and 799) and of the Kiso-shisui drilling hole (off Kanazawa). Black thin lines shows previous seismic survey lines using OBSs discussed in the text: line 1 (Nishisaka et al., 2001), line 2 (Nishizawa and Asada, 1999), line 3 (Sato et al., 2014), line 4 (Nakahigashi et al., 2013), and line 5 (Sato et al., 2006b). Orange small circles show epicenters of earthquakes that are equal to or greater than magnitude 2 at depths equal to or lower than 50 km from 2000 to November 2017 (Japan Metrological Agency, 2017). The orange diamond shows the epicenter of the 1983 Nihon-kai-chubu Earthquake (Mj 7.7), which struck along the eastern margin of the Japan Sea. Bathymetric data used JTOPO30 published by Japan Coast Guard. The inset depicts a topographic map of the Japan Sea. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

clockwise rotation (e.g., Otofuji et al., 1985; Otofuji et al., 1991). Another proposal is that after crustal thinning, ocean floor spreading started in the Late Oligocene in the eastern Japan Basin with southwestward propagation, which ceased in the late early Miocene (Tamaki et al., 1992). The final proposal is that based on the dating of the basaltic rock recovered by the ODP drilling at Sites 794 and 797 in the Yamato Basin, and at Site 795 in the end of the eastern Japan Basin, the ocean floor spreading is estimated to have age of 21.2–17.7 Ma (Kaneoka et al., 1992; Nohda, 2009).

To elucidate the back-arc opening processes of the Japan Sea, numerous seismic surveys have been conducted using ocean bottom seismographs (OBSs). The Japan Basin has an oceanic crust with total thickness of about 6.5–8 km without the sedimentary layer (e.g., Hirata et al., 1992; No et al., 2014). In the topographic high domain, the Kita-Oki Bank located between the Yamato and the Tsushima Basins suggests a stretched continental crust fragment because the crust is 22 km thick and has a homogeneous 6 km/s layer with small velocity gradient that resembles the continental upper crust (Kurashimo et al., 1996). The Yamato Bank has features of the continental crust in the shallow part (Ludwig et al., 1975; Murauchi, 1972). By contrast, in the Tsushima Basin, the crustal thickness is 10–17 km (e.g., Kim et al., 1998; Kurashimo et al., 1996; Sato et al., 2006a). Similarly, the Yamato Basin has crustal thickness of 13–16 km, so that the crust is thought to be neither typical oceanic nor typical continental crust (e.g., Hirata et al., 1989; Nakahigashi et al., 2013; Nishisaka et al., 2001; Nishizawa and Asada, 1999; Sato et al., 2006b; Sato et al., 2014; Shinohara et al., 1992). Recently, Sato et al. (2014) reported that the northern Yamato Basin has a thick oceanic crust based on the results of the seismic survey and on geochemical results of basalts recovered by ODP drilling in the western Yamato Basin (Site 797) by Hirahara et al. (2015).