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Active faulting at the western tip of the Gulf of Corinth, Greece, from high-resolution seismic data

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ABSTRACT

The Gulf of Corinth is one of the fastest-spreading intra-continental rifts on Earth. GPS data indicate that the rift is currently opening in a NNE-SSW direction, with a rate of extension reaching up to 16 mm yr^{-1} in its westernmost part. Although the rest of the offshore rift has been well studied, the western tip of the rift is still poorly explored. We present an accurate map of submarine faults in this area based on two high-resolution seismic reflection surveys (single-channel sparker). In the eastern part of the studied area, the sedimentary infill is affected by the known North Eratini, South Eratini, and West Channel faults. Further to the west, the seafloor is mostly flat and is bounded to the north by the normal, south-dipping, Trizonia fault. To the north, the shallower part of the Gulf shows to the east a diffuse pattern of normal and strike-slip deformation, which is replaced to the west by a 7.5 km long SE striking strike-slip fault zone, called the Managouli fault zone. To the westernmost tip of the Gulf, in the Nafpaktos Basin, two fault sets with different strikes are encountered; the one with a NE-SW strike exhibits a clear strike-slip component. The western tip of the Gulf of Corinth is the only part of the Corinth Rift where convincing evidence for strike-slip movement has been found. This fault pattern is likely related to the complex deformation occurring at the diffuse junction at the western tip of the Rift between three crustal blocks: Continental Greece, Peloponnese, and the Ionian Island-Akarnania block.

1. Introduction

The Gulf of Corinth is one of the most active intra-continental rifts on earth. This 120 km long, N120°E-trending structure separates the continental Greece to the north from the Peloponnese to the south (Fig. 1). Dating from uplifted syn-rift sediments covering the northern Peloponnese suggests that the rifting initiated around 5 Ma ago (Kontopoulos and Doutsos, 1985; Collier and Dart, 1991). Since 1.8–1.5 Ma, the deformation migrated northward, in parallel with an increase of the extension rate (Ori, 1989; Sorel, 2000; Rohais et al., 2007; Ford et al., 2013). Concerning the tectonic controls on the rifting, it might result from the extension in the back-arc region of the Aegean subduction zone, enhanced by the interaction with the western tip of the North Anatolian Fault (Armijo et al., 1996, 2004; Jolivet, 2001; Hubert-Ferrari et al., 2003; Kokkalas et al., 2006; Reilinger et al., 2010; Pérouse et al., 2012). Except for its Western tip, i.e., west of the town of Aigion, the structure and evolution of the offshore rifting has been reconstructed based on seismic reflection data (Stefatos et al., 2002; Leeder et al., 2002; Moretti et al., 2003; McNeill et al., 2005a; Lykousis et al., 2007a; Sakellariou et al., 2007a, 2007b; Bell et al., 2008, 2009; Taylor et al., 2011; Charalampakis et al., 2014). These studies have highlighted a complex basin structure (Bell et al., 2009) characterized by significant along strike variations associated to changes in the inherited basement fabric (Taylor et al., 2011). The deformation is currently localized on *en-echelon* north-dipping normal faults delimiting the southern coastline, as well as on N- and S-dipping offshore faults (Fig. 1) (Avallone et al., 2004).

The western tip of the Corinth Rift is characterized by the highest extensional rate (up to 16 mm yr^{-1}), and the geodetic measurements show that most of present-day deformation is concentrated offshore in a narrow band (Briole et al., 2000; Avallone et al., 2004). In this area, the southern coast is bounded by the *en-echelon* Eliki–Aigion–Kamarai–Psathopyrgos fault system (Fig. 1). Late Quaternary slip rates of these faults have been estimated at about 1.9–2.7 mm yr^{-1} (Kamari fault system), 0.3–2.0 to 7–11 mm yr^{-1} (Eliki faults), and 1.6–6.3 to 9–11 mm yr^{-1} (Aigion fault) based on the analysis of trenches (Koukouvelas et al., 2001, 2005, 2008; Pantosti et al., 2004; Palyvos et al., 2005) and uplifted shorelines combined with dislocation modeling

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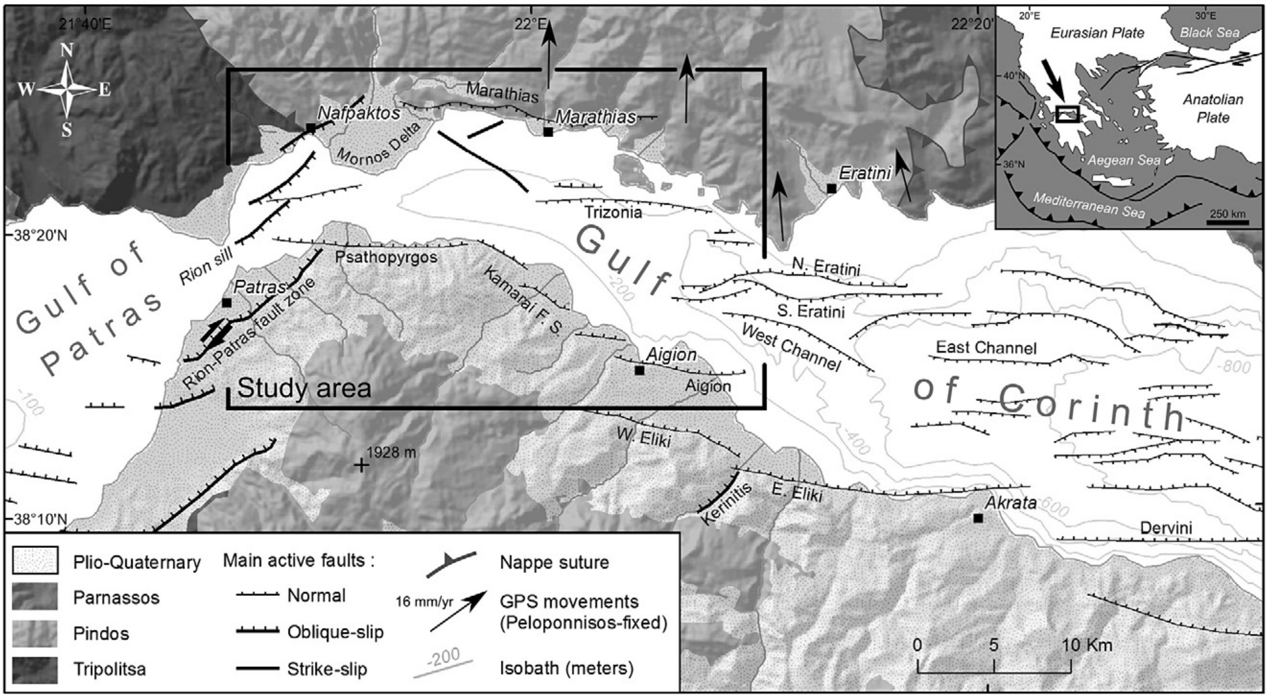

Fig. 1. Tectonic map of the Western and Central Gulf of Corinth. Onshore active faults from Ford et al. (2009, 2013), Palyvos et al. (2005, 2008), Flotté et al. (2005), and references therein. Main offshore faults from Flotté et al. (2005) for the Gulf of Patras, this study, McNeill et al. (2005a), Bell et al. (2008, 2009), and Taylor et al. (2011) for the Western and Central Gulf of Corinth. Isobaths from Bell (2008). GPS displacement vectors from Avallone et al. (2004). Elevation: NASA SRTM DEM (http://srtm.csi.cgiar.org/).

(De Martini et al., 2004) or combined with seismic data (McNeill and Collier, 2004; McNeill et al., 2005b, 2007), and drilling (Cornet et al., 2004; Lemeille et al., 2004). On the northern coastline, the 14 km long Marathias fault has been mapped, but its activity has not been proven (Gallousi and Koukouvelas, 2007). Offshore, only sparse seismic data exist (Sakellariou et al., 2001, 2007b; Moretti et al., 2003; Bell et al., 2008). They allowed mapping four major faults: the West Channel, the South and North Eratini, and the Trizonia faults (Fig. 1). Bell et al. (2008, 2009) studied in detail the first three faults and estimated Late Quaternary slip rates of ~0.5, 1.0–1.9, and > 1.4 mm yr^{-1}, respectively. The activity of the Trizonia fault is unknown, and its footwall is now subsiding at a rate of 5 ± 2 mm yr^{-1} according to GPS measurements (Moretti et al., 2003; Bernard et al., 2006). At depths greater than 5 km, seismological studies have evidenced a fully asymmetrical extensional system, where deformation occurs on a horizontal or low-dipping zone of microseismicity linked to the north-dipping coastal fault system (Rigo et al., 1996; Lyon-Caen et al., 2004). This zone has been interpreted as the brittle-ductile transition (Hatzfeld et al., 2000), or as a crustal-scale detachment (Jolivet et al., 2010), or as a newly formed blind detachment (Lambotte et al., 2014).

The present study aims to complete the fault map of the Corinth Rift at its Western tip, west of Aigion (Fig. 1), using a dense grid of high-resolution seismic reflection data. These additional data are then used to investigate how this tectonic regime is accommodated in relationship with the Corinth Rift system toward the east, and the strike-slip faults highlighted around the Gulf of Patras toward the west. This is achieved by the development of (i) a seismo-chronostratigraphic model for the sedimentary infill, (ii) the analysis of the seafloor morphology, (iii) the production of a new map of active faults in the westernmost Gulf of Corinth and (iv) the assessment of their geodynamic implication at a regional scale.

2. Previous chronostratigraphic model for the Gulf of Corinth

Seismic profiles across the Gulf of Corinth show that the shallow sedimentary infill consists of a distinct alternation between seismic-stratigraphic units with parallel, continuous high-amplitude reflections and units with parallel, continuous low-amplitude reflections to acoustically transparent seismic facies (Bell et al., 2008, 2009; Taylor et al., 2011). Generally, the semi-transparent units are thicker than the highly reflective units (Taylor et al., 2011). These alternating seismic-stratigraphic units have been observed throughout the Gulf of Corinth and have been interpreted as depositional sequences linked to glacio-eustatic cycles (Bell et al., 2008, 2009; Taylor et al., 2011; Li et al., 2014). Because of the presence of the 62 m deep Rion Sill, the Gulf was disconnected from the World Ocean during Quaternary lowstands and was thus a non-marine sedimentary environment. The marine and non-marine environments are associated with different climatic regimes (Leeder et al., 1998, 2005; Collier et al., 2000). During glacial stages, the sparse vegetation cover was more favorable to erosion than during interglacials, so high quantities of sediments were routed towards the Gulf. These lowstand deposits appear as thick, low-reflective units. The thin, high-reflective units are interpreted to represent the marine highstand deposits. The change in reflectivity between seismic units could be due to variations in sediment density and velocity, but the sedimentological origin for this change is still unclear (Li et al., 2014). The last lacustrine-marine transition has been sampled in different sedimentary cores (Collier et al., 2000; Moretti et al., 2004; Lykousis et al., 2007a; Van Welden, 2007; Campos et al., 2013). This geomorphological setting and the consequences on the seismic stratigraphy are similar to the Gulf of Cariaco, NE Venezuela (Van Daele et al., 2011).

3. Data acquisition and fault mapping

Two high-resolution reflection-seismic surveys (sparker and single-channel streamer) were performed aboard HCMR's R/V ALKYON in 2011 and 2012, within the framework of the SISCOR ANR Project (Fig. 2). The area covered lies between the Rion Sill to the west and the eastern extremity of the Aigion fault, to the east (Fig. 2). Our seismic lines tie with Bell et al.'s (2009) data set, therefore a direct correlation with our data set is possible and allows to estimate the age of our