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Basin filling related to the Philippine Sea Plate motion in Beppu Bay, southwest Japan

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ABSTRACT

Strike-slip basins are one of the most important accumulation spaces for sediment of terrigenous, biogenic, and volcanic origins, and generally include large amount of event deposits. Although these event deposits are important basin filling process, research on this topic, particularly the effects of event deposits, is insufficient. In this study, we discuss sedimentation features based on grain composition and other properties for ca. 3000 year periods in Beppu Bay, which is strike-slip basin located at the western end of an arc-bisecting dextral fault known as Median Tectonic Line (MTL) associated with the northwestward subduction of the Philippine Sea Plate. This sediment is composed of hemipelagic clay and coarser event layers of turbidites referred to as types A, B, and C; ash layers referred to as type D; and other referred to as type E. The turbidite event layers, which accounted for 92% of the total major event layer, with >1 cm thickness, consist of particles related to volcanism, including hydrothermal activity. The events control the regional filling rate and transportation of coarse and heavy volcaniclastic materials. In particular, type A, which accounted for 73% of the total major event layer thickness, is likely induced by earthquakes related to the MTL, according to its age. As a result, the basin filling processes are controlled mainly by tectonics related to the subduction of the Philippine Sea Plate.

1. Introduction

A strike-slip basin that develops around a subduction zone, continental collision zone, or transform zone is one of the most important accumulation spaces for sediment of terrigenous, biogenic, and volcanic origins. These coastal basins, particularly convergent margins, are hence able to directly record the paleoclimate history (e.g. Hughen et al., 1996) or its development (e.g. Trop et al., 2012). Furthermore, because convergent margins dominate the global flux of volcaniclastic material (Manville et al., 2009), these basins are key in understanding the paleo transport and deposition system, or event history along the convergent margins. Generally, coastal basins include large amounts of event deposits caused by volcanism, earthquakes, and floods (Einsele et al., 1996). Thus, the event deposits in strike-slip basin are important for recording events (e.g. Cole and Ridgway, 1993) in addition to basin-filling process. Therefore, an understanding of characteristics and deposition processes of event deposits is crucial. However, studies on these basin-filling processes, particularly the effects of event deposits, are insufficient because the estimation of triggers and timing is difficult owing to the complexity of initiation mechanisms such as turbidity currents (Nakajima, 2000). Moreover, the lack of correlatable event records and high-resolution age models adds additional challenges. In this study, we focus on Beppu Bay, located on the coast of Kyushu in southwestern Japan (Fig. 1), where some of the best preserved sediments are located in the strike-slip basin around the convergent plate boundary between the Philippine Sea Plate and the Eurasia Plate (Noda, 2013). A sedimentary core drilled at Beppu Bay serves as an example for discussing the filling processes in the strike-slip basin on the basis of grain composition and other physical properties.

1.1. Tectonic and geologic settings

Beppu Bay (Fig. 1A and B) is located at the western end of an arc-bisecting dextral fault greater than 1000 km length known as

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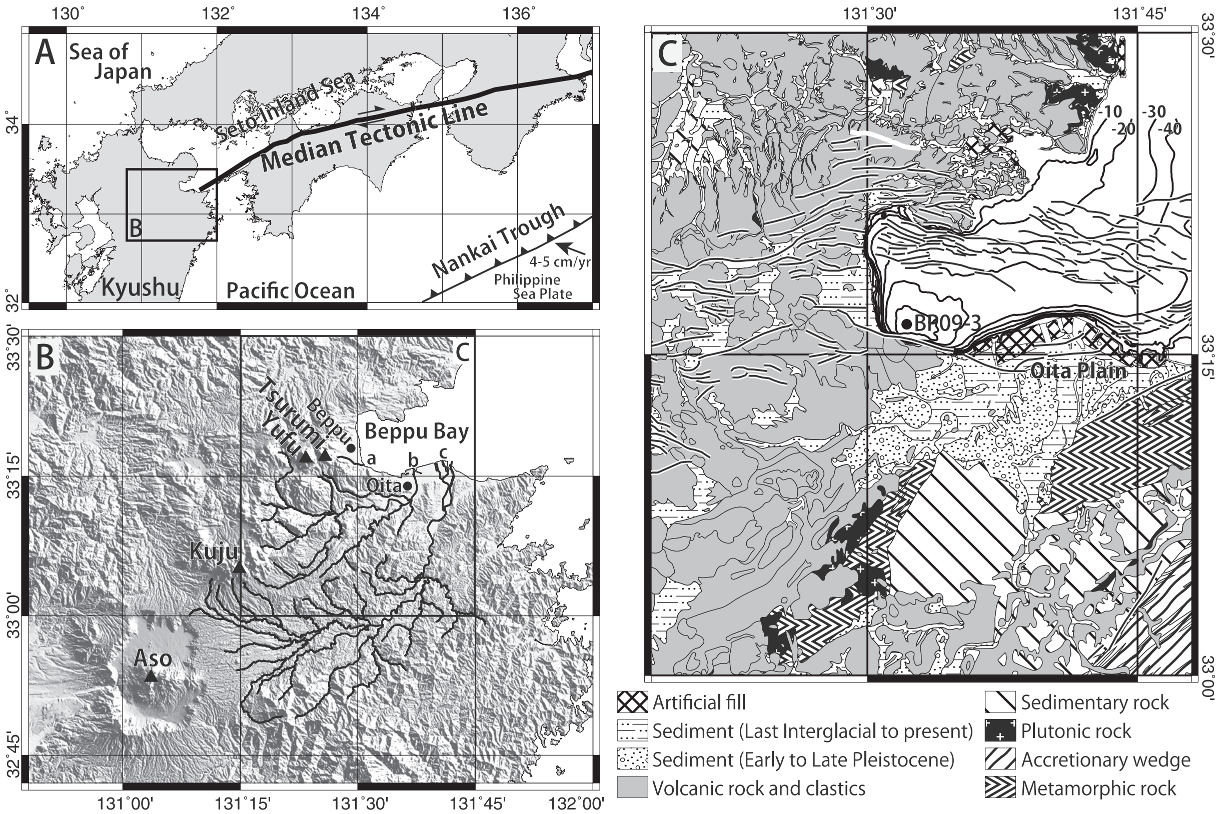

Fig. 1. Topographical and geological map of the study site. (A) Map of southwest Japan (after Itoh et al., 2014). Solid line shows the arc-bisecting dextral fault known as the Median Tectonic Line (MTL) associated with the northwestward subduction of the Philippine Sea Plate (direction indicated by the solid arrow). (B) Shade map around Beppu Bay based on the 10 m resolution digital elevation model (DEM) of the Geospatial Information Authority of Japan. Solid lines show the major channels of three rivers that feed into Beppu Bay at (a) Asami River, (b) Oita River, and (c) Ono River. Solid triangles indicate Aso, Kuju, Yufu, and Tsurumi active volcanoes. (C) Geological map (after GSJ, 2014; Hoshizumi and Morishita, 1993; Hoshizumi et al., 1988; Ishizuka et al., 2005; Ono, 1963; Teraoka et al., 1992; Yoshioka et al., 1996) and bathymetric chart. Solid lines show active faults (after AIST, 2012).

the Median Tectonic Line (MTL). This fault is associated with the northwestward subduction of the Philippine Sea Plate at 4–5 cm/yr (Seno et al., 1993; Loveless and Meade, 2010). According to Itoh et al. (1998) and Itoh et al. (2014), the process of the bay formation was divided into two stages. The older stage, 5–1.5 Ma, was dominated by a northward-inclined half-graben, whereas pull-apart stress resulting from the right-stepping of the MTL developed during the younger stage of 1.5 Ma to the present, particularly from 0.7 Ma to the present. As a result, active faults are densely distributed in and around the bay (Fig. 1C; AIST, 2012).

In this region, Ryoke low-pressure/high temperature and Sambagawa high-pressure metamorphic rock are distributed under the sedimentary rocks of Onogawa Group and Oita Groups. These rocks are mainly mantled with volcanic rocks and clastic materials that erupted from Aso, Kuju, Yufu, Tsurumi, and other volcanoes beginning in the middle–late Pleistocene and Holocene (Fig. 1B; GSJ, 2014; Hoshizumi and Morishita, 1993; Hoshizumi et al., 1988; Ishizuka et al., 2005; Ono, 1963; Teraoka et al., 1992; Yoshioka et al., 1996). The high-angle dextral fault of the MTL is driven by the northwestward subduction of the Philippine Sea Plate (Itoh et al., 2014; Tsutsumi et al., 1991), which cut the thrust fault between the Sambaga and Ryoke metamorphic rocks associated with the northward subduction of the Philippine Sea Plate (Isozaki, 1996; Itoh et al., 2014).

At present, the Oita and Ono rivers, which flow into the southern side of the bay, and some streams including the Asami River, which flow into the western and northern sides of the bay, formed the Oita Palin delta and alluvial fan located in the city of Beppu (Fig. 1B and C). These rivers supplied terrestrial clastics into the bay and, seamless, thick Quaternary sediments including volcaniclastics were consequently deposited at a high sedimentation rate in Beppu Bay.

1.2. Depositional environment

Beppu Bay lies at the west end of the Seto Inland Sea and has a maximum depth of 72 m at the western end and a drainage mouth 52 m in depth at its eastern end (Fig. 1A and C). Sedimentary cores (Okamura et al., 1992) and seismic reflection profiles have shown that the basin structure has caused clastics originating from the Oita and Ono rivers to be trapped and rapidly deposited at an average rate of ca. 2.5 m/ky in the bay (Fig. 2; Yamada et al., 2014). In addition, dissolved oxygen in the deepest part of the bay is very low, at 0–6 ml/L, because thermal stratification occurred in the summer (Kameda and Fujiwara, 1995). As a result, thick Quaternary sediments are well preserved in the bay. Furusawa and Umeda (2000), Takemura (1995), and Umeda et al. (1996) revealed that sediments at the shallower, northern end of the bay at ca. 30 m in depth recorded five air fall tephra deposits in the Holocene sediment, although reworked layers such as turbidites were not present. However, Kuwae et al. (2013) recently documented that sediments in the deepest part of the bay held some reworked layers. These differences may reflect the transport and deposition processes of terrigenous materials in the bay, including subaerial volcaniclastics in the bay, and may be key in understanding the