Tectonophysics 592 (2013) 150–158

Contents lists available at SciVerse ScienceDirect

Tectonophysics

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

Long-term versus short-term deformation of the meizoseismal area of the 2008 Achaia–Elia (M_W 6.4) earthquake in NW Peloponnese, Greece: Evidence from historical triangulation and morphotectonic data

Stathis Stiros [a,*], Fanis Moschas [a], Lujia Feng [b], Andrew Newman [c]

[a] Department of Civil Engineering, University of Patras, Patras 26500, Greece
[b] Earth Observatory of Singapore, Nanyang Technological University, 50 Nanyang Avenue, Block N2-01a-15, 639798, Singapore
[c] School of Earth and Atmospheric Sciences, Georgia Institute of Technology, 311 Ferst Drive, Atlanta, GA 30332, USA

ARTICLE INFO

Article history:
Received 4 May 2011
Received in revised form 20 January 2013
Accepted 7 February 2013
Available online 20 February 2013

Keywords:
Ionian Sea
Aegean Arc
Patras
Seismic risk
Detachment-thin-skin tectonics
Accuracy-precision

ABSTRACT

The deformation of the meizoseismal area of the 2008 Achaia–Elia (M_W 6.4) earthquake in NW Peloponnese, of the first significant strike slip earthquake in continental Greece, was examined in two time scales; of 10^2 years, based on the analysis of high-accuracy historical triangulation data describing shear, and of 10^5–10^6 years, based on the analysis of the hydrographic network of the area for signs of streams offset by faulting. Our study revealed pre-seismic accumulation of shear strain of the order of 0.2 μrad/year in the study area, consistent with recent GPS evidence, but no signs of significant strike slip-induced offsets in the hydrographic network. These results confirm the hypothesis that the 2008 fault, which did not reached the surface and was not associated with significant seismic ground deformation, probably because of a surface flysch layer filtering high-strain events, was associated with an immature or a dormant, recently activated fault. This fault, about 150 km long and discordant to the morphotectonic trends of the area, seems first, to contain segments which have progressively reactivated in a specific direction in the last 20 years, reminiscent of the North Anatolian Fault, and second, to limit an 150 km wide (recent?) shear zone in the internal part of the arc, in a region mostly dominated by thrust faulting and strong destructive earthquakes.

1. Introduction

The Aegean and the Continental Greece are notable for their active normal faulting and the associated earthquakes (Mercier et al., 1979; Shaw and Jackson, 2010) and only a zone of thrusting is observed to the NW, along the Ionian Sea front, while evidence of strike slip faulting inlands in the mainland and the Aegean Islands is at least meager (Mercier et al., 1979; Underhill, 1989). For this reason, the 2008 M_W 6.4 seismic sequence in Achaia–Elia near Patras, in SW Greece (Fig. 1) was a surprise, because it was the first significant earthquake providing clear seismological evidence of strike slip faulting in this region. This was not the only surprise. This earthquake was not associated with any known fault; on the contrary it was discordant with the neotectonic trends of the area. Furthermore, in contrast to the predictions of elastic modeling, it produced no significant ground deformation, especially afterslip, as GPS and INSAR data reveal (Briole et al., 2008; Feng et al., 2010; Ganas et al., 2009; Giannopoulos et al., 2013; Margaris et al., 2010; cf. Marone et al., 1991).

These led Feng et al. (2010) to assign the 2008 earthquake to an immature fault, and the absence of surface deformation to thin-skin tectonics (cf. Fialko et al., 2005), imposed by a decollement horizon associated with low-strength flysch deposits (cf. Bernard et al., 2006; Kamberis et al., 2000) not permitting the propagation of the rupture to the surface.

While the available data permit to understand the deformation of the area during the 2008 earthquake, no information on the long-term and the pre-seismic deformation is available, especially on the process of accumulation and release of shear strain.

In order to shed some light on this problem, the tectonic deformation of the area in two time scales was examined. In a scale of ~100 years, based on the analysis of historical triangulation data, and in a scale of 10^5–10^6 years, based on the analysis of the hydrographic network of the area, focusing on possible stream offsets, indicative of unknown major historical or prehistoric strike slip earthquakes.

This study is important (1) to confirm or revise the hypothesis of an immature 2008 fault, (2) to put some constraints in the process of shear strain build up along the trace of the 2008 fault, (3) to discuss the relationship between shear and thrust deformation along the

* Corresponding author.
E-mail addresses: stiros@upatras.gr (S. Stiros), fmoschas@upatras.gr (F. Moschas), lfeng@ntu.edu.sg (L. Feng), anewman@gatech.edu (A. Newman).

0040-1951/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.tecto.2013.02.016

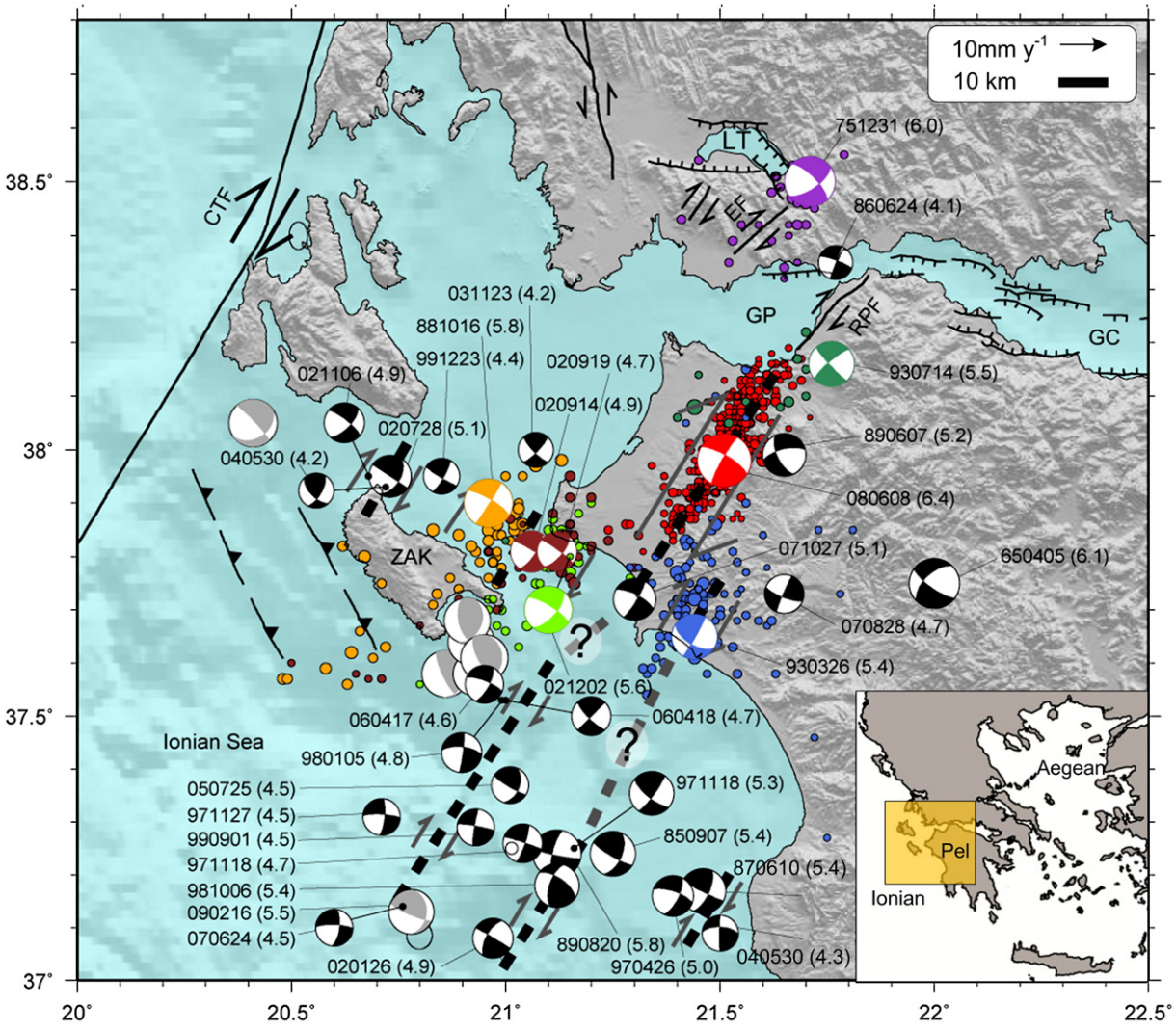

Fig. 1. Seismicity and focal mechanisms in the wider region of the 2008 earthquake in NW Peloponnese, Greece (red symbols; other colors indicate different sources of data, see Feng et al., 2010 for details). The strike slip fault offshore Cephalonia (CTF) and the possible strike slip fault marking the east edge of the Patras Gulf (PRF) are shown. This last fault seems to delineate with the predicted trace of the 2008 fault and those of previous strike slip earthquakes farther SW, indicating an about 150 km long immature or dormant fault, segments of which reactivated in a NE direction in the last 20 years. A zone of shear between these faults is inferred. Location map in the inset.
Modified from Feng et al. (2010).

Aegean Arc, and (4) to shed some light on the problem of seismic risk of Patras, the major city (approximately 250,000 inhabitants) in western Greece, mainly because of the apparent, gradual propagation of seismic faulting towards Patras (Fig. 1).

2. Geological and geodynamic background

Various lines of evidence summarized by Ganas et al. (2009) and Feng et al. (2010) indicate that the 2008 earthquake was associated with a 25 km long, sub-vertical right-lateral blind strike-slip fault, approximately 25 to 5 km deep. On the surface, most of the area is covered by an up to 3 km thick layer of flysch favoring plastic deformation.

The meizoseismal area of the 2008 earthquake is located at the boundary, an extensional province to the east, mainly represented by the Gulf of Corinth and a compressional province to the west, along the arc, mainly represented by the Ionian Islands, characterized by intense seismicity, compressional faulting and strong earthquakes (Bernard et al., 2006; Jackson et al., 1981; Mercier et al., 1979; Shaw and Jackson, 2010). The most recent major earthquake was the catastrophic 1953 Cephalonia earthquake sequence of magnitude 7.2 (Stiros et al., 1994).

These major earthquakes have produced coastal uplifts (Pirazzoli et al., 1996) and are assigned to thrusting, but focal mechanisms of relatively recent smaller ($M<6.5$) earthquakes tend to indicate that the west edge of the Aegean Arc is marked by a strike slip fault offshore Cephalonia (CTF; Fig. 1; Benetatos et al., 2004; Shaw and Jackson, 2010). There is evidence that strike slip faulting is important farther east as well: The 2008 earthquake seems to correlate with an about 150 km lineament, which may correspond to a segmented or continuous strike slip fault. To the SW this lineament corresponds to a series of smaller faults which ruptured during a period of about 20 years before 2008, but without any significant surface rupture, while to the NE, it corresponds to a fault delimiting the late Quaternary Gulf of Patras to the SE, regarded as a strike slip fault (RPF in Fig. 1; Chronis et al., 1991; Clews, 1989; Flotte et al., 2005; Piper et al., 1990; Roumelioti et al., 2004). Between this lineament and CTF other strike slip earthquakes have been found, indicating a >150 km-wide shear zone in the internal part of the arc (>200 km wide according to Floyd et al., 2010; Shaw and Jackson, 2010). Still, it is not possible to identify significant geologic traces of faults in