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Sediment accumulation patterns in a tectonically subsiding incised valley: Insight from the Echigo Plain, central Japan

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ABSTRACT

The Echigo Plain is on the Japan Sea coast of the island of Honshu and is bounded to the west by the Echigo Plain Western Margin Fault Zone. The Shinano River incised valley lies east of the bounding fault zone and runs seaward, approximately parallel to it. The incised valley deepens to more than 160 m below mean sea level near the coast, deeper than sea-level fall during the Last Glacial Maximum, because of subsidence governed by the fault zone. In this study, we examined the sediment stacking patterns of the incised-valley fill at 1000-year scale by analyzing sedimentary facies and radiocarbon ages from three sediment cores from the Echigo Plain. The latest Pleistocene to Holocene Shinano River incised-valley fill sediments unconformably overlie a basement of late Pleistocene flood plain sediments that contain Aira-Tn (AT) tephra dated at 25,120 ± 220 BP (ca. 30 cal kyr BP). The fill sequence comprises sediments of meandering river (>12 cal kyr BP), estuarine (13–9 cal kyr BP), and barrier–lagoon (9–0 cal kyr BP) systems, in ascending order. Thousand-year isochrons based on radiocarbon ages show that the meandering river and estuarine systems were deposited aggradationally and retrogradationally and the barrier–lagoon system was deposited progradationally and aggradationally. These sediment stacking patterns resemble those of other incised-valley fill sequences in East and Southeast Asia, which indicates that the last deglacial eustasy was a major factor controlling sediment stacking patterns of incised-valley fill in these regions. However, aggradational sedimentation in all three depositional systems is only observed in the Echigo Plain and suggests that long-term subsidence at 2.7–3.8 mm/yr is an important factor controlling the 1000-year scale sediment stacking pattern in this tectonically subsiding incised valley.

1. Introduction

Incised valleys form in coastal lowlands as a result of river incision during glacial sea-level lowstands. The characteristic valley fill is riverine sediment discharged during deglacial sea-level rises (Reading and Collinson, 1996). Studies of modern and ancient analogs have revealed that the incised-valley fills consist of lowstand and transgressive fluvial depositional systems overlain by transgressive and highstand marine depositional systems (Dalrymple et al., 1992; Zaitlin et al., 1994).

Modern incised valleys in coastal lowlands in East and Southeast Asia formed during the Last Glacial Maximum (LGM) and are filled with fluvial and marine sediments related to the last deglacial sea-level rise and the sea-level highstand after the middle Holocene (Hori et al., 2006). Recent core and radiocarbon age studies of these latest Pleistocene to Holocene incised-valley fills have revealed their 1000-year scale stacking patterns and have allowed isochrons to be drawn. These studies (e.g. Changjiang delta in China, Hori et al., 2002; Red River delta in Vietnam, Tanabe et al., 2006) have revealed that the valleys formed during a sea-level lowstand and that they were filled by transgressive fluvial, estuarine, and highstand deltaic depositional systems. The fluvial and estuarine systems show aggradational and retrogradational stacking patterns, whereas the deltaic systems show progradational stacking patterns. The aggradational and retrogradational stacking patterns, respectively, show building up of uniform and deepening-upward facies successions. These stacking patterns are generally controlled by the last deglacial eustasy.

In the Ganges–Brahmaputra delta, tectonic subsidence also affects the sediment stacking patterns of the Holocene deltaic sediments (Goodbred and Kuehl, 2000; Goodbred et al., 2003). Its stacking patterns show aggradation and progradation, whereas those of the deltaic systems in East and Southeast Asia show monotonous progradation. But the sediment stacking patterns of the Ganges–Brahmaputra delta are simulated by a model with limited numbers of radiocarbon date. Also, they lack thick transgressive sediments, which typically fill the incised valleys in East and Southeast Asia

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(Hori et al., 2002; Tanabe et al., 2006). Therefore, it is necessary to examine the sediment stacking patterns of the entire sequence of a transgressive and regressive incised-valley fill using real isochrons to test the effects of tectonic subsidence on the depositional processes in a tectonically subsiding region. Furthermore, incised-valley fills in tectonically subsiding regions have more potential to be preserved as strata than those in tectonically stable or uplifting regions. Therefore, their characteristics of sedimentary facies are important to reconstruct paleo tectonics from outcrop information.

The Echigo Plain on the Japan Sea coast is regarded as a barrier–lagoon system (Urabe et al., 2004) bounded to the west by the Echigo Plain Western Margin Fault Zone (Kobayashi, 1996) (Fig 1). The Echigo Plain comprises the Shinano River incised valley, which runs roughly parallel to the fault zone and deepens to 160 m below mean sea level at the coast (Editorial Committee of Subsurface Geology of Niigata Prefecture, 2002). Along the coast of the Japanese Islands, sea level during the LGM was 100 to 120 m lower than it is today (Nakada et al., 1991). Therefore, it is believed that the extra depth of the incised valley is due to tectonic subsidence along the fault. The present interseismic subsidence rate along the coast is 3–4 mm/yr (Commission for the Investigation of Subsidence in the Niigata Area, 1959). Thus, the Echigo Plain is a suitable area to investigate the 1000-year scale stacking patterns of latest Pleistocene to Holocene incised-valley fill sequences influenced by tectonic subsidence.

In this study, we compiled sedimentary facies and radiocarbon dates from previously obtained sediment cores YA (Tanabe et al., 2009) and GS-KNM-1 (Nakanishi et al., 2010; Tanabe et al., 2010), and a new core GS-NIF-1 from the coastal area of the Echigo Plain. From these data, we examined the 1000-year scale stacking patterns of the latest Pleistocene to Holocene Shinano River incised-valley fill sequence in relation to the last deglacial eustasy and tectonic subsidence. The sediment stacking patterns of the entire sequence of the incised-valley fill in a tectonically subsiding region have not been revealed yet. Furthermore, the characteristics of the facies succession of the incised-valley fill in a tectonically subsiding region are somewhat unknown compared with those in a tectonically stable region. We also took into consideration the radiocarbon age of the Aira-Tn (AT) tephra recovered from the basement underlying the Shinano River incised-valley fill sequence. The AT tephra widely distributed over the Japanese Islands and the Korean Peninsula, and it often occurs at the basement underlying the latest Pleistocene to Holocene incised-valley fills (Machida and Arai, 2003). Radiocarbon age of the tephra has been debated from the 1970s, and its absolute age is also important in the context of examining the evolution of the latest Pleistocene to Holocene incised-valley fills in East Asia.

2. Study area

The Echigo Plain was formed by the interaction of sea-level changes during the last deglacial and sediment discharges from the Shinano and Agano rivers (Fig. 1). The spring tidal range of the Japan Sea is less than 0.3 m and the present-day water discharges from the Shinano and Agano rivers are 19.3 and 16.7 km^3/yr, respectively (National Astronomical Observatory, 2009). Sea level along the Japan Sea coast during the LGM was 100 to 120 m lower than the present level (Nakada et al., 1991), at which time the Shinano River became incised. Because of tectonic subsidence of the Echigo Plain, the incised valley is deeper than the sea-level drop during the LGM, reaching 160 m below sea level today. The incised valley subsequently filled with latest Pleistocene to Holocene sediments derived mainly from the Shinano River (Editorial Committee of Subsurface Geology of Niigata Prefecture, 2002). On the basis of sedimentary facies and diatom assemblages, Kamoi et al. (2002) divided the Shinano River incised-valley fill into basal fluvial sediments (Unit I), overlain in turn by brackish sediments (Unit D), shallow marine sediments (Units H, G, and C), barrier–lagoon sediments (Units F and E), and modern barrier–lagoon sediments (Units B and A). The barrier–lagoon and modern barrier–lagoon sediments correspond to transgressive and regressive barrier–lagoon systems, respectively (Urabe et al., 2004). The regressive barrier–lagoon system can also be regarded as a strandplain system.

On the present-day Echigo Plain, a series of beach ridges forms a band about 10 km wide along the coast, with reclaimed lagoons and floodplains landward of them (Fig. 1). The beach ridges have prograded seaward during the Holocene sea-level highstand since shortly after

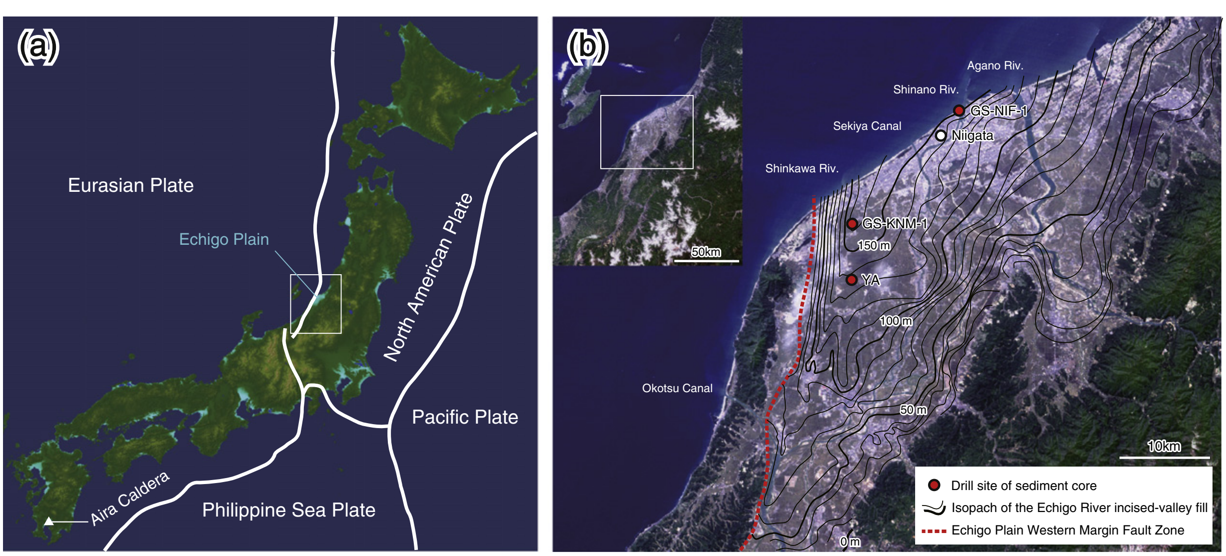

Fig. 1. Regional and local location maps of the study area. (a) Distribution of coastal lowlands in the Japanese Islands. Coastal lowlands with elevations of <15 m are shown in light blue. White lines indicate tectonic plate boundaries. The topographic map is based on a 250-m grid digital elevation map from the Japanese Geographical Survey Institute. (b) Isopach map of incised-valley fill sediments under the Echigo Plain showing locations of cores used in this study. Isopach contours and the location of the Echigo Plain Western Margin Fault Zone are from Editorial Committee of Subsurface Geology of Niigata Prefecture (2002). The Okotsu Canal, Shinkawa River, and Sekiya Canal are present-day distributaries of the Shinano River. Light-colored areas along the coast are beach ridges or urban areas of Niigata City. Landsat TM image downloaded from the Earth Science Data Interface at the Global Land Cover Facility (http://glcfapp.umiacs.umd.edu).
This figure is modified after Tanabe et al. (2009).