Progradation of the Changjiang River delta since the mid-Holocene

Hori Kazuaki[1], Saito Yoshiki[2], ZHAO Quanhong (赵泉鸿)[3], WANG Pinxian (汪品先)[3] & LI Congxian (李从先)[3]

1. Department of Earth and Planetary Science, University of Tokyo, Hongo 7-3-1, Bunkyou-ku, Tokyo 113-0033, Japan;
2. Marine Geology Department, Geological Survey of Japan, Higashi 1-1-3, Tsukuba 305-8567, Japan:
3. Laboratory of Marine Geology, Tongji University, Shanghai 200092, China

Corresponding author: Kazuaki Hori (e-mail: khori@gsj.go.jp)

Present address: c/o Dr. Yoshiki Saito, Marine Geology Department, Geological Survey of Japan, Higashi 1-1-3, Tsukuba, 305-8567, Japan

Received March 27, 2000

Abstract Subaqueous deltaic deposits with approximately 30 radiocarbon ages show that the Changjiang River delta was strongly affected by tides and that the delta progradation rate after 2 kaBP was almost double the rate before 2 kaBP. This change in the progradation rate correlates well with the active extension of the subaerial delta plain shown by previous work. Widespread human activities, such as farming, deforestation, and dike construction, probably resulted in an increase in sediment discharge to the river-mouth area.

Keywords: Changjiang, Yangtze, sediment discharge, delta progradation, AMS radiocarbon dating, human impact.

The Changjiang River, one of the largest rivers in the world, has formed a large delta at its mouth since about 6—7 kaBP, when sea level reached or approached its present position. Previous work has described the active extension of the subaerial delta plain after about 2 kaBP[1—3]. Most of these studies, however, were based only on paleogeographic maps and on land chenier studies. Thus, the subaqueous deltaic deposits constituting the main part of the delta system are poorly known. In this study, we investigated the subaqueous deltaic deposits and delta front progradation by analyzing samples from three boreholes.

The three boreholes (CM97, JS98, and HQ98) were drilled in the present subaerial delta plain in 1997—1998. The cores were split, described, and photographed. X-radiographs were taken using slab samples from all split cores. Five-cm-thick samples were taken every 20 cm for the determination of sand and mud content. Approximately thirty radiocarbon ages were measured on molluscan shells and plant materials by the Accelerator Mass Spectrometry (AMS) method through Beta Analytic Inc.

The deltaic deposits, 25—30 m thick, were classified into five facies: prodelta, delta front, lower intertidal to subtidal flat, upper intertidal flat, and surface soil, in ascending order based on sediment facies analyses[4]. The prodelta facies was characterized by dark gray silt to clay with occasional thin shell beds and thin coarse-silt layers. The delta front facies consisted mainly of silty to fine sand with parallel or ripple lamination. Very thinly interbedded sand and mud were also common. The lower intertidal to subtidal flat facies showed an upward-fining succession and was mainly composed of very thinly interbedded silty to very fine sand and mud. The upper intertidal flat facies consisted predominantly of very thinly interbedded to interlaminated sand and mud containing plant rootlets. The surface soil facies was characterized by dull brown clayey silt with plant rootlets and snail shells. The prodelta and upper part of the delta front facies displayed an upward-coarsening succession overlain by an upward-fining succession from the upper part of delta front to the surface soil facies. Sedimentary structures of very thinly interbedded sand and mud and bidirectional ripple lamination show that tides strongly influenced the deposition of these sediments (fig. 1).

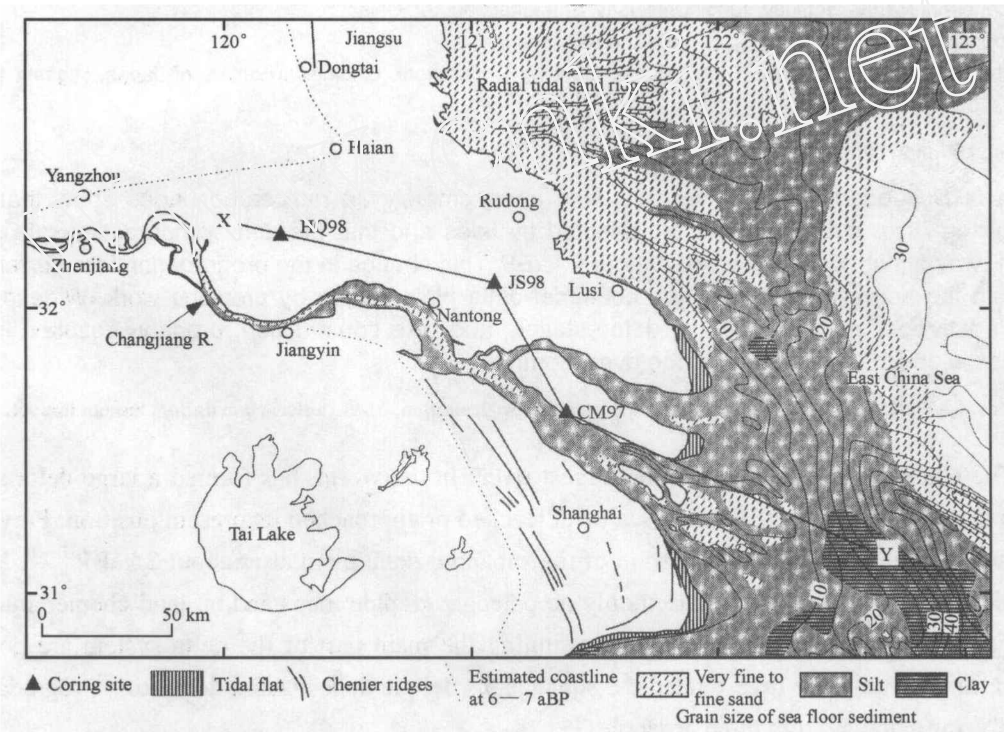

Fig. 1. The location of borehole sites and the longitudinal cross section (X-Y) shown in fig. 2 (modified after Hori et al.).

Radiocarbon ages associated with the depositional facies revealed the sediment accumulation rate of each facies. The accumulation rate of the prodelta deposits was about 1.1 m/ka at the CM97 and HQ98 sites. A maximum accumulation rate of approximately 10 m/ka was observed in the delta front to lower intertidal to subtidal flat deposits in all cores. There was a large difference in accumulation rates between the prodelta and the lower intertidal to subtidal flats to the delta front.

The paleo-water depth can be estimated by comparing accumulation (age-depth) curves of core sediments with the late Quaternary sea-level curve for the East China Sea[5]. Paleo-water depth around 8 kaBP was approximately 10—15 m. The maximum paleo-water depth of 20—25 m occurred around 6—7 kaBP, when the sea-level rise greatly decelerated, and sea-level was close to or slightly higher than its present position. The paleo-water depth decreased rapidly as demonstrated by the rapid accumulation of sediments as the delta front passed each borehole site (fig. 2).

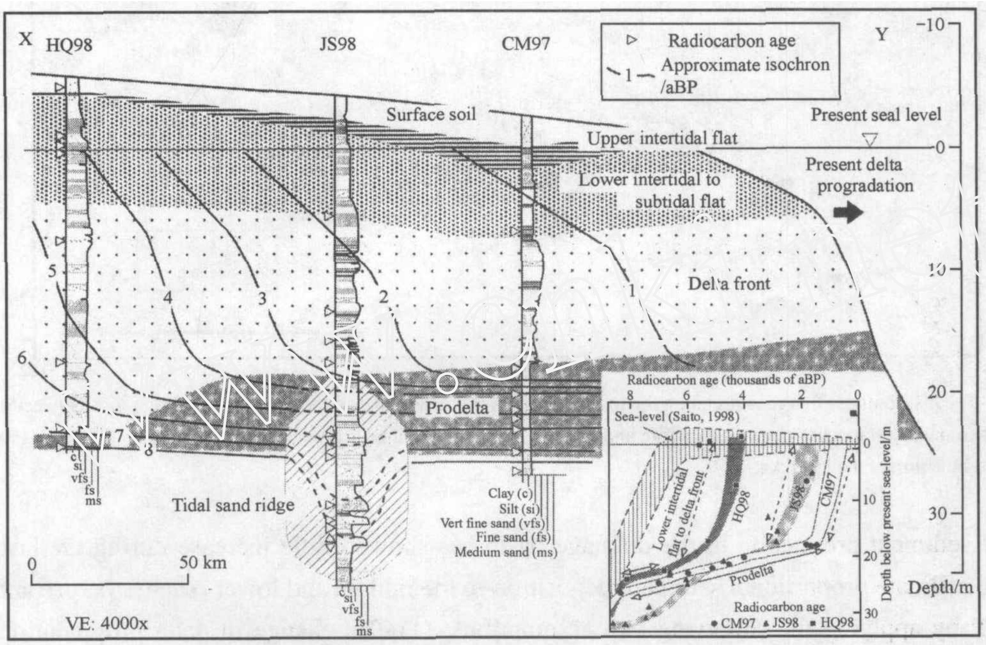

Fig. 2. Stratigraphy of a longitudinal cross section (X-Y) and accumulation curve for each borehole site and a late Quaternary sea-level curve for the East China Sea. Isochron lines are based on ^{14}C dates and accumulation curves (modified after Hori et al.).

The delta front has prograded more than 250 km since 6 kaBP. However, the progradation rate increased abruptly about 2 kaBP, going from 38 to 80 km/ka. This change almost coincided with the active growth of the subaerial delta plain[1—3]. The increase in the progradation rate probably reflected the change in sediment discharge to the river-mouth area, because the deltaic deposits show little variation in thickness in the longitudinal profile.

Several possible causes may explain the active progradation. One possible cause was an increase in sediment production, particularly suspended sediment, in the drainage area due to widespread human activities, such as intensive rice cultivation and deforestation[2, 6]. Another possible cause was a relative decrease in deposition in the middle reaches in relation to river-channel stability. Extensive flood plains and numerous natural lakes occur in the middle reaches of the river between Yichang and Hukou. Even now, the middle reaches are frequently subject to heavy flooding during the rainy season, and approximately 20% of the suspended sediment load that passes through Yichang station is trapped in Dongting Lake[7]. The cooling of the climate after the mid-Holocene[8] together with the construction of dikes might have decreased the flooding in the middle reaches, resulting in the relative increase in sediment discharge to the river-mouth area (fig. 3).

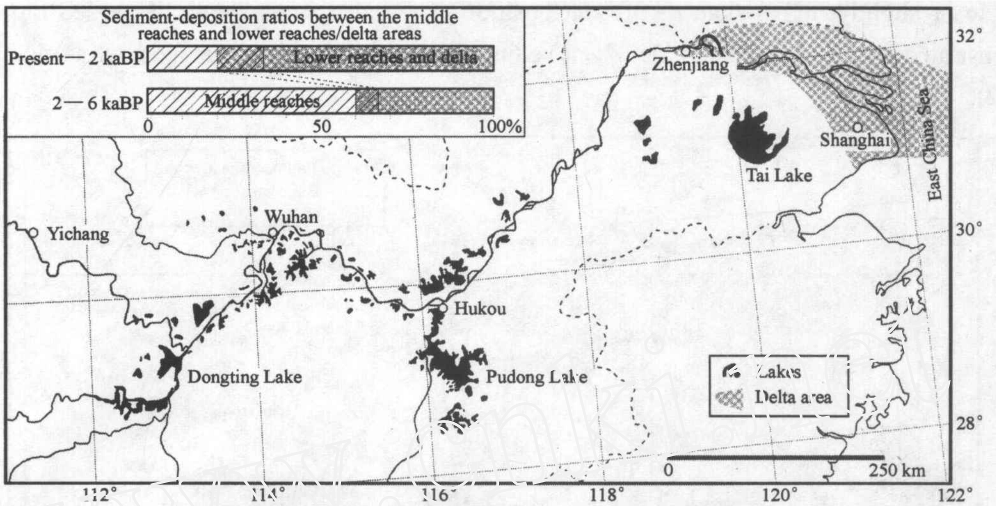

Fig. 3. The distribution of large lakes along the middle and lower reaches, and the sediment-deposition ratios between the middle reaches and lower reaches/delta areas before and after 2 kaBP. It is assumed that sediment production in the drainage area has increased little during the last 6 ka.

If sediment production in the drainage basin has showed little increase during the last 6 ka, we can estimate proportional sediment deposition in the middle and lower reaches before and after 2 kaBP by applying the following two assumptions: (1) The change in delta progradation rates reflects approximately the change in sediment load carried to the lower reaches and the delta area. Deltaic deposits showed little variation in thickness in the longitudinal profile. Therefore, sediment discharge in the lower reaches after 2 kaBP must have been almost double the amount of discharge before 2 kaBP. Because the delta is funnel shaped, this estimate is expected to be a minimum. (2) Presently, one-third to two-fifths of the sediment discharge from the upper reaches is trapped in the middle reaches[7, 9], and the remainder is deposited in the lower reaches and delta area. Because the effect of sediment discharge from the tributaries in the middle and lower reaches is not taken into account, this assumption is also a minimum estimate. Based on these two assumptions, we estimated that the middle reaches trapped at least three-fifths to two-thirds of the sediment discharge before 2 kaBP. Even though this estimate is a minimum, the depositional pattern in the middle reaches versus the lower reaches and delta area reversed at that time.

The shift of the Yellow River mouth from the Bohai Sea to the Yellow Sea did not directly contribute to this phenomenon. Because the Yellow River debouched into the Yellow Sea in Jiangsu Province from 1128 to 1855 AD, the change to rapid progradation of the Changjiang delta occurred about 1 ka before the course change of the Yellow River. Sediment supply from the old Yellow River, however, must have increased progradation rates on the coastal plain of Jiangsu Province during the last 1 ka.

Acknowledgments K. H. thanks the JSPS for a research fellowship. This work was supported by the Global Environment Research Fund of the Environment Agency of Japan, and in part by a Grant-in-aid from the Scientific Research Project (Grant No. 10-5088) of the Ministry of Education, Science and Culture of Japan.

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