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Coastal processes and sedimentary facies in the Zohreh River Delta (Northern Persian Gulf)

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ABSTRACT

The Zohreh River Delta is one of the largest deltaic plains along the northern coast of the Persian Gulf. This delta is located near an international navigation corridor, which is affected by long-term delta progradation. Therefore, the research objectives of this study were to determine the coastal sedimentary processes of the Zohreh River Delta and to detect the evolutionary trend of the deltaic plain at the northern Persian Gulf. The research method was formulated to achieve objectives herein, including field measurements, numerical modeling, remote sensing and laboratory analyses. The results showed that flash floods and turbidity currents transport sediment to the deltaic area, and tidal currents play an important role in sediment redistribution and in the high diversity of sedimentary facies. Flood plains, tidal flats, crevasse splays, nebka, and sabkha are the most important sedimentary facies in the study area. Gypsum and salt crystal are frequently grown in supratidal and intertidal zones because of a dominantly arid climate. The river and tidal currents are responsible for an annual sediment transport of 321,310 m^3, while the sediment transport by littoral drift is calculated to be 81,000 m^3 annually. MIKE-21 (a coastal modeling software) revealed that 80% of the sediment is transferred into the subtidal zone and the remaining 20% is deposited at the river mouth. Applications of GIS tools showed that the mean annual sedimentation rate at the river mouth and the long-term shoaling rate have been 0.07 m and 2.45 m, respectively. The rate of long-term progradation of the delta implies an increase of sediment supply from the catchment area due to land use changes and river bank erosion. A key part of this research is presenting the implications of the permanent shoaling trend which is prograding toward the international shipping corridor at the north of the Persian Gulf.

1. Introduction

The Persian Gulf is one the most important basins around the world and is well known for its geological, commercial, navigational and geopolitical aspects. The regional importance of the north of the Persian Gulf has been highlighted by several scientists and recent politicians. For instance, Arnold Wilson (1988–1955), who was the colonial administrator of Mesopotamia (Iraq) during and after the First World War, believed that no water channel has been so significant as the Persian Gulf to geologists, archeologists, geographers, merchants, politicians, excursionists, and scholars in the past or even at present. This water channel which separates the Iran Plateau from the Arabian Plate has become an Iranian Identity since at least 2200 years ago (UNGEGN, 2006).

The Zohreh River Delta is adjacent to an international corridor of navigation at the north of the Persian Gulf. The progradation and morphological changes of this delta showed that the migration of this body of land toward the navigation corridor is permanent. The most important gaps in knowledge were the rate of shoaling and land progradation, coastal and deltaic processes that contributed to the evolutionary trend of the Hendijan Delta. Deltas are important coastal sedimentary environments and reflect the general geological setting, climate, river hydrology and hydrodynamic conditions of the surrounding environment. Deltaic landforms, such as paleoshorelines are indicative of paleoclimate, the ancient geography of the deltaic plain, tectonics and eustatic sea level changes. Furthermore, evidence of late-Holocene human activity has been observed on delta plains worldwide (Gharibreza et al., 2008; Leeder, 1999; Pye, 1994; Reading, 1986; Reijers, 2011). Therefore, evolutionary trend of the coastal area of the Persian Gulf since the late-quaternary has been studied by Falcon (1947), Vita-Finzi (1979), Lambeck (1996), Reyss et al. (1998) and Gharibreza et al. (2008). These studies have reconstructed the sedimentary basin during the late Quaternary using the ^{14}C dating method. Previous studies (Falcon, 1947; Vita-Finzi, 1980; Reyss et al., 1998) have highlighted the effects of tectonics along Iran's coast since the Last Glacial Maximum (LGM), the end of which began 18,000 BP. Since then, the coastal processes and the evolution of the deltaic plains, particularly along the northern Persian Gulf, have been controlled by eustatic and tectonic factors. Complementary methods, such as application

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of remote sensing and comprehensive sediment sampling, are the recommended methods for mapping the geomorphic and sedimentary facies of recent coastal environments (Boyd et al., 1992; Dalrymple and Choi, 2007; Dalrymple et al., 1992; Heap et al., 2004; Nichol, 1991). For example, Heap et al. (2004) mapped the sedimentary facies of several wave and tide-dominated estuaries and deltas in Australia by visually inspecting aerial photographs, Landsat TM images and topographic maps. A literature review has revealed that the evolutionary trend of the northern Persian Gulf which has been drawn by Gharibreza et al. (2008) and Heyvaert and Baeteman (2007) needs to be verified and checked by investigating current coastal sedimentary processes. Therefore, a study of sedimentary facies, the hydrology of the Zohreh River and the hydrodynamics of wave-induced and tidal currents were recognized to verify previous studies and reveal contributors in the evolution of the Hendijan Delta. The research hypothesis is that long-term trends of deltaic evolution will be revealed by investigating current coastal processes. Therefore, the study's primary objectives were to determine the sedimentary processes and identify facies present in the Zohreh River Delta. Additionally, this study aimed to determine the relative contributions of various mechanisms contributing to erosion and sedimentation in the study area. Accordingly, the research method was formulated to carry out the comprehensive field observation and to run numerical models (Mike 21) and to use geographic information system (GIS) in order to investigate deltaic processes which are involved in the evolution of the Hendijan Delta.

1.1. Study area

The Zohreh River Delta (Hendijan Delta) is an active, morphodynamic area located in southwestern Iran and the northern Persian Gulf, between 29°59′–30°15′ and 49°25′–49°50′. It is a river-dominated delta that has developed into the Persian Gulf in a southwesterly direction. The river catchment area is 16,033 km^2 and is divided into mountainous (10,789 km^2), lowland (5244 km^2) and coastal areas. The mean and annual discharge values for the Zohreh River are 87 $m^3\,s^{-1}$ and 2729 million cubic meters (MCM), respectively. In addition, the mean annual sediment discharge of the Zohreh River is 8 Mt. The mean annual rainfall and evaporation are 200 mm and 3471 mm, respectively. Gharibreza (2005) reported the hydrodynamic characteristics of the Hendijan Delta. For the purpose of this report, the mean higher high water (MHHW), mean lower high water (MLHW), mean higher low water (MHLW), mean lower low water (MLLW) and mean sea level (MSL) of the Hendijan Delta are 2.7 m, 2.07 m, 1.3 m, 0.73 m and 1.67 m, respectively.

1.1.1. Geological setting

The Zohreh River Delta is part of the Khuzestan Plain, which has developed at the southwest of the Zagros structural zone. Lower- to upper-Miocene strata are well exposed at the Rag Sefid anticline to the northeast of the delta. The Miocene stratigraphy includes the Ghachsaran (Early Miocene), Mishan (Middle Miocene), Aghajary (Late Miocene), and Bakhtiary (Plio-Pleistocene) Formations. Overall, the slope gradient of the southern flank of the anticline is 8° to the southwest. The Quaternary sequence includes 39 m of undifferentiated fine-grained sediments and shell debris (Fig. 1). This sequence was obtained from an exploration well (Hendijan No. 6) drilled by Iran's oil company in the center of the Zohreh River Delta. According to the glacial-hydro-eustatic model described by Lambeck (1996), the sea level was 2 to 3 m higher than its present level at 6000 BP and began to decline at 4000 BP. Therefore, the upper Quaternary sedimentary sequence of the Hendijan Delta may be composed of the following elements: (1) basal deposits composed of deltaic sediments that were deposited during the Last Glacial Maximum (18,000 BP) when the Euphrates River discharged directly into the middle of the Persian Gulf; (2) marine deposits that were deposited on the deltaic deposits since 6000 BP; (3) the accumulation of detritus and fluvial deposits on marine sediments since 4000 BP; or (4) upper Holocene and recent deltaic deposits that were deposited since 2500 BP.

2. Materials and methods

The research method is one of the key parts of this study in which geological setting, paleoshorelines, sedimentary facies, wave-induced, river and tidal currents, wave regime, shoreline changes, erosion and the sedimentation situation of a delta were studied by using field measurements, laboratory analysis, numerical modeling and the geographic information system. This method was formulated in order to achieve the objectives of the research. The authors believe that the present research method is a suitable guideline in order to investigate the evolution of the deltaic processes around the world because the evolutionary trend of a delta would be comprehensively revealed.

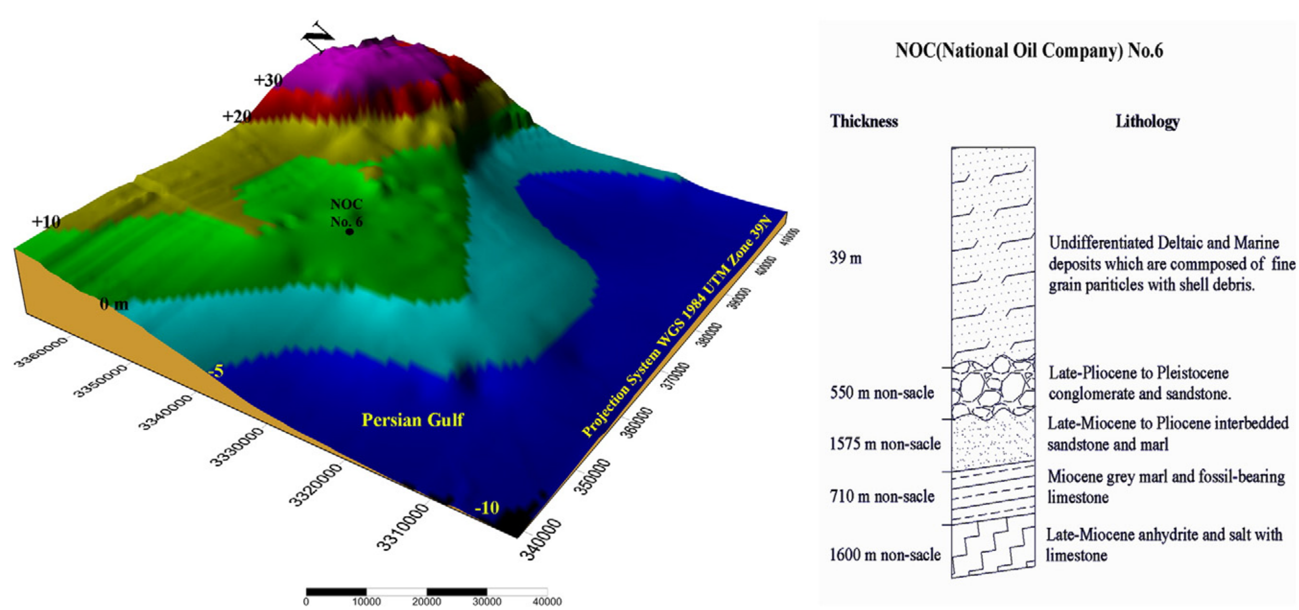

Fig. 1. Morphology and sedimentary sequences at the Zohreh River Delta.