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Temporal changes of a delta: Example from the Holocene Yahagi delta, central Japan

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ABSTRACT

The depositional history of a delta was investigated by using radiocarbon-dated borehole cores from the Yahagi delta (Nishimikawa plain), Central Japan. In particular, historical changes in the gradient, thickness, and grain size distribution of the delta front and sediment discharge of the Yahagi River are discussed. The latest Pleistocene to Holocene sequence in the Yahagi delta is interpreted as an incised valley fill system formed after the Last Glacial and subdivided into five sedimentary facies: facies A (fluvial), facies B (estuary), facies C (prodelta), facies D (delta front), and facies E (gravelly tidal flat). In the main axis of the incised valley, facies A, facies B, facies C, facies D, and facies A are deposited, in ascending order. In the western area of the valley, facies E adjoins facies D. The delta front was formed by river floods without reworking by wave or tide. The succession was interpreted as a transgressive systems tract and highstand systems tract formed under sea-level rise until ca. 7 cal kyr BP and the subsequent highstand. After the formation of the delta in ca. 7 cal kyr BP, characteristic features of the delta front changed twice as the delta prograded. First, during 4–5 cal kyr BP, the delta front became thicker and steeper. This change was induced by differences in water depth between the middle incised valley and the outer incised valley, which resulted from a buried clinoform. Second, in ca. 3 cal kyr BP, the grain size distribution of the delta front became coarser and the sorting became poorer. The sediment discharge of the Yahagi River also increased abruptly. This change was induced by the increase of erosional capacity in the hinterland. Increasing human activities such as deforestation and poor soil conservation might have induced this change.

1. Introduction

Deltas that develop at river mouths are population centers and food-producing areas for mankind. Information regarding their subsurface lithofacies distributions is useful to our society, providing countermeasures against earthquake disasters, groundwater exploitation, and so on. Moreover, deltas are highly vulnerable to rises in sea-level and decreases in sediment discharge from rivers. Recently, coastal protection from erosion became necessary because the damming of rivers leads to a decrease in sediment discharge (Milliman and Syvitski, 1992) and predicted global warming may accelerate sea-level rise. Understanding the relation between long-term delta development, sediment discharge, and sea-level changes will help us to manage coastal environments.

Many studies on deltas have focused on evolution and formation processes. Tides and waves are important factors in delta morphology, development, and sediment dynamics (Galloway, 1975). Along with hydraulic processes, grain size (Orton and Reading, 1993) and water depth (Postma, 1990) are also recognized as important factors.

Many Holocene deltaic sediments are underlain by late Pleistocene to Holocene nearshore marine transgressive deposits (Stanley and Warne, 1994). Deltas sometimes develop within incised valleys formed during the Last Glacial, for example, the Changjiang (Yangtze River) (Hori et al., 2001a) and Kiso (Nobi plain) (Yamaguchi et al., 2003) deltas, as well as in areas in active margins. In these settings, controlling factors, especially water depth, are strongly affected by the topography of the basement of the delta system, which underlies the transgressive sediment or basement of the incised valley. To understand the delta systems in these settings, basement topography is important because it is related to water depth, especially in the initial stages of the delta. The timing of the present delta initiation is about 8500–6500 yr BP (Stanley and Warne, 1994). Delta initiation is induced by a deceleration of

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postglacial sea-level rise (Stanley and Warne, 1994; Hori et al., 2004). A further understanding of initial delta stages will enable us to more precisely predict their responses to sea-level changes.

The purposes of this study are to reconstruct the depositional history of a delta within an incised valley system and to reveal the processes controlling delta evolution based on sedimentological studies of high-resolution radiocarbon-dated cores. Changes of sediment discharge, delta front gradients, grain size distribution, relative sea-level in Mikawa Bay, and the relation between water depth and sedimentation rate are also discussed.

2. Geological setting

The Yahagi delta (Nishimikawa plain) is located at the mouth of the Yahagi River facing Mikawa Bay in Central Japan (Fig. 1). This delta is surrounded by the Mikawa Plateau and the Owari Hill. The Yahagi River has its headwaters in the Ookawairi Mountain at a height of 1908 m and flows down the western side of the Mikawa Plateau. The river is 117 km long and drains an area of 1830 km^2, its average water discharde is 44 m^3 s^{-1}. The slope gradient of the riverbed is 0.005 at the river mouth (Yatsu, 1955). The channel style is braided. The previous lower channel was switched to the present channel in 1605 for flood control. Before the work, the river emptied the central part of Mikawa Bay.

The old channel now hardly flows and has been renamed the "Old Yahagi River". In this paper, "Yahagi River" means the Yahagi River before the channel change, because our subject is the late Pleistocene to Holocene deposits of the Yahagi River. The basement rock of the drainage area is mostly granite (Kobayashi, 1972). The river-transported sediments are mainly granules and coarse sand. These sediments are granitic in origin, which tend to yield grains of individual minerals upon disintegration (Boggs, 1968). The river has no alluvial fan because of a lack of gravel (Kuwahara, 1982). Mikawa Bay is a nearly closed bay surrounded by the Chita and the Atsumi peninsulas, its mean tidal range is less than 2 m (microtidal), and its wave energy is very low.

The geometry and subsurface structure of the Yahagi delta were revealed by Moriyama and Ozawa (1972) and Kuwahara (1982) based on considerable borehole data. The bird's eye view of the Yahagi delta roughly approximates a "curved trumpet" shape (Fig. 1), which is curved at about 8 km northeast of the mouth. The delta width is about 8 km at the coastline, decreases gradually toward the upper stream, and is 1.5 km wide at the narrowest point (13 km from the mouth; middle of YG3 and YG4 (described later)). At the more upper streamward point, the delta is inflated in width again. The latest Pleistocene to Holocene deposits in the Yahagi delta plain are 50 m thick at the mouth, and overlie the basement. The deposits are subdivided into basal gravels (BG), lower muds (LM), lower sands (LS), middle muds (MM), upper muds (UM), upper sands (US), top muds (TM), and top sands (TS) in ascending order (Moriyama and Ozawa, 1972). It is analogous to many other delta successions in Japan (Umitsu, 1981), for example, the Kiso delta (Nobi plain) (Yamaguchi et al., 2003). This succession was deposited over the incised valley formed during the Last Glacial (Kaizuka et al., 1977). The BG consist of very coarse sand to granules and are 5–10 m thick. The LS consist of fine sand to coarse sand and are 3–12 m thick. The MM consist of mud and are 8–15 m thick. This unit is distributed only in the area 15 km from the coastline.

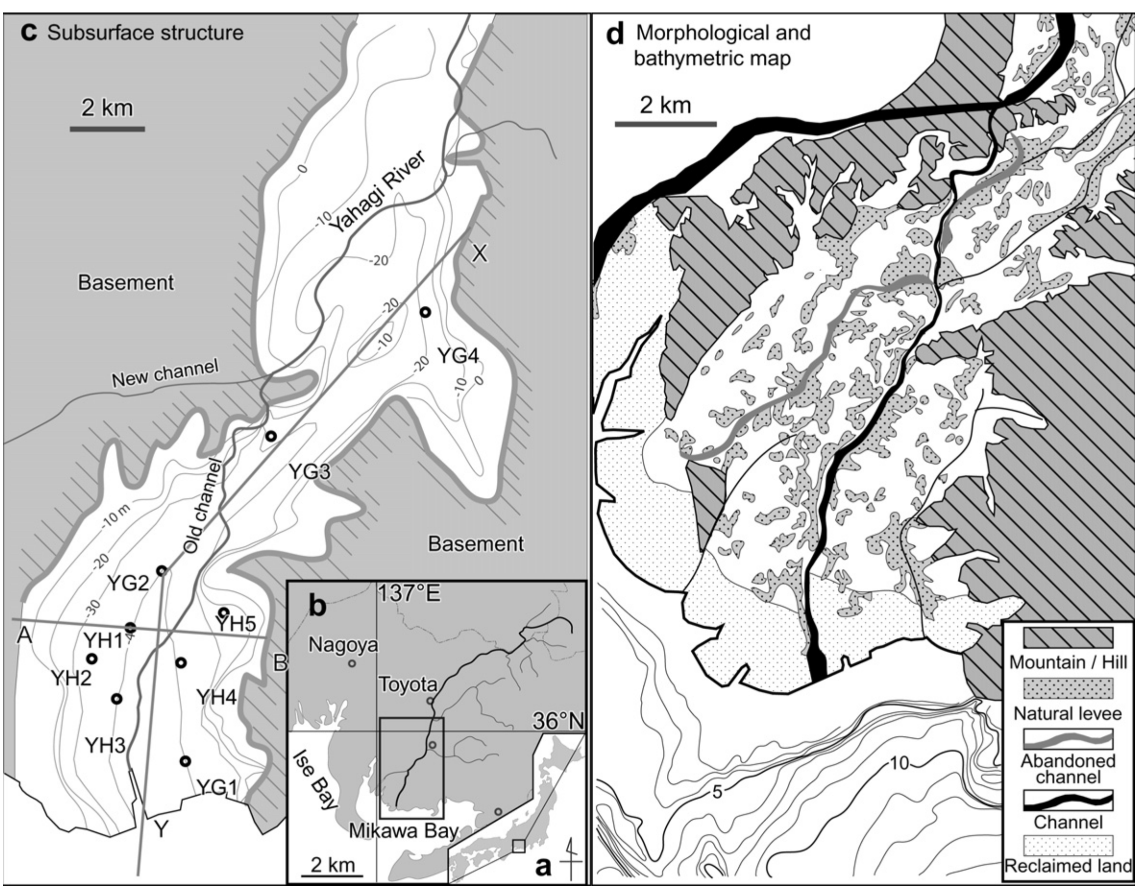

Fig. 1. Location maps. (a, b) Location of study area. Area of (c) is represented by a rectangle. (c) Contour map of basement of the Yahagi incised valley and location of drilling sites. X–Y is the incised valley axis. (d) Morphological map of the Yahagi delta and bathymetric map of Mikawa Bay (simplified after Moriyama and Ozawa, 1972).