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Geomorphology of the Kerinitis River fan-delta (North Peloponnese, Greece)

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Introduction

Deltas and fan-deltas are important geomorphic and sedimentary environments, acting as major sinks for fluvial sediments in the coastal zone, as important ecological systems, and as foci for urban and agricultural development. River deltas are relatively complex systems and subject to a range of fluvial, climatic, tectonic and sea-level controls (Coleman and Wright, 1975). The size and shape of a delta is controlled by the balance between watershed processes that supply sediment and coastal-marine processes (mainly wave activity, long-shore currents and tides) which redistribute that sediment. The size, geometry, and location of the receiving basin also play an important role in the evolution of fan-delta (Coleman and Wright, 1975).

The present study aims at a better understanding of the prevailing processes which contributed to the recent geomorphic evolution of the Kerinitis River fan-delta, located in the North Peloponnese (Central Greece), during the Late Holocene through geomorphological mapping and fieldwork. One of the objectives of this study was to assess mean shoreline change rates along the apron of the fan-delta using remote sensing data and GIS techniques.

Study Area

The fan-delta of the Kerinitis River is located along the southern coast of the western Gulf of Corinth and has been prograding in deep waters since the deceleration of sea-level rise during the upper Holocene like all the fan-deltas of the broader area of the northern Peloponnese. It has an area of 6.16 km^2 and the mean slope of its plain is 0.03.

The Kerinitis River drains an area of 80.84 km^2. The drainage basin is relatively elongated along a S.SW-N.NE trending axis and reaches an elevation of 1760 m in its southeastern end. Lithologically, the basin consists of 53.23 % limestones, 9.25 % cherts, 7.13 % flysch and 30.39 % Plio-Pleistocene deposits (mainly conglomerates and marls). Hence a significant area of the catchment is occupied by easily erodible geological formations. The general climatic conditions of the study area are typical of the temperate Mediterranean. The mean annual precipitation ranges from 800 mm near the coastline to more than 1200 mm in the southernmost highlands.

The receiving basin (Gulf of Corinth or the Corinth Rift) is one of the most active neotectonic features of the Eastern Mediterranean. It is a "back arc" elongated graben, formed by normal faulting associated with an approximately N-S crustal extension (Armijo *et al.*, 1996). The fan delta lies on the hanging wall of the Eliki fault, which is the most prominent fault appearing to control the westernmost sector of the Gulf (Koukouvelas *et al.*, 2001). The Gulf of Corinth can be characterized as a microtidal environment with an average mean tidal range of 0.15 m. Wave climate is primarily wind driven with offshore mean significant wave heights average heights < 0.3 m according to the output of the wave model (POSEIDON program).

Methodology

In order to determine the dominant processes responsible for the evolution and configuration of the fan-delta, detailed geomorphological mapping was carried out, which includes the identification and depiction of the dominant landforms of both the fan-delta plain (such as modern distributary channels, natural levees, abandoned channels, etc.) and the fan-delta coastal front (sandy and pebbly beaches, low cliffs, etc.). Mapping has been performed using a 5X5 resolution DEM obtained from the Hellenic Cadastre. The initial identification of the landforms is mainly based on the analysis of the DEM utilizing Esri ArcGIS 10. Additionally, study of old maps and interpretation of a series of geo-referenced aerial photos (taken in 1996) as well as Google Earth images were an invaluable source of information for the recognition of the fan-delta features. Data were organized into a Geographic Information System (GIS) spatial geodatabase using Esri ArcGIS 10. Field control was necessary to avoid mistakes made from the analysis of the DEM as well as from the interpretation of both aerial photos and Google Earth images. During the extensive field survey the entire deltaic area was examined following the traditional protocol of geomorphological mapping, verifying all the features and landforms identified during the initial phase of the research.

For the study of the recent changes of the fan-deltas shoreline, comparative observations of the coastlines of 1945, 1969, 1996, 2009 and 2017 have been made. The coastlines of 1945 and 1996 have been digitized from georeferenced aerial photo-mosaic obtained from the Hellenic Millitary Geographical Service (HMGS) and the Greek Ministry of Agriculture respectively. The coastlines of 1969 and 2009 have been derived from the topographic diagrams of the HMGS and the detailed DEM of the Hellenic Cadastre while the most recent coastline of 2017 has been obtained from digitization in Google Earth. This comparison allowed us to identify areas of progradation and parts of the fan-delta plain that are being eroded as well as to estimate mean annual progradation and erosion rates for the last 72 years. Using the 1945 digitized shoreline, 322 measurement sites were created every 10 m using an automated procedure. Coastal retreat or progradation was calculated for the intervals between the dates of the imagery by measuring the distance separating the two shorelines (in vector format) perpendicular to the older shoreline. These distances were then divided by the number of years to provide average annual coastal retreat or accretion rates.

Results and Conclusions

The active distributary of Kerinitis River has a braided pattern. It crosses the western part of the deltaic plain flowing parallel with the east Eliki fault segment for about 1.15 km and then turns to the east following a S.SW-N.NE flow direction for 1.2 km and flows into the Gulf of Corinth (Figure 1). Numerous presently inactive abandoned linear distributaries were recognized across the fan-delta plain. Old maps of the area along with aerial photographs of 1996 as well as the detailed DEM of the area have been particularly useful in identifying and mapping these traces of the abandoned river courses. A palaeochannel has been identified flowing along the east Eliki fault segment leading to the eastern border of the fan-delta. According to Pavlides et al. (2004) it corresponds to the main channel of the river before 1500 AD. A 1700 AD Venetian map of the area (Dokos and Panagopoulos, 1993) indicates that the course of the main channel during that period was similar to the recent one while a topographic map of Schmidt's (1879) (after a major 1861 earthquake during which the east Eliki fault segment was broadly ruptured for about a distance of 13 km and a vertical displacement up to 1 m occurred) shows the main channel flowing east of its present course (Pavlides *et al.*, 2004). These observations show a migration of the river after the 1861 event towards the central portion of the east Eliki fault segment but then the main channel changed its course flowing along its present position, which is similar with its 1700 AD path (Figure 1). The above mentioned changes of the main channel indicate that Kerinitis River appears to have been strongly affected by tectonic movements related to the westward propagation of the east Eliki fault segment.

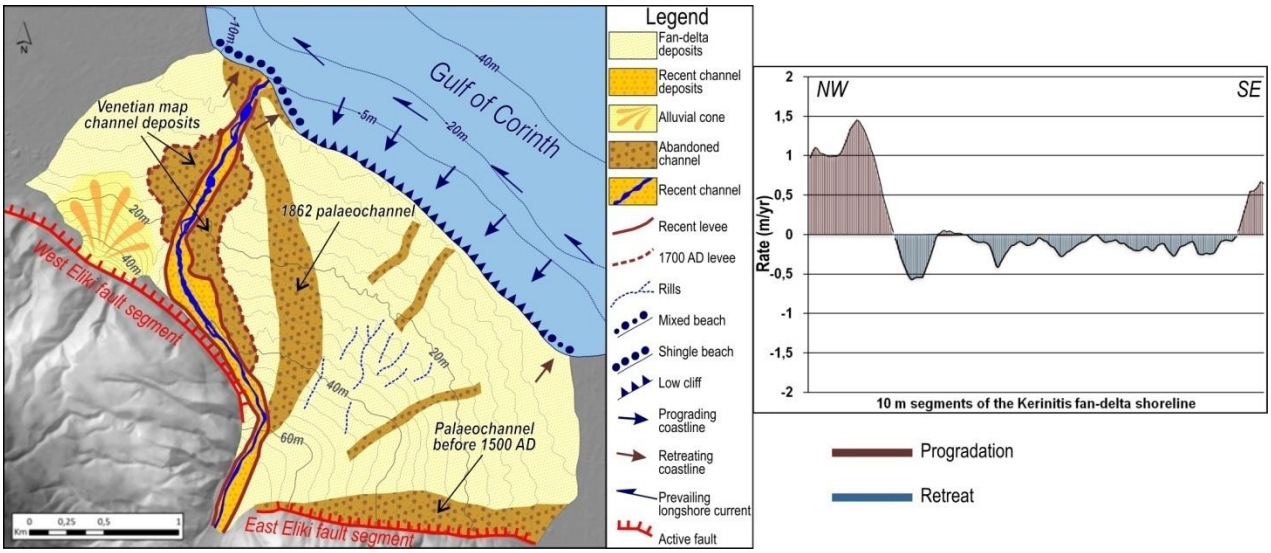

Figure 1. Geomorphological map of the Kerinitis River fan-delta and diagram showing progradation and retreat rates (in m/yr) estimated along the fan-delta shoreline for the time period between 1945 and 2017.

The comparable analysis of the 1945 and 2017 fan-delta shorelines shows that the main process along a significant part of the fan-delta front is intense and rapid erosion. Progradation (with a maximum mean rate of +1.46 m/yr) is observed only at the area around the presently active mouth of the river and at the easternmost edge of the fan-delta (Figure 1). A significant segment of the fan-delta shoreline is currently undergoing erosion with a maximum mean rate of -0.57 m/yr for the time period between 1945 and 2017. Evidence of coastal retreat is the appearance of a low cliff along the coastline due to the erosion of the top soil surface layer of the fan. Additionally, the presence of destroyed structures (designed to protect the coastline), along the central fan-delta apron indicates intense erosion.

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