Marine Geology 351 (2014) 58–75

Contents lists available at ScienceDirect

Marine Geology

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

The tectono-sedimentary evolution of the Lechaion Gulf, the south eastern branch of the Corinth graben, Greece

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ARTICLE INFO

Article history:
Received 19 April 2013
Received in revised form 31 January 2014
Accepted 17 March 2014
Available online 24 March 2014

Communicated by G.J. de Lange

Keywords:
Corinth rift
assymetric graben
Lechaion Gulf
tectono-sedimentary evolution

ABSTRACT

The Gulf of Corinth is the second most active continental rift in the world and thus a much-studied natural laboratory for analyzing details of rift history. A new detailed offshore seismic survey combined with previously acquired data in its least studied part, the Lechaion Gulf, shed light on the tectono-sedimentary evolution of the eastern end of the Corinth rift. This study shows that: (i) the Lechaion Gulf is the submerged northern part of the onshore Corinth–Nemea basin, (ii) they are both bounded to the south by the north dipping Klenia and Kenchreai faults, which are considered at present inactive, (iii) both the Corinth–Nemea basin and the Lechaion Gulf were formed at around between 3.6 and 4 Ma BP (middle to late Pliocene), at the same time with the Megara basin, and (iv) the Lechaion Gulf was submerged and took its present shape at around between 0.7 and 1.7 Ma BP, at the same time with the Gulf of Corinth and the Alkyonides Gulf. Furthermore, sequence stratigraphy interpretation of seismic profiles from the Lechaion Gulf revealed: (i) a total post-alpine sediment thickness of almost 3 km below the Lechaion Gulf, (ii) at least 400 m of sediments accumulated during the last 245 ka, corresponding to a mean sedimentation rate of 1 m/ka for the last 245 ka and 2.3 m/ka for the Holocene, and (iii) differential vertical movement, in the order of 4.5 km, between the bedrock under the Lechaion Gulf and the adjacent mountains yields an accumulative average slip rate of 0.9 m/ka or less, over the last 4 Ma. Therefore, for estimating more accurately the slip rates, the uplift rates, the extensional rates and the earthquake recurrence interval over the eastern end of the Corinth rift, the presently mentioned tectono-sedimentary evolution of the Lechaion Gulf must be taken into consideration.

1. Introduction

The Gulf of Corinth is a graben structure that occupies the northern part of the Corinth rift, representing its present day active component (Fig. 1). It is the second fastest graben in the world, after the Woodlark basin in the Pacific Ocean (Taylor et al., 2009), while its aerial extent (~120 km long × 40 km wide) characterizes it as the smallest, far behind the 800 km wide and more diffused Basin and Range province (Thatcher et al., 1999). In comparison with other regions that undergo continental extension, it is significantly younger, with age almost ten times smaller than other rifts, such as the East African rift (Hayward and Ebinger, 1996) or the Baikal rift (Mats, 1993) (Table 1). Holocene extension rates derived from GPS studies vary from 15 ± 2 m/ka to 10 ± 4 m/ka for the western and eastern parts, respectively (Clarke et al., 1997, 1998; Briole et al., 2000; McCluskey et al., 2000; Avallone et al., 2004). A high uplift rate of 2.0 m/ka has been measured for the south rift margin in the center, which decreases to 0.8 m/ka to the west and 0.3 m/ka to the east (Turner et al., 2010).

Rift flank uplift is characterized mostly by vertical tectonic movements along numerous faults (Stefatos et al., 2002; Moretti et al., 2003; McNeill et al., 2005; Lykousis et al., 2007; Bell et al., 2008) and is the most seismically active zone in Europe (Papazachos and Papazachou, 1997; Papadopoulos, 2000). For this reason, great emphasis has been given to the study of slip rates, total displacement and recurrence intervals of paleo-earthquakes on the active faults around the Gulf of Corinth, in relation to the past and present day extension rates and the strain taken by the active faults.

These studies were based mainly on onshore data (e.g. Collier, 1990; Armijo et al., 1996; Goldsworthy and Jackson, 2001; Morewood and Roberts, 2001; Westaway, 2002; Leeder et al., 2003; McNeill and Collier, 2004; Roberts et al., 2009; Turner et al., 2010). The 1995 Aigion earthquake increased the interest in the study of the tectono-sedimentary structure in the marine part of the Gulf, which had already

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http://dx.doi.org/10.1016/j.margeo.2014.03.014
0025-3227/

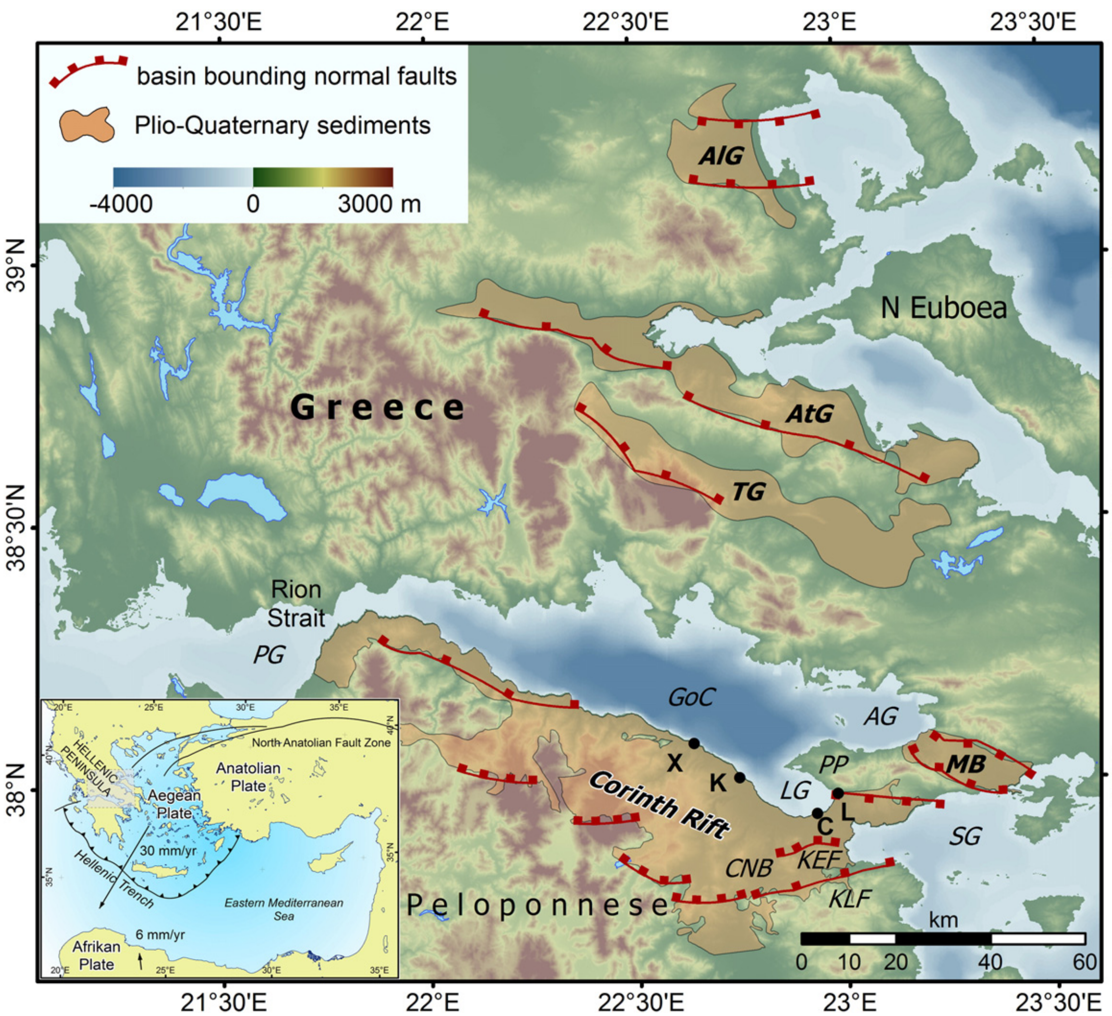

Fig. 1. Simplified map of tectonic grabens on the eastern Hellenic Peninsula (faults and grabens after Doutsos and Kokkalas, 2001). Abbreviations: AG — Alkyonides Gulf, AlG — Almyros graben, AtG — Atalanti graben, GoC — Gulf of Corinth, CNB — Corinth Nemea Basin, KEF — Kenchreai Fault, KLF — Klenia Fault, LG — Lechaion Gulf, MB — Megara Basin, PG — Patras Gulf, PP — Perachora Peninsula, SG — Saronic Gulf, TG — Tithorea Graben. Inset: Summary map of the Aegean–Mediterranean domain. (Modified after McClusky et al. (2000)).

been the subject of earlier studies (Heezen et al., 1966; Brooks and Ferentinos, 1984; Papatheodorou and Ferentinos, 1993). Systematic mapping and numerous marine geophysical surveys have been conducted since 1995 and shed light on the structure of the rift below the seafloor (Lykousis et al., 1998, 2007; Sakellariou et al., 1998, 2001, 2007; Leeder et al., 2002; Stefatos et al., 2002; Moretti et al., 2003; McNeill and Collier, 2005; Bell et al., 2009; Taylor et al., 2011) and have shown the importance of offshore faulting in the understanding of long-term and Holocene vertical movements in the area and their role in the evolution of the rift.

Table 1
Comparison between active continental rift zones.

Rift	Length (km)	Width (km)	Opening rate (m/ka)	Age (Ma)	Publications
Corinth	120	40	10–15	3.6	Avallone et al. (2004)
Rhine	350	50	0.5–1	33	Dezes et al. (2004)
Woodlark	600	100	56–72	6	Taylor et al. (2009)
Rio Grande	700	200	<5	21	Berglund et al. (2012)
Basin and Range Province	800	200	3	18	Thacher et al. (1999)
Baikal	1500	100	3.5	30	Petit and Deverchere (2006)
East African	3000	100	<3	32	Karp et al. (2012)

The purpose of this paper is to study the southeastern branch of the Gulf of Corinth, known as the Lechaion Gulf (Fig. 1), which is the least studied part of the Corinth rift. Furthermore, this study aims to compare the tectono-sedimentary evolution of the Lechaion Gulf to the evolution of: (i) the Gulf of Corinth and the Alkyonides Gulf and (ii) the Corinth rift and the Megara basin (Fig. 1).

2. Geological setting

The central Hellenic Peninsula represents the classic "basin and range" type extensional area in Greece (Doutsos and Kokkalas, 2001). According to Doutsos and Kokkalas (2001) a series of WNW-trending asymmetric grabens takes up most of the extension in the area (Fig. 1). These are, from north to south, the Almyros, Atalanti, Tithorea, Megara graben and the Corinth rift with the presently active Corinth graben. Roberts and Jackson (1991) suggested that the 150 km wide area between the N Peloponnese and N Euboea has undergone an overall NNE–SSW extension of at least 20–30 km during the last 5 Ma, with present day motion of 10–20 mm/a.

Extensional stresses have been attributed to the following geological processes, such as the back-arc extension due to the roll back of the African plate as it subducts beneath the Aegean plate along the Hellenic Arc (McKenzie, 1972, 1978; Doutsos et al., 1988; Vita-Finzi, 1993), the westward propagation of the North Anatolian fault and the consequent