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Impact of water and sediment discharges on subaqueous delta evolution in Yangtze Estuary from 1950 to 2010

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Abstract: In order to determine how the subaqueous delta evolution depends on the water and sediment processes in the Yangtze Estuary, the amounts of water and sediment discharged into the estuary were studied. The results show that, during the period from 1950 to 2010, there was no significant change in the annual water discharge, and the multi-annual mean water discharge increased in dry seasons and decreased in flood seasons. However, the annual sediment discharge and the multi-annual mean sediment discharge in flood and dry seasons took on a decreasing trend, and the intra-annual distribution of water and sediment discharges tended to be uniform. The evolution process from deposition to erosion occurred at the −10 m and −20 m isobaths of the subaqueous delta. The enhanced annual water and sediment discharges had a silting-up effect on the delta, and the effect of sediment was greater than that of water. Based on data analysis, empirical curves were built to present the relationships between the water and sediment discharges over a year or in dry and flood seasons and the erosion/deposition rates in typical regions of the subaqueous delta, whose evolution followed the pattern of silting in flood seasons and scouring in dry seasons. Notably, the Three Gorges Dam has changed the distribution processes of water and sediment discharges, and the dam's regulating and reserving functions can benefit the subaqueous delta deposition when the annual water and sediment discharges are not affected.

Key words: *water discharge; sediment discharge; seasonal change; delta; Yangtze Estuary*

1 Introduction

Over the past hundred years, sediment discharge of rivers all over the world has sharply declined because dams or water transfer projects have been implemented along rivers, resulting in erosion of subaqueous deltas, especially deltas in estuary regions (Trenhaile 1997). Changes of sediment discharge not only affect the deposition rate, but also alter the features of silting and scouring (Syvitski et al. 2005). Many submerged deltas have been deposited more slowly or eroded after a decrease of seaward sediment discharge all around the world, such as along the Nile River (Frihy et al. 2003), the Colorado River (Carriquiry et al. 2001), and the

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Yellow River (Xu 2008). During the deltaic evolution, contradictions exist between rivers and oceans, and rivers usually dominate the process (Ren 1989). Chinese scholars (Yang et al. 2003a; Li et al. 2004; Li et al. 2007; Wang et al. 2010; Gao 2010; Yang et al. 2011) have investigated the relationship between the evolution of the Yangtze subaqueous delta and the sediment discharge, and established empirical curves of the relation between the sediment discharge and the evolution of typical regions of subaqueous deltas. However, the relation between delta evolution and seaward water discharge has not been analyzed. The water cycle mechanism in the delta region of the American Colorado River has changed due to the reduction of water discharge, resulting in a different mechanism of deposition in the estuary delta region (Fanos 1995). Meanwhile, the decreased sediment blocked the extension of the Colorado delta. In the Mississippi River Basin, the sediment transport was reduced by 40% from 1963 to 1989 due to the extremely high usage of river water, which was considered the major reason for the deltaic erosion in estuary areas (Qian et al. 1989). Yang et al. (2003b) showed that it was not rigorous in theory to use only water discharge, sediment discharge, or sediment concentration as a single index to determine the critical value of water or sediment discharge for maintaining the balance of deposition and erosion in delta regions.

Generally, when the increase rate of water discharge is higher than that of the sediment discharge, the sediment concentration will decrease. Hence, the variations of basin water and sediment discharges may trigger significant delta changes. In the Yangtze Estuary, flooding plays a riverbed-rebuilding role. When the water discharge is larger than 60 000 m^3/s, the water level in the middle and lower reaches of the Yangtze River is significantly enhanced. Meanwhile, the silting and scouring variations in the river channel are significant. When the flood discharge exceeds 70 000 m^3/s, new river branches and erosion appear frequently (Gong and Yun 2002). Especially in 1954 and 1998, two heavy floods greatly influenced the erosion and deposition of the subaqueous delta in the river mouth. Studies on the evolution of the Yellow River delta revealed that the water and sediment discharges not only drove the delta-rebuilding but also determined the deltaic evolution trend (Xu 2002). Thus, when studying the deltaic evolution, the sediment discharge should not be the only considered factor. Instead, the collective influence of both water and sediment discharges should receive full attention. In recent years, with gradually increasing human activities in the Yangtze River Basin, their effects on water discharge, sediment discharge, and the intra-annual distribution processes of water and sediment discharges have already appeared (Yang et al. 2004; Chen et al. 2005; Dai et al. 2008; Dai et al. 2009; Li et al. 2011), and the water discharge and sediment discharge, as well as their intra-annual distribution processes, have also had a direct effect on the subaqueous delta development. Overall, it is necessary to establish the relationship between the subaqueous delta evolution and the water and sediment discharges in the Yangtze Estuary, and, in particular, to determine how the distributions of water and sediment discharges over different seasons affects the subaqueous delta evolution.