

Song Hong (Red River) delta evolution related to millennium-scale Holocene sea-level changes

Tanabe S., Hori K., Saito Y., Haruyama S., Vu P.V., Kitamura A.

Grad. Sch. of Science and Technology, Niigata University, Ikarashi-2 8050, Niigata 950-2181, Japan; Japan Soc. for the Prom. of Science, c/o MRE, Geological Survey of Japan, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan; MRE, Geological Survey of Japan, AIST, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan; Graduate School of Frontier Sciences, University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-0033, Japan; Department of Geography, Hanoi National University, Nguyen Trai 334, Thanh Xuan, Hanoi, Viet Nam; Institute of Geosciences, Shizuoka University, Ohya 836, Shizuoka 422-8529, Japan; Sedimentary Geology Research Group, Geological Survey of Japan, AIST, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan

Abstract: The Song Hong (Red River) delta occurs on the northwest coast of the South China Sea. Its evolution in response to Holocene sea-level changes was clarified on the basis of sedimentary facies and 14 radiocarbon dates from the 40 m long Duy Tien core from the delta plain, and using previously reported geological, geomorphological, and archaeological data. The delta prograded into the drowned valley as a result of early Holocene inundation from 9 to 6 cal. kyr BP, as sea-level rise decelerated. The sea-level highstand at +2-3 m from 6 to 4 cal. kyr BP allowed widespread mangrove development on the delta plain and the formation of marine notches in the Ha Long Bay and Ninh Binh areas. During sea-level lowering after 4 cal. kyr BP, the former delta plain emerged as a marine terrace, and the delta changed into the present tide- and wave-influenced delta with accompanying beach ridges. Delta morphology, depositional pattern, and sedimentary facies are closely related to Holocene sea-level changes. In particular, falling sea level at 4 cal. kyr BP had a major impact on the evolution of the Song Hong delta, and is considered to be linked to climate changes. © 2003 Elsevier Ltd. All rights reserved.

Index Keywords: Climate change; Oceanography; Sea level; Delta morphology; Geology; delta; facies; Holocene; landform evolution; paleoceanography; sea level change; Asia; Eurasia; Red River Delta; Southeast Asia; Viet Nam

Year: 2003

Source title: Quaternary Science Reviews

Volume: 22

Issue: 21-22

Page : 2345-2361

Cited by: 30

Link: Scopus Link

Correspondence Address: Tanabe, S.; Sedimentary Geology Research Group, Geological Survey of Japan, AIST, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan; email: s.tanabe@aist.go.jp

ISSN: 2773791

CODEN: QSRED

DOI: 10.1016/S0277-3791(03)00138-0

Language of Original Document: English

Abbreviated Source Title: Quaternary Science Reviews

Document Type: Article

Source: Scopus

Authors with affiliations:

- Tanabe, S., Grad. Sch. of Science and Technology, Niigata University, Ikarashi-2 8050, Niigata 950-2181, Japan, Sedimentary Geology Research Group, Geological Survey of Japan, AIST, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan
- Hori, K., Japan Soc. for the Prom. of Science, c/o MRE, Geological Survey of Japan, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan
- Saito, Y., MRE, Geological Survey of Japan, AIST, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan
- Haruyama, S., Graduate School of Frontier Sciences, University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-0033, Japan
- Vu, P.V., Department of Geography, Hanoi National University, Nguyen Trai 334, Thanh Xuan, Hanoi, Viet Nam
- Kitamura, A., Institute of Geosciences, Shizuoka University, Ohya 836, Shizuoka 422-8529, Japan

References:

- Allen, G.P., Posamentier, H.W., Sequence stratigraphy and facies model of an incised valley fill: The Gironde Estuary, France (1993) *Journal of Sedimentary Petrology*, 63, pp. 378-391
- Biswas, B., Quaternary changes in sea-level in the South China Sea (1973) *Geological Society of Malaysia Bulletin*, 6, pp. 229-256
- Boyd, R., Dalrymple, R.W., Zaitlin, B.A., Classification of clastic coastal depositional environments (1992) *Sedimentary Geology*, 80, pp. 139-150
- Choowong, M., The geomorphology and assessment of indicators of sea-level changes to study coastal evolution from the Gulf of Thailand (2002) *Proceedings of the Symposium on Geology of Thailand*, pp. 207-220. , Mantajit, N. (Ed.), Department of Mineral Resources, Bangkok
- Coleman, J.M., Wright, L.D., Modern river deltas: Variability of processes and sand bodies (1975) *Deltas: Models for Exploration*, pp. 99-149. , Broussard, M.L. (Ed.), Houston Geological Society, Houston
- Collinson, J.D., Alluvial sediments (1996) *Sedimentary Environments: Processes, Facies and Stratigraphy*, pp. 37-82. , Reading, H.G. (Ed.), Blackwell Science, Oxford
- Dalrymple, R.W., Baker, E.K., Harris, P.T., Hughes, M.G., Sedimentology and stratigraphy of a tide-dominated, foreland-basin delta (Fly river, Papua New Guinea) (2003) *SEPM Special Publication* 76, , Sidi, F.H., Nummendal, D., Imbert, P., Darman, H., Posamentier, H.W. (Eds.), *Tropical Deltas of Southeast Asia - Sedimentology, Stratigraphy, and Petroleum Geology*, in press
- Davis, R.A., Hayes, M.O., What is a wave-dominated coast? (1984) *Marine Geology*, 60, pp. 313-329
- Dinh, V.T., Nguyen, D.D., The stages of development of mangrove in the Red River's delta during Holocene (2000) *Journal of the Sciences of the Earth*, 22, pp. 120-126. , in Vietnamese with English abstract
- Frey, R.W., Basan, P.B., Coastal salt marshes (1985) *Coastal Sedimentary Environments*, pp. 225-301. , Davis, R.A. (Ed.), Springer-Verlag, New York
- Fujimoto, K., Miyagi, T., Murofushi, T., Mochida, Y., Umitsu, M., Adachi, H., Pramojanee, P., Mangrove habitat dynamics and Holocene sea-level changes in the Southwestern coast of Thailand (1999) *Tropics*, 8, pp. 239-255
- Galloway, W.E., Process framework for describing the morphologic and stratigraphic evolution of deltaic depositional systems (1975) *Deltas, Models for Exploration*, pp. 87-98. , Broussard, M.L. (Ed.), Houston Geological Society, Houston
- Galloway, W.E., Hobday, D.K., (1996) *Terrigenous Clastic Depositional Systems: Applications to Fossil Fuel and Groundwater*

Resources, 489p. , Springer-Verlag, Berlin

- (1996) Vietnam National Atlas, 163p. , General Department of Land Administration, Hanoi
- Geyh, M.A., Kudrass, H.-R., Streif, H., Sea-level changes during the late Pleistocene and Holocene in the Strait of Malacca (1979) *Nature*, 278, pp. 441-443
- Goodwin, I.D., Did changes in Antarctic ice volume influence late Holocene sea-level lowering? (1998) *Quaternary Science Reviews*, 17, pp. 319-332
- Hanebuth, T., Stattegger, K., Grootes, P.M., Rapid flooding of the Sunda Shelf: A late-glacial sea-level record (2000) *Science*, 288, pp. 1033-1035
- Harrison, T.M., Leloup, P.H., Ryerson, F.J., Tapponnier, P., Lacassin, R., Chen, W., Diachronous initiation of transtension along the Ailao Shan-Red River Shear Zone, Yunnan and Vietnam (1996) *The Tectonic Evolution of Asia*, pp. 208-226. , Yin, A., Harrison, T.M. (Eds.), Cambridge University Press, New York
- Haruyama, S., Vu, V.P., Coastal change in the Southern Song Hong delta (2002) *Journal of Geography*, 111, pp. 126-132. , in Japanese with English abstract
- Hori, K., Saito, Y., Zhao, Q., Cheng, X., Wang, P., Sato, Y., Li, C., Sedimentary facies and Holocene progradation rates of the Changjiang (Yangtze) delta, China (2001) *Geomorphology*, 41, pp. 233-248
- Hori, K., Saito, Y., Zhao, Q., Wang, P., Architecture and evolution of the tide-dominated Changjiang (Yangtze) River delta, China (2002) *Sedimentary Geology*, 146, pp. 249-264
- Jian, Z., Li, B., Uwe, P., Wang, P., Late Holocene cooling in the western Pacific (1996) *Science in China (Series D)*, 39, pp. 543-550
- Jian, Z., Wang, P., Saito, Y., Wang, J., Pflaumann, U., Oba, T., Cheng, X., Holocene variability of the Kuroshio Current in the Okinawa Trough, northwestern Pacific Ocean (2000) *Earth and Planetary Science Letters*, 184, pp. 305-319
- Korotky, A.M., Razjigaeva, N.G., Ganzey, L.A., Volkov, V.G., Grebennikova, T.V., Bazarova, V.B., Kovalukh, N.N., Late Pleistocene-Holocene coastal development of islands off Vietnam (1995) *Journal of Southeast Asia Earth Sciences*, 11, pp. 301-308
- Lam, D.D., Boyd, W.E., Holocene coastal stratigraphy and model for the sedimentary development of the Hai Phong area in the Red River delta, north Viet Nam (2000) *Journal of Geology (Series B)*, 15-16, pp. 18-28
- Lam, D.D., Boyd, W.E., Some facts of sea-level fluctuation during the late Pleistocene-Holocene in Ha Long Bay and Ninh Binh area (2001) *Journal of Sciences of the Earth*, 23, pp. 86-91. , in Vietnamese with English abstract
- Lambeck, K., Nakada, M., Late Pleistocene and Holocene sea-level change along the Australian coast (1990) *Palaeogeography, Palaeoclimatology, Palaeoecology*, 89, pp. 143-176
- Lee, T.-Y., Lawyer, L.A., Cenozoic plate reconstruction of the East Vietnam Sea region (1994) *Tectonophysics*, 235, pp. 149-180
- Mathers, S.J., Zalasiewicz, J.A., Holocene sedimentary architecture of the red river delta vietnam (1999) *Journal of Coastal Research*, 15, pp. 314-325
- Mathers, S.J., Davies, J., McDonald, A., Zalasiewicz, J.A., Marsh, S., The Red River Delta of Vietnam (1996) *British Geological Survey Technical Report WC/96/02*, 41p
- Meckel, L.D., Holocene sand bodies in the Colorado Delta area, northern Gulf of California (1975) *Deltas, Models for Exploration*, pp. 237-265. , Broussard, M.L. (Ed.), Houston Geological Society, Houston
- Miall, A.D., Alluvial deposits (1992) *Facies Models: Response to Sea Level Change*, pp. 119-139. , Walker, R.G., James, N.P. (Eds.), Geological Association of Canada, Waterloo, Ontario
- Milliman, J.D., Haq, B.U., (1996) *Sea-level Rise and Coastal Subsidence: Causes, Consequences, and Strategies*, 369p. , Kluwer

Academic Publishers, Dordrecht

- Milliman, J.D., Rutkowski, C., Meybeck, M., (1995) *River Discharge to the Sea: A Global River Index*, 125p. , LOICZ Core Project Office, Texel, Netherlands
- Nakada, M., Lambeck, K., The melting history of the Late Pleistocene Antarctic ice sheet (1988) *Nature*, 333, pp. 36-40
- Nguyen, D.T., (1991) *Coastal Evolution: Changes of Environment in Coastal Regions of Viet Nam and Problems of Management and Exploration*, Mineral Resources Development Series, 60, pp. 109-114. , United Nations, New York
- Nguyen, D.T., (1991) *Marine Terraces of Indochina*. Mineral Resources Development Series 60, pp. 47-50. , United Nations, New York
- Nguyen, Q.M., Le, K.P., Some results of ¹⁴C dating in investigation on Quaternary geology and geomorphology in Nam Dinh-Ninh Binh area, Viet Nam (2000) *Journal of Geology (Series B)*, 15-16, pp. 106-109
- Nguyen, T.V., Nguyen, D.D., Pham, V.H., Pham, V.M., Dao, V.T., Ngo, Q.T., (2000) *Weathering Crust and Quaternary Sediments Map of Vietnam*, , Department of Geology and Minerals of Vietnam, Hanoi
- Nguyen, V.L., Ta, T.K.O., Tateishi, M., Late Holocene depositional environments and coastal evolution of the Mekong River Delta, Southern Vietnam (2000) *Journal of Asian Earth Sciences*, 18, pp. 427-439
- Nielsen, L.H., Mathiesen, A., Bidstrup, T., Vejbaek, O.V., Dien, P.T., Tiem, P.V., Modelling of hydrocarbon generation in the Cenozoic Song Hong Basin, Vietnam: A highly prospective basin (1999) *Journal of Asian Earth Sciences*, 17, pp. 269-294
- Nishimura, M., Shell midden sites in Vietnam and Thailand (1993) *Journal of Southeast Asian Archaeology*, 13, pp. 25-50. , in Japanese
- Ogura, S., (1997) *History of Vietnam: Dynamics of One Billion Peoples*, 388p. , Chuko-shinsho 1372, Chuokoronshinsha, Tokyo, in Japanese
- Pirazzoli, P.A., (1991) *World Atlas of Holocene Sea-level Changes*, 300p. , Elsevier, Amsterdam
- Pruszek, Z., Szmytkiewicz, M., Nguyen, M.H., Pham, V.N., Coastal processes in the Red River Delta area, Vietnam (2002) *Coastal Engineering Journal*, 44, pp. 97-126
- Rangin, C., Klein, M., Roques, D., LePichon, X., Trong, L.V., The Red River fault system in the Tonkin Gulf, Vietnam (1995) *Tectonophysics*, 243, pp. 209-222
- Reading, H.G., Collinson, J.D., *Clastic coast (1996) Sedimentary Environments: Processes, Facies and Stratigraphy*, pp. 154-231. , Reading, H.G. (Ed.), Blackwell Science, Oxford
- Reinson, G.E., Transgressive barrier island and estuarine systems (1992) *Facies Models: Response to Sea Level Change*, pp. 179-194. , Walker, R.G., James, N.P. (Eds.), Geological Association of Canada, Waterloo, Ontario
- Saito, Y., *Deltas in Southeast and East Asia: Their evolution and current problems (2001) Proceedings of APN/LOICZ Joint Conference on Coastal Impacts of Climate Change and Adaptation in the Asia-Pacific Region*, pp. 185-191. , Mimura, N., Yokoi, H. (Eds.), Global Change and Asia Pacific Coasts. APN and Ibaraki University, Ibaraki, Japan
- Saito, Y., Wei, H., Zhou, Y., Nishimura, A., Sato, Y., Yokota, S., Delta progradation and chenier formation in the Huanghe (Yellow River) delta, China (2000) *Journal of Asian Earth Sciences*, 18, pp. 489-497
- Saito, Y., Yang, Z., Hori, K., The Huanghe (Yellow River) and Changjiang (Yangtze River) deltas: A review on their characteristics, evolution and sediment discharge during the Holocene (2001) *Geomorphology*, 41, pp. 219-231
- Sinsakul, S., Evidence of Quaternary sea level changes in the coastal areas of Thailand: A review (1992) *Journal of Southeast Asian Earth Sciences*, 7, pp. 23-37
- Southon, J., Kashgarian, M., Fontugne, M., Metivier, B., Yim, W.W.-S., Marine reservoir corrections for the Indian Ocean and Southeast Asia (2002) *Radiocarbon*, 44, pp. 167-180
- Stanley, J.D., Dating modern deltas: Progress, problems, and prognostics (2001) *Annual Review on Earth and Planetary*

Sciences, 29, pp. 257-294

- Stanley, D.J., Warne, A.G., Worldwide initiation of Holocene marine deltas by deceleration of sea-level rise (1994) *Science*, 265, pp. 228-231
- Stuiver, M., Braziunas, T.F., Modeling atmospheric ^{14}C influences and ^{14}C ages of marine samples back to 10,000 BC (1993) *Radiocarbon*, 35, pp. 137-189
- Stuiver, M., Reimer, P.J., Extended ^{14}C database and revised CALIB radiocarbon calibration program (1993) *Radiocarbon*, 35, pp. 215-230
- Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., Spurk, M., INCAL98 radiocarbon age calibration, 24,000-0 cal BP (1998) *Radiocarbon*, 40, pp. 1041-1083
- Ta, T.K.O., Nguyen, V.L., Tateishi, M., Kobayashi, I., Saito, Y., Nakamura, T., Sediment facies and late Holocene progradation of the Mekong River delta in Bentre Province, southern Vietnam: An example of evolution from a tide-dominated to a wave-dominated delta (2002) *Sedimentary Geology*, 152, pp. 313-325
- Ta, T.K.O., Nguyen, V.L., Tateishi, M., Kobayashi, I., Tanabe, S., Saito, Y., Late Holocene delta evolution and sediment discharge of the Mekong River, southern Vietnam (2002) *Quaternary Science Reviews*, 21, pp. 1807-1819
- Tanabe, S., Ta, T.K.O., Nguyen, V.L., Tateishi, M., Kobayashi, I., Saito, Y., Delta evolution model inferred from the Mekong delta, southern Vietnam (2003) *SEPM Special Publication* 76, , Sidi, F.H., Nummendal, D., Imbert, P., Darman, H., Posamentier, H.W. (Eds.), *Tropical Deltas of Southeast Asia - Sedimentology, Stratigraphy, and Petroleum Geology*, in press
- Tanabe, S., Saito, Y., Sato, Y., Suzuki, Y., Sinsakul, S., Tiyapairach, S., Chaimanee, N., Stratigraphy and Holocene evolution of the mud-dominated Chao Phraya delta, Thailand (2003) *Quaternary Science Reviews*, 22, pp. 789-907
- Tanabe, S., Hori, K., Saito, Y., Haruyama, S., Doanh, L.Q., Sato, Y., Hiraide, S., Sedimentary facies and radiocarbon dates of the Nam Dinh-1 core from the Song Hong (Red River) delta, Vietnam (2003) *Journal of Asian Earth Sciences*, 21, pp. 503-513
- Tjia, H.D., Sea-level changes in the tectonically stable Malay-Thai Peninsula (1996) *Quaternary International*, 31, pp. 95-101
- Tran, D.T., (1993) *Geological Evolution of the Bach Dang Estuary during the Holocene*, 135p. , Ph.D. Thesis, Hanoi University, Hanoi, unpublished
- Tran, D.T., Holocene stratigraphy and structure of the intertidal flats in Haiphong Coastal Area (1999) *Journal of Sciences of the Earth*, 21, pp. 197-206. , in Vietnamese with English abstract
- Tran, D.T., Dinh, V.H., Coastal development of the modern Red River delta (2000) *Bulletin of the Geological Survey of Japan*, 51, p. 276
- Tran, N., Ngo, Q.T., Development history of deposits in the Quaternary of Vietnam (2000) *The Weathering Crust and Quaternary Sediments in Vietnam*, pp. 177-192. , Nguyen, T.V. (Ed.), Department of Geology and Minerals of Vietnam, Hanoi, in Vietnamese
- Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.F., Louit, T.S., Hardenbol, J., An overview of the fundamentals of sequence stratigraphy and key definitions (1988) *Sea-level Changes: An Integrated Approach*, No. 42, pp. 39-45. , Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.), Society of Economic Paleontologists and Mineralogists, Special Publication
- (1994) *Vietnam Hydrometeorological Atlas*, 68p. , General Department of Land Administration, Hanoi
- Vu, Q.L., Changes of coastal line in the Red river delta during Holocene (2000) *CCOP Technical Publication*, 27, pp. 67-73