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Middle–Late Holocene earthquake history of the Gyrtoni Fault, Central Greece: Insight from optically stimulated luminescence (OSL) dating and paleoseismology

Ioannis M. Tsodoulos [a,*], Konstantinos Stamoulis [a,b], Riccardo Caputo [c,d], Ioannis Koukouvelas [e,d], Alexandros Chatzipetros [f,d], Spyros Pavlides [f,d], Christina Gallousi [a], Christina Papachristodoulou [a], Konstantinos Ioannides [a,b]

[a] Department of Physics, University of Ioannina, GR-45110 Ioannina, Greece
[b] Archaeometry Center, University of Ioannina, GR-45110 Ioannina, Greece
[c] Department of Physics & Earth Sciences, University of Ferrara, I-44122 Ferrara, Italy
[d] Research and Teaching Center for Earthquake Geology, Tyrnavos, Greece
[e] Department of Geology, Division of Marine Geology and Geodynamics, University of Patras, GR-26500 Patras, Greece
[f] Department of Geology, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece

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ABSTRACT

The south-dipping Gyrtoni Fault defines the northeastern boundary of the Middle-Late Quaternary Tyrnavos Basin, Central Greece. The recognition and recent tectonic activity of the fault were previously based on mapping, remote sensing analyses and electrical resistivity tomography studies. To understand the Holocene seismotectonic behavior of the Gyrtoni Fault we excavated two paleoseismological trenches. To estimate the timing of past earthquakes using luminescence dating, we obtained twenty five fluvial-colluvial sediment and pottery samples from both the upthrown and the downthrown fault blocks. We applied the Optically Stimulated Luminescence (OSL) dating to coarse grain quartz using the single-aliquot regenerative-dose (SAR) protocol. Our investigations of luminescence characteristics using various tests confirmed the suitability of the material for OSL dating. We found that the estimated OSL ages were internally consistent and agreed well with the available stratigraphical data, archaeological evidence and radiocarbon dates. The performed paleoseismological analysis emphasized the occurrence of three surface faulting events in a time span between 1.42 ± 0.06 ka and 5.59 ± 0.13 ka. Also, we recognized an earlier faulting event (fourth) has been also recognized to be older than 5.59 ± 0.13 ka. The mean throw per event value of 0.50–0.60 m could correspond to a ca. M_w 6.5 earthquake. An average fault slip rate of 0.41 ± 0.01 mm/a and an average recurrence time of 1.39 ± 0.14 ka were also estimated. Our results suggest that the elapsed time from the most recent event (minimum age 1.42 ± 0.06 ka) is comparable with the mean return period.

1. Introduction

In recent years, interest has increased in using paleoseismology to investigate the recent tectonic activity of small faults (10–20 km) with low slip rates (<1 mm/a) capable of producing moderate-to-strong linear morphogenic earthquakes (sensu Caputo, 2005) in intra-plate extensional systems of the broader Aegean region (e.g. Caputo et al., 2004; Caputo and Helly, 2005a; Chatzipetros et al., 2005; Vanneste et al., 2006; Kokkalas et al., 2007; Palyvos et al., 2010; Özkaymak et al., 2011; Moro et al., 2013; Zygouri et al., 2015; Galli et al., 2016; Grützner et al., 2016). Some of these faults were related to either historically or instrumentally recorded earthquakes and thus paleoseismological investigations extended the paleoseismic record further back in time. However, considerably less attention was given in faults located in regions with poor historic and low instrumental seismicity. Consequently, the study of these faults is then required for improving the seismic hazard assessment (Lafuente et al., 2011; Caputo et al., 2015), especially in densely populated areas (Zygouri et al., 2015; Grützner et al., 2016).

The Gyrtoni Fault (GF) is a south-dipping normal fault affecting Thessaly, Central Greece (Caputo, 1995; Pavlides et al., 2010), and is located ~13 km from Larissa, one of the largest cities of Greece with a population of ~163,000 (HSA, 2011) (Fig. 1). Therefore, the understanding of the seismotectonic behavior of this active fault in terms of slip rate, recurrence interval and date of past earthquakes (Keller and Pinter, 2002; McCalpin, 2009c), is of great importance considering that

* Corresponding author.
E-mail address: itsodoul@cc.uoi.gr (I.M. Tsodoulos).

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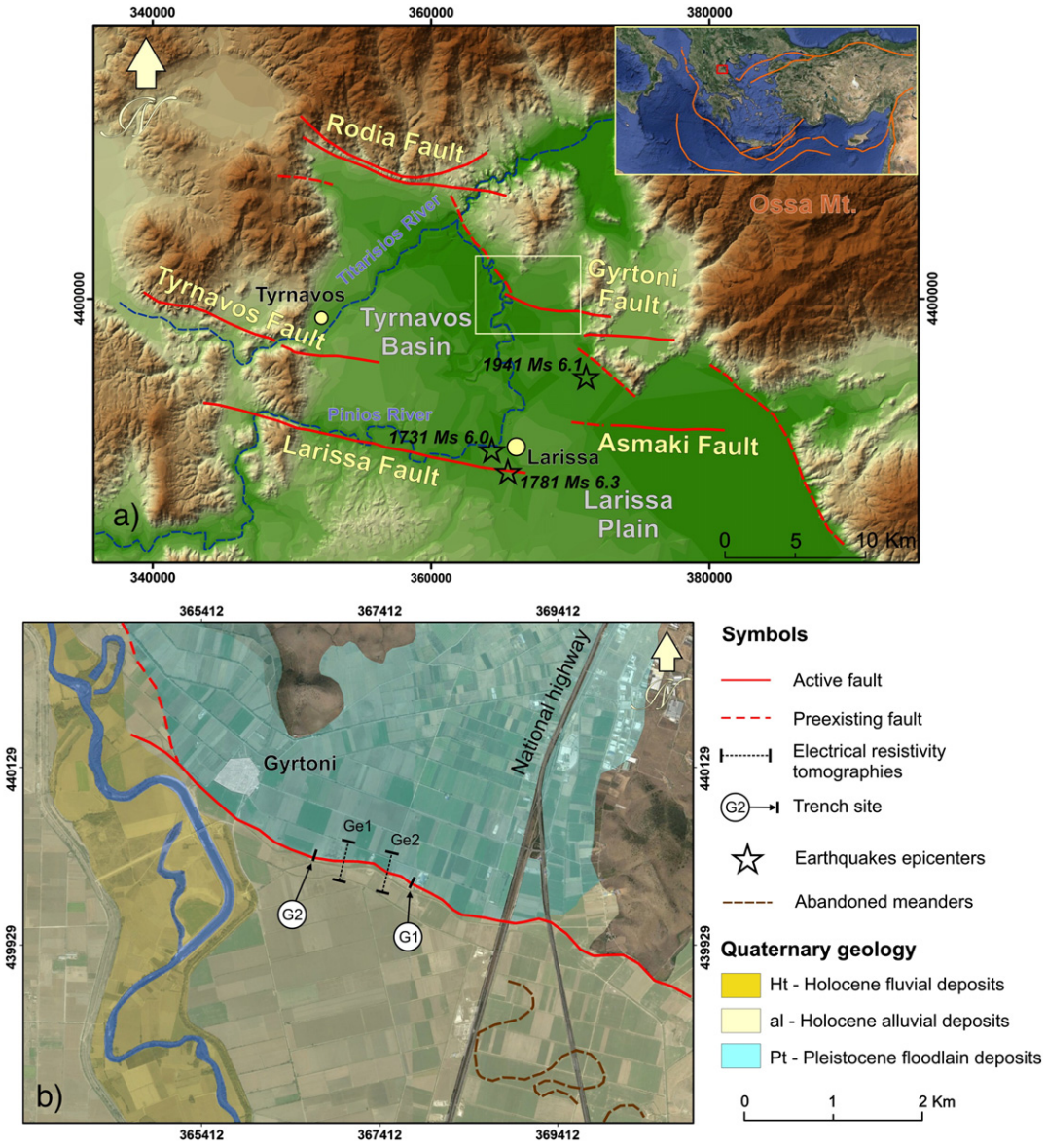

Fig. 1. (a) Digital Elevation Model with hill-shading relief of the Tyrnavos Basin showing the main structural features (faults adopted from Caputo et al., 1994). Location of earthquakes epicenters (stars) compiled from SHEEC (1000–1899) interactive catalogue (Stucchi et al., 2013), Galanopoulos (1950); Papaioannou (1988); Ambraseys and Jackson (1990); Caputo (1995) and Papazachos and Papazachou (1997). (b) Simplified geological map (IGME, 1985; Caputo, 1990) of the study area, and the locations of the two trenches. Images taken form Google Earth.

northern Thessaly may represent an important seismic gap within the broader Aegean Region (Caputo, 1995).

Previous palaeoseismological (Caputo et al., 2004; Caputo and Helly, 2005a), morphotectonic (Caputo, 1993a, 1993b), and geophysical studies (Caputo et al., 2003; Oliveto et al., 2004) as well as historical and instrumental records (Caputo and Helly, 2005b; Caputo et al., 2006) provide evidence for seismic activity along the major faults bordering the Tyrnavos Basin (Fig. 1a). Several large events have occurred in Thessaly during historical times and the instrumental period (Caputo and Helly, 2005b; Caputo et al., 2006 and references therein), but only three of these events have been directly related to the Tyrnavos Basin; the 1731 (M_s 6.0), the 1781 (M_s 6.3) and the 1941 (M_s 6.1) earthquakes (Galanopoulos, 1950; Papaioannou, 1988; Ambraseys and Jackson, 1990; Caputo, 1995; Papazachos and Papazachou, 1997) (Fig. 1a). Also, archaeological data, based on remains and damaged monuments, provide evidence of strong earthquakes in the Tyrnavos Basin during the last 2–3 ka (Caputo and Helly, 2005b). However, the correlation of these events with specific faults of Tyrnavos Basin and in particular with the GF is unknown.

Optically Stimulated Luminescence (OSL) dating (Huntley et al., 1985) provides age estimates for the last time a sediment was exposed to sunlight and it is a potentially useful tool in dating earthquake-related deposits (e.g. Porat et al., 1996; Chen et al., 2003; Fattahi et al., 2006, 2010). The single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000, 2003) is extensively used for measuring the equivalent dose (D_e), providing a high degree of precision and accuracy for OSL ages (Murray and Olley, 2002; Rhodes et al., 2003; Murray and Funder, 2003) but also the multiple-aliquot regenerative-dose (MAR) protocol (Singhvi et al., 1982; Jain et al., 2003) has been applied in some cases.

A few previous studies have applied luminescence dating to fault-related deposits associated with paleoearthquakes, in Greece. Chatzipetros et al. (1998) were the first who applied thermoluminescence (TL) and ^{14}C dating to colluvial sediments associated with the Palaeochori-Sarakina Fault in western Macedonia, Greece, for estimating recurrence intervals of past earthquakes. In palaeoseismological investigations carried out along the Tyrnavos and the Rodia faults,