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Holocene floodplain evolution in the Shiribeshi-Toshibetsu River lowland, northern Japan

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A B S T R A C T

The influence of sea-level and climate changes on the evolution of coastal floodplains is an important problem in fluvial geomorphology and geology. However, few studies have constructed detailed chronologies of floodplain evolution, and the influence of sea-level and climate changes at submillennial time scales is not clear. This study investigated the Holocene evolution of the floodplain in the Shiribeshi-Toshibetsu River lowland, Hokkaido, northern Japan, based on 13 auger cores, 15 radiocarbon ages, and 2 cross sections made using existing columnar sections. In the study area, peat beds 3–6 m thick in the uppermost Holocene sediments are underlain by fluvial sediment that mainly consists of sand beds resulting from crevassing or progradational avulsion. Age–elevation plots of the bases of these peat beds suggest that fluvial aggradation was continuous until peat formation began, which in turn suggests that peat beds began to form with the cessation of fluvial deposition. The chronology of floodplain sediments based on radiocarbon ages indicates that peatlands began to develop locally before ca. 6500 cal BP and became moderately widespread before 5600 cal BP. Peatlands then became more extensive after two periods of rapid expansion during ca. 5300–5000 and 4100–3900 cal BP. Comparison with sea-level and regional climate changes suggests that the initiation of these peat beds before 5600 cal BP was associated with the deceleration of sea-level rise at ca. 7000 cal BP. The two later periods of peatland expansion may have been strongly influenced by reduced fluvial activity due to decreased precipitation from a weakened East Asian summer monsoon. This interpretation suggests that floodplain evolution was controlled by sea-level and climate changes and that the response to climate change occurred at submillennial time scales. A comparison with the Ishikari lowland on Hokkaido showed that the two floodplains have slightly different histories, possibly because of differences in internal characteristics of the fluvial systems such as the number and size of tributary rivers, water discharge, and sediment supply, although their responses to sea-level and climate changes were similar. The fluvial response to sea-level and climate changes revealed in this study has implications for studies of the Holocene evolution of other coastal floodplains.

1. Introduction

Low-gradient, fine-grained floodplains generally evolve by aggradation of fluvial deposits such as overbank deposits, crevasse-splay deposits, and avulsion deposits (Makaske, 2001; Slingerland and Smith, 2004), and thus the depositional history of these deposits has attracted much attention in studies of fluvial geomorphology and geology (Törnqvist, 1993: Morozova and Smith, 2000; Makaske et al., 2002; Stouthamer and Berendsen, 2007; Hijma and Cohen, 2011; Funabiki et al., 2012). In coastal areas, the evolution of floodplains is strongly influenced by postglacial changes in sea level. Crevassing and progradational avulsion occurred frequently in response to rapid sea-level rise during the early Holocene, leading to rapid aggradation of floodplains (Aslan and Autin, 1999; Aslan and Blum, 1999; Goodbred and Kuehl, 2000; Stouthamer et al., 2011; Tanabe et al., 2015). Fluvial aggradation decreased considerably after rapid sea-level rise ended, and in some cases lateral migration of rivers may have become significant (Aslan and Autin, 1999; Aslan and Blum, 1999). However, fluvial deposition did not completely cease, and formation of natural levees, crevassing, and avulsion continued to play a role in floodplain evolution (Goodbred and Kuehl, 2000; Stouthamer et al., 2011; Shen et al., 2015).

After the major phase of deglaciation ended at ca. 7000 cal BP (Fleming et al., 1998; Peltier, 2002, 2004; Bradley et al., 2011; Yokoyama et al., 2012; Lambeck et al., 2014), climate changes as well as human disturbances likely had a significant impact on the evolution

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of coastal floodplains. A substantial change in climate, through its effect on the discharge of water and sediment from upstream catchments, can alter the style of fluvial deposition (Aalto et al., 2003; Giosan et al., 2012).

Recently, Ishii et al. (2016) argued that changes in the strength of the East Asian summer monsoon (EASM) may have had a great impact on the evolution of the Ishikari lowland in Hokkaido, northern Japan. They suggested that decreases in fluvial activity and subsequent widespread peat initiation at 5600–5000, 4600–4300, and 4100–3600 cal BP in different areas of the lowland were probably the consequences of decreases in precipitation from a weakened EASM. This argument implies that the same mechanism affected other coastal floodplains in the EASM region. In Hokkaido, where peatlands are widespread, it follows that peat initiation on floodplains may be correlated with climate events. However, chronologies of coastal floodplains in Hokkaido other than the Ishikari lowland are not well constrained. For example, it may be that fluvial aggradation on other floodplains in Hokkaido almost ceased because of the cessation of rapid sea-level rise at ca. 7000 cal BP, such that widespread peatlands developed before the weakening of the EASM. More research is needed on these floodplains in Hokkaido, and elsewhere in the EASM region.

In the Shiribeshi-Toshibetsu River lowland, located near the Ishikari lowland in southwestern Hokkaido (Fig. 1), peatlands were extensive in the 19th century, when intense human activities began in the area (Oka and Mitani, 1981). The uppermost peat beds are 3–6 m thick and are underlain by fluvial or deltaic deposits (Oka, 2009). Oka (2009) inferred that the extensive peat formation dates from the time of maximum flooding in the early to middle Holocene, although the chronology has not been established. Establishing a detailed chronology of floodplain evolution here may shed light on the fluvial response to sea-level and climate changes, and also the history of other floodplains in Hokkaido and elsewhere in the EASM region.

This paper presents a reconstruction of the evolution of the floodplain based on 13 auger cores, 15 radiocarbon ages, and 2 cross-sections constructed using existing columnar sections. It compares this reconstruction with records of sea level and climate change to evaluate their influence on the evolution of the floodplain, and then compares the records of the Shiribeshi-Toshibetsu River lowland and the Ishikari lowland.

2. Regional setting

The Shiribeshi-Toshibetsu River originates on Mt. Oshamambe (972 m elevation) and enters an elongated lowland about 20 km east of its mouth on the Sea of Japan (Fig. 1). The river has a catchment area of approximately 720 km^2, and its current length of about 80 km has been shortened by twentieth century flood-control measures. Its mean annual discharge is 28 m^3/s. Its mean channel gradient is approximately 1/500 near the upstream edge of the lowland, 1/1400 near its confluence with the Toshibetsumena River (Fig. 2), and 1/3000 near its mouth (Hokkaido Regional Development Bureau, 2007). The mean tidal range is 0.1 m and the mean wave height (2010–2014) is 0.76 m at Setana Port, near the river mouth (Fig. 1). The coast can be classified as a wave-dominated coast (Davis and Hayes, 1984).

The mean annual precipitation (1981–2010) is ca. 1300 mm at Imakane (Fig. 1), and more than half of the precipitation occurs in the EASM season (May–October). The formation of the quasi-stationary Baiu and Akisame rainbands is a prominent feature of the EASM. The Baiu rainband forms off the southern coast of Japan in May and slowly moves northward from early June to early August. The Baiu rainband often disappears in the northern part of the study area and thus does not affect the study area every year. The Akisame rainband appears in Hokkaido and then migrates southward from late August to October. In the winter monsoon season, heavy snowfall occurs in Hokkaido; the

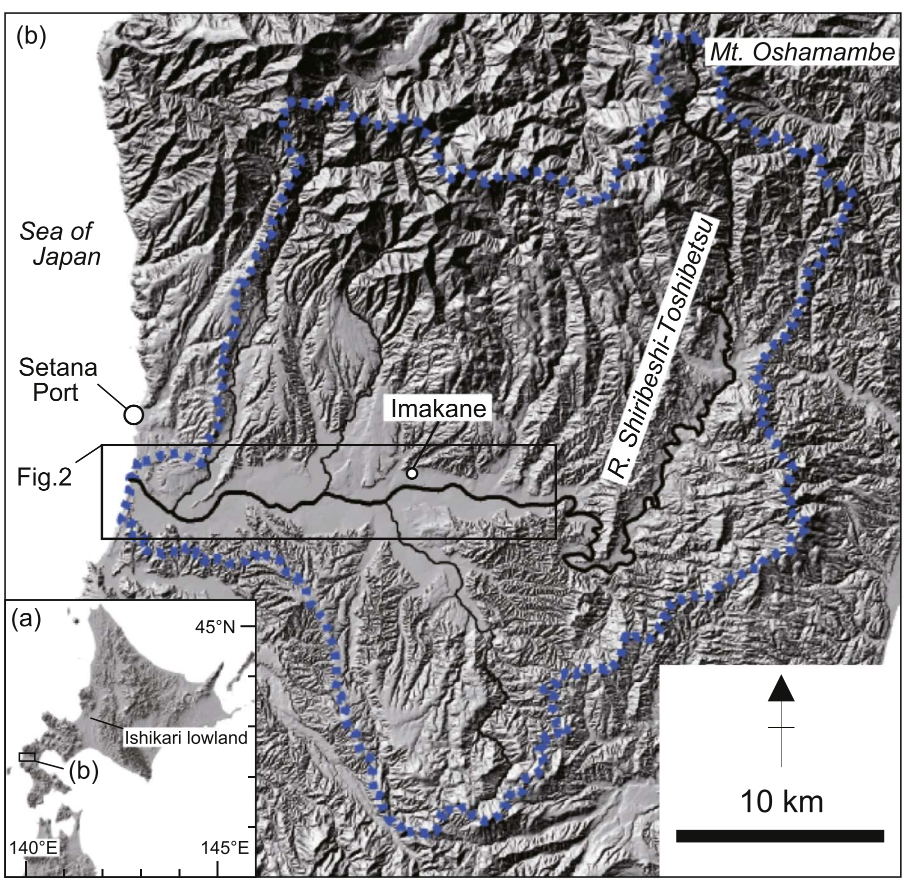

Fig. 1. (a) Location map of the Shiribeshi-Toshibetsu River lowland, Hokkaido. (b) Shaded relief map of the study area. The dotted line indicates the watershed boundary.