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Middle to late Holocene delta plain evolution of the Kimotsuki lowland, Kyushu (southern Japan)

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A B S T R A C T

The evolution of delta plains and coastal floodplains is commonly believed to be influenced by sea-level and climate changes. However, regional climate change influences on the evolution of delta plains and floodplains are poorly understood compared with responses to rapid sea-level rise since the last deglaciation. This study investigated the Kimotsuki lowland delta plain evolution (Kyusyu, southern Japan), including allogenic controls, based on 28 auger cores and 28 radiocarbon ages. Large-scale crevasse splay deposition occurred at 7000–6000 cal yr BP in response to sea-level rise or increased sediment supply following a volcanic eruption. Afterwards, widespread peat was formed in the absence of substantial fluvial sedimentation. Decreased precipitation from a weakened East Asian summer monsoon may have dried the peatlands around 4000 cal yr BP. With increasing precipitation and storminess around 2000 cal yr BP, peat formation resumed at areas further from the Kimotsuki River, while increased overbank flows deposited organic-rich mud near the river. These changes may reflect an increased frequency of La Niña events and higher ocean surface temperatures of the Kuroshio extension. The increased storminess around 2000 cal yr BP may have produced similar influences on delta plain and coastal floodplain evolution across the East Asia region. The results of this study suggest that regional climate change in the late Holocene has a potential to control the evolution of coastal floodplains and delta plains.

1. Introduction

Allogenic controls on fine-grained coastal floodplains and delta plains, such as climate change, sea-level fluctuations, and neotectonics are well documented across several disciplines, including geomorphology, geology, and archaeology (Aslan and Autin, 1999; Aslan and Blum, 1999; Blum and Törnqvist, 2000; Stouthamer and Berendsen, 2001, 2007; Pennington et al., 2016). Climate change during the middle to late Holocene was driven by declining summer insolation in the Northern Hemisphere (Wanner et al., 2008; Marcott et al., 2013). Some recent studies suggest this substantial climate change influenced the evolution of coastal floodplains and delta plains. The rarity of large-scale crevassing and slower aggradation in the Nile delta after 6000–5000 cal yr BP (Marriner et al., 2012a, 2012b; Pennington et al., 2017) are associated with decreased African monsoon precipitation (Shanahan et al., 2015), although decreased sea-level rise may have contributed more to the slower aggradation (Pennington et al., 2017). Similarly, decreased precipitation from a weakened EASM reduced fluvial activity and led to near-cessation of overbank deposition followed by widespread peat initiation at 5600–5000 and 4100–3600 cal yr BP in the Ishikari and Shiribeshi-Toshibetsu River lowland, northern Japan (Ishii et al., 2016; Ishii, 2017a). These studies suggest that climate change in the middle to late Holocene had a substantial influence on the evolution of coastal floodplains and delta plains.

In contrast, the impact of regional climate change on the floodplain evolution in the late Holocene is not well understood because the magnitude of regional climate change generally seems to be small. In the EASM region, precipitation was reduced throughout the late Holocene due to the reduced summer insolation in the Northern Hemisphere (Dykoski et al., 2005). Meanwhile, a large increase in sediment discharge from man-made deforestation occurred in many Asian large rivers (Saito et al., 2001; Tanabe et al., 2006), and its impact on the floodplain evolution may be substantial. Previous studies inferred that the active fluvial deposition was highly influenced by increased sediment discharge from man-made deforestation (Kawase, 1998; Hasada, 2015; Itoh et al., 2017). However, the active overbank sedimentation may reflect the activity of El Niño-Southern Oscillation (ENSO) because it is related to the magnitude and frequency of tropical storms and typhoons in the East Asia region (e.g. Camargo et al., 2007).

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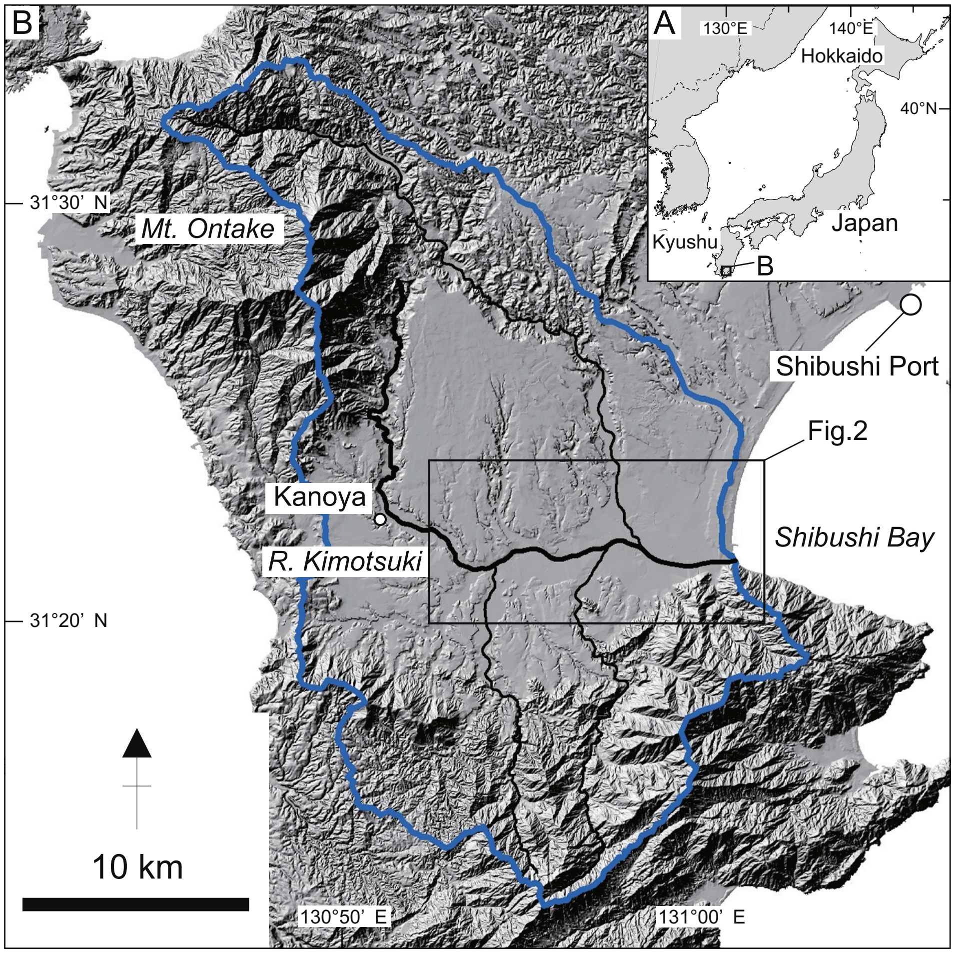

Fig. 1. Map showing the study area. A. Kimotsuki River lowland location. B. Shaded-relief map of the Kimotsuki River basin and surrounding area. The blue line indicates the watershed boundary. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Zhu et al. (2017) recently indicated that the magnitude and frequency of floods increased after 2000 cal yr BP in central China possibly in response to enhanced ENSO activity. More research is needed to better understand the susceptibility of floodplains to the regional climate change in the late Holocene.

A detailed floodplain chronology is necessary to understand fluvial responses to centennial-scale changes in regional climate. The presence of widespread peat enables a reconstruction of detailed floodplain chronology because peat includes abundant plant and wood fragments suitable for radiocarbon dating and widespread peat initiation or cessation reflects a major change in sedimentary environment (Ishii et al., 2016; Ishii, 2017a). While widespread peat is relatively common on delta plains and coastal floodplains in the northern part of Honshu and Hokkaido, it rarely occurs to the south (Sakaguchi, 1974). Although the conditions for a dearth of peat in central and southern Japan are not completely clear, higher temperatures in coastal areas may inhibit peat formation (Yabe, 1989; Tomita, 2010). One exception is the Kimotsuki River delta plain in southern Japan (Kyushu, Fig. 1), where widespread peat layers develop up to 4 m thick. Abundant spring water from the surrounding plateau appears to promote peat formation (Sakaguchi, 1960; Arizono, 1985). This indicates that the peat formation is susceptible to changes in the amount of precipitation and thus a good indicator for climate change, while it is also affected by fluvial deposition near the river due to enhanced storminess. Therefore, climate change and fluvial activity may influence the delta plain evolution in a different way, which allows a reliable comparison of fluvial activity with climate change.

Peat is absent near the Kimotsuki River and thickens toward the southern edge of the lowland (Sakaguchi, 1960). A radiocarbon age of 6600–6200 cal yr BP was obtained from the base of the peat (Nagasako et al., 1999). A mud layer possibly formed under the influence of climate change and/or human activities overlies the widespread peat (Sakaguchi, 1979; Nagasako et al., 1999). However, the stratigraphy and chronology of the delta plain have not been studied in detail. The purpose of this study is to investigate the evolution of the Kimotsuki River delta plain based on the radiocarbon ages from 28 auger cores and evaluate the influences of EASM and ENSO on the delta plain evolution. A special focus is on the influence of climate change on the increased fluvial activity in the late Holocene.

2. Regional setting

The Kimotsuki River headwaters originate from Mt. Ontake (1182 m elevation) and flow south through the Shirasu Plateau, which was formed by the eruptions from the Aira Caldera around 30,000 cal yr BP (Smith et al., 2013) and is mostly composed of unwelded pyroclastic flow deposits of high permeability (Fig. 1). The river has a catchment area of 485 km^2 and length of 34 km (Kyushu Regional Development Bureau, 2012). The channel gradient is about 0.1% near the confluence with the Aira River and 0.038% at the mouth (Kyushu Regional Development Bureau, 2012). The mean tidal range and wave height at Shibushi Port (Fig. 1) (2010–2014) are 1.11 and 0.42 m, respectively. The tidal influence extends about 6 km upstream of the river mouth.

Mean annual precipitation at Kanoya (Fig. 1) is about 2400 mm (1981–2010), where roughly 70% of the precipitation falls during the EASM season (May–October). The quasi-stationary Baiu and Akisame