Quaternary International xxx (2015) 1–15

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Differential impact of long-shore currents on coastal geomorphology development in the context of rapid sea level changes: The case of the Old Sefidrud (Caspian Sea)

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ARTICLE INFO

Article history:
Available online xxx

Keywords:
Coastal lagoons
Caspian Sea
Rapid sea level rise
Geomorphological changes
Little Ice Age

ABSTRACT

In the face of global rise in sea level, understanding the response of the shoreline to sea level rise is an important key for coastal management. The rapid sea level fluctuations taking place in the Caspian Sea provide a live model for studying shoreline response to sea level rise. Coastal lagoon deposits provide an ideal archive to study sea level fluctuation. In this study, two lagoons on both sides of the Old Sefidrud River (south coast of the Caspian Sea) have been subjected to study using sedimentology, palynology and macro-remains analyses: the Amirkola and the Klaus Lagoons. The results demonstrate how these coastal lagoons, related to one single river within the same delta, during the last decades respond differently to sea level fluctuations and show the crucial role played by long-shore current.

1. Introduction

The Caspian Sea (CS) is the largest lake in the world (surface area of 371,000 km^2). It is well known for its large fluctuation of the water levels: during the 20th century it has experienced a ~3 m fall and rise (Fig. 1A), while the global sea level has fluctuated approximately 2 mm/y in the same period (Kroonenberg et al., 2007). Coastal geomorphology has undergone rapid and varied changes in response to water level changes including passive inundation, beach–ridge formation, barrier–lagoon development and common coastal erosion (Kaplin and Selivanov, 1995; Naderi Beni et al., 2013a). On the southwestern CS coast of Iran, major geomorphological changes occurred in the east of the Sefidrud Delta where the Old Sefidrud delta is located (Fig. 1B). The Sefidrud avulsed several times during the Holocene, and the last major avulsion occurred when the river diverted its course from the Amirkola Lagoon area in the east to the Kiashahr Lagoon area in the west some 400 years ago (Kousari, 1986; Krasnozhon et al., 1999; Lahijani et al., 2009; Leroy et al., 2011; Kazancı and Gulbabazadeh, 2013; Naderi Beni et al., 2013b). The pre-avulsion river is known as Old Sefidrud. Holocene lagoonal deposits around the old-Sefidrud delta comprise of coastal geomorphological response to sea level change and delta-avulsion. This paper discusses sea level change for the Caspian Sea, although the CS is strictly a lake. This multidisciplinary study focuses especially on the Amirkola Lagoon (located east of the Old Sefidrud) and a newly discovered lagoon, i.e. Klaus Lagoon (west of the Old Sefidrud) (Fig. 1B). We aim to investigate the impact of rapid CS level fluctuations on coastal geomorphology and vegetation.

2. Study area

2.1. Caspian Sea

During the last millennium, CS level experienced two significant changes: a poorly identified drop in the early medieval period and a slightly better known rise at the end of the Medieval Climatic Anomaly (MCA, AD 950–1250) and a clear highstand in the Little Ice Age (LIA, AD 1350–1850) (dates defining these periods from Kroonenberg et al., 2007; Ruddiman, 2008; Mann et al., 2009: Leroy et al., 2011; Naderi Beni et al., 2013a; Haghani et al., 2015). During the 20th century, the CS has experienced a ~3 m fall and rise. After the water levels peaked in 1995, at −26.24 m bsl, levels have been dropping slightly (at −27.41 m bsl, in 2014).

Inundation, erosion and sand barrier and back-barrier lagoon formation are the main responses of the coastal area to rapid water level rise (Kaplin and Selivanov, 1995; Kroonenberg et al., 2000;

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http://dx.doi.org/10.1016/j.quaint.2015.11.127

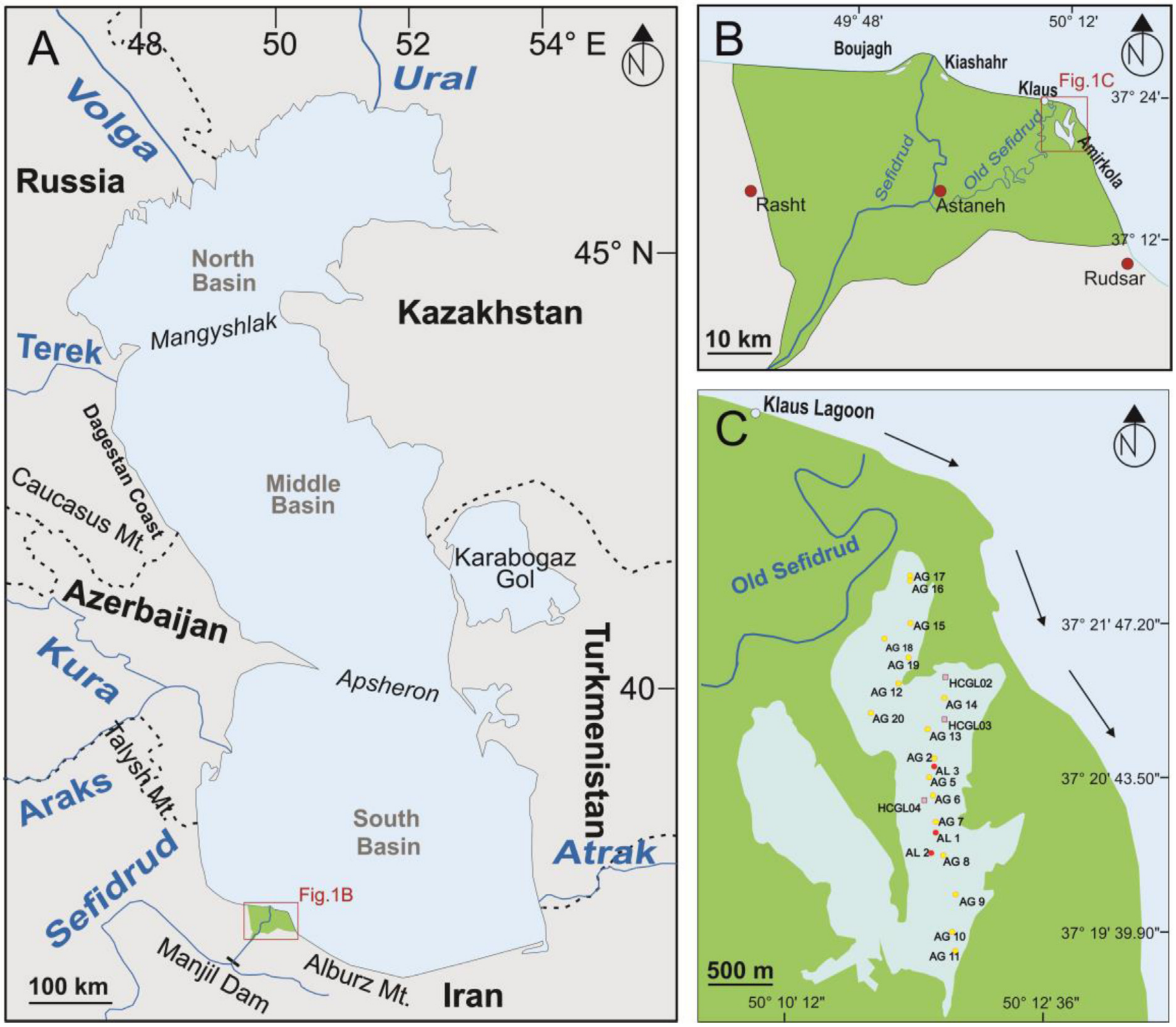

Fig. 1. A: Location map of the Caspian and major rivers flowing to the Caspian Sea. Black dashed lines: international boundaries, Mt.: Mountains, B: Location of Amirkola and Klaus Lagoons within the Sefidrud Delta. Red dots: location of important towns, C: Location of the cores taken from Amirkola Lagoon. Core identification has been simplified in this map, i.e.: AG17 full identification is AL11G17. Red dots represent the location of core taken by Livingstone corer and yellow dots the location of cores taken by gravity corer. Pink squares show location of cores in Leroy et al. (2011). Black arrows show the direction of longshore currents.

Naderi Beni et al., 2013b). The CS level rise between 1979 and 1995 affected deltas by inundation and erosion. Kroonenberg et al. (2000) showed that this period was characterised by erosion and development of sand barrier and lagoons behind them in Dagestan Coast (western coast of the middle CS). Sand barriers can also be formed during water level fall as small bars without lagoon development (Kroonenberg et al., 2000). During such a period of fall, existing lagoons also became shallower and narrower (Kroonenberg et al., 2000) and some changed to marshland (Kaplin et al., 2010). Human activities such as reduction of sediments by dam construction may cause intensive erosion of coasts and deltas (Ignatov et al., 1993; Lahijani et al., 2008) by sediment starvation.

2.2. Lagoon setting

The Sefidrud has repeatedly changed its course through the area between the Anzali and Amirkola lagoons (Kousari, 1986). The last major avulsion occurred some 400 years ago when the river diverted its course from the east, near Amirkola Lagoon, towards the west near Kiashahr Lagoon, shifting its outlet ~23 km westwards (Krasnozhon et al., 1999; Lahijani et al., 2009; Leroy et al., 2011; Kazancı and Gulbabazadeh, 2013; Naderi Beni et al., 2013b).

The Amirkola Lagoon is associated with the Old Sefidrud and has a maximum water depth of 2 m (Naderi Beni et al., 2013b). The lagoon has no river inflow and receives freshwater by precipitation and surface water passing through rice fields that surround the lagoon. Lahijani et al. (2009) studied the coastal evolution of the Sefidrud Delta including lagoon development in the area. The authors suggested that the Amirkola Lagoon was formed by littoral drift of sediments supplied by the Old Sefidrud, during the Little Ice Age (LIA: around 1600 AD), as a result of CS level rise. Naderi Beni et al. (2013b) studied the area around the Amirkola Lagoon using Ground Penetrating Radar (GPR) profiles and concluded that the development of this lagoon was a response to rapid CS level rise during the LIA, but age confirmation was lacking. Leroy et al. (2011) conducted a palynological study on Amirkola Lagoon cores. Their investigation shows that Amirkola Lagoon was under CS level influence during the Late LIA and became isolated from the CS after the high stand. A radiocarbon dating provided in their study shows

Please cite this article in press as: Haghani, S., Leroy, S.A.G., Differential impact of long-shore currents on coastal geomorphology development in the context of rapid sea level changes: The case of the Old Sefidrud (Caspian Sea), Quaternary International (2015), http://dx.doi.org/10.1016/j.quaint.2015.11.127