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Seismotectonic analysis of the 2014 seismic swarm at the Western Corinth Gulf (Greece)

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Tectonic Setting

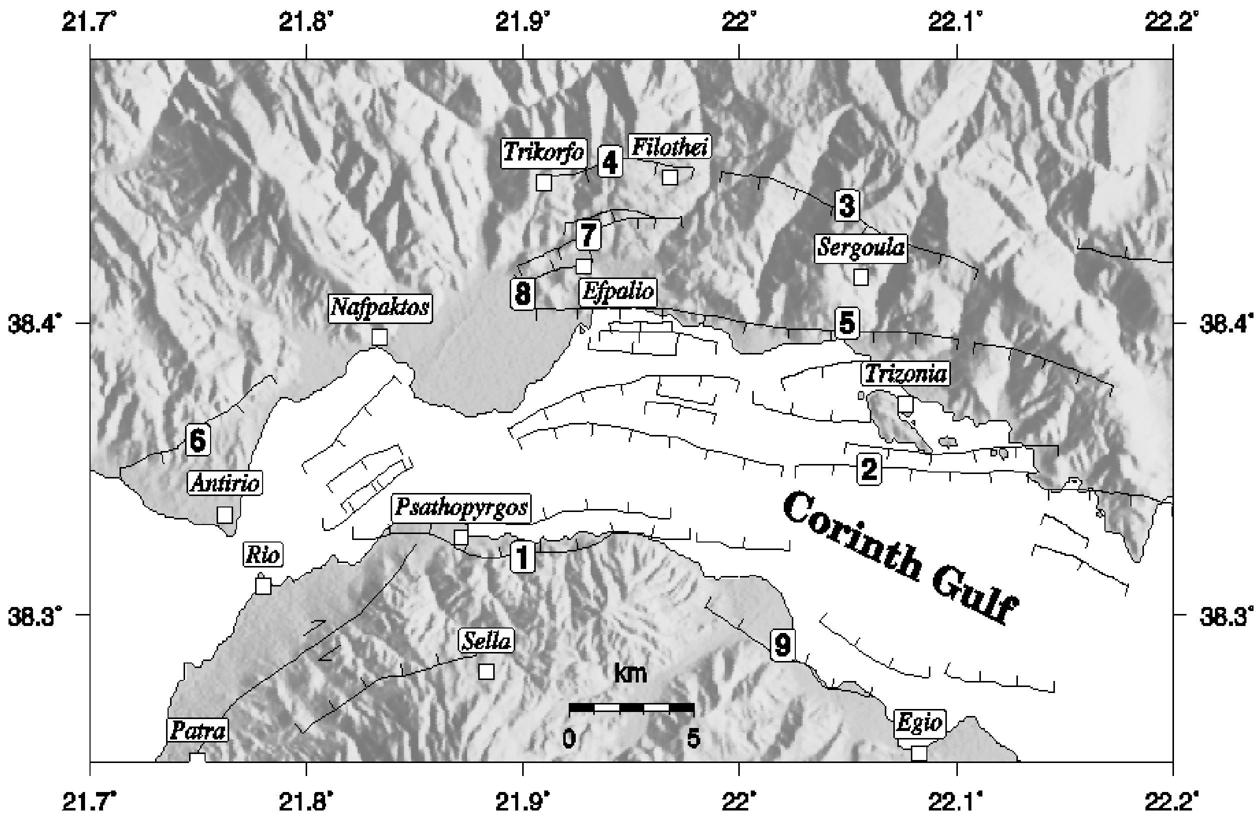

Figure 1. Western part of the Corinth Gulf. Major faults are shown: 1=Psathopyrgos, 2=Trizonia, 3=Trikorfo, 4=Filothei, 5=Marathia, 6=Antirio, 7=Drosato, 8=Efpalio, 9=Selianitika and other on- and off-shore faults. Fault traces were taken from Valkaniotis 2009 and Papanikolaou et al., 1997.

The Corinth Gulf, Greece, is a well-known active continental rift (e.g. Armijo et al.,1996). The high interest to this rift arises from the high extension rate along the gulf from ~5 mm/yr at the eastern part, to ~15 mm/yr at the western part and most the fact that is considered as one of the most seismically active continental rifts around the world (Briole et al. 2000; Hatzfeld et al. 2000; Avallone et al., 2004). Particularly seismically active is the western part of the Corinth Gulf where major tectonic elements include the ESE-WNW oriented normal faults, steeply dipping to the NNE (Figure 1). South dipping faults also exist and towards the west, these are considered to dominate the structural evolution of the Gulf (Bell et al., 2008). The most prominent active fault in south cost of western CG, is the Psathopyrgos fault, while on the northern coast, the Marathias fault dips at about 55° to the south with a total length of 12 km (Gallousi and Koukouvelas, 2007). The dip angles of the faults at the surface range between 40° and 70° while several low-angle, north-dipping, normal focal mechanisms also have been determined for events located at depths between 9.5 and 10 km (Rigo et al. 1996). Besides normal faults with a general EW strike there is also a seismological evidence for active transfer faults connecting the major en echelon faults (Pacciani and Lyon-Caen, 2010, Zahradnik et al., 2004).

2014 Swarm's Analysis

Earthquake swarms are space-time clusters of seismicity that cannot easily be explained by typical aftershock behavior. They likely result from physical changes in the crust, such as slow slip or fluid flow. Swarms are better explained by fluid flow because their estimated linear migration velocities are far smaller than those of typical creep events while large values of best-fitting hydraulic diffusivity are found (Zhang & Shearer, 2016). The origin of swarms in the Corinth rift is believed not to be related, at least directly, to significant changes in the crustal stresses. When considering the probable reason for the appearance of swarms, a certain fluid diffusion in the upper portions of the crust is meant; both deep and surface (due to precipitation) origins of the fluid are assumed possible (Bourouis and Cornet, 2009). The seismicity of the area is continuously monitored by the stations of the Corinth Rift Laboratory Network (CRL Net). The availability of a dense permanent seismological network allows the extensive analysis of the seismic swarms which occur frequently. In this study, the September 2014 swarm located at the western part of the Corinth Gulf is analyzed

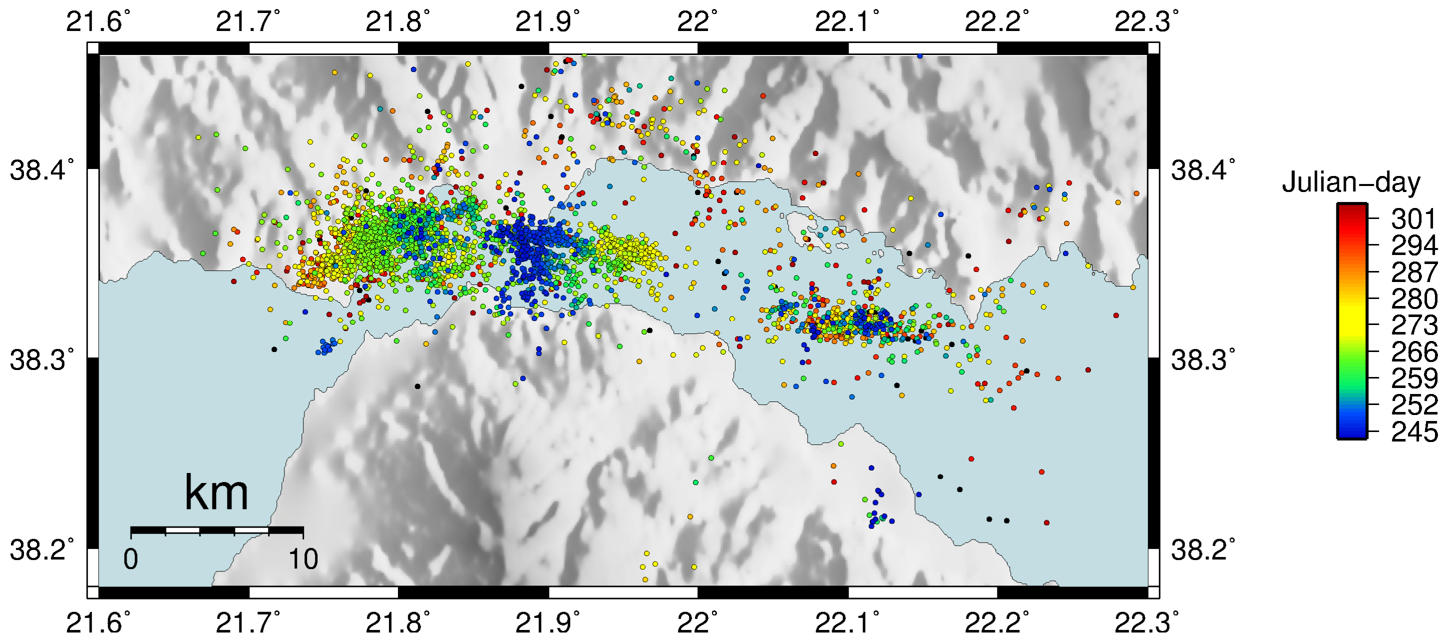

Figure 2. Space-time distribution of the relocated events (initially automatically located) recorded by CRL-Net. The color scale refers to the Julian day of occurrence.

A two stages procedure was followed concerning the seismicity. Initially, more than 4000 automatically located events (CRL-Net), of a two month period, were relocated using the HYPODD algorithm, incorporating both catalogue and cross-correlation differential traveltimes. Consequently, the initial seismic cloud was separated into several smaller, densely concentrated clusters (Figure 2).

2014 Swarm's Analysis

Next, a dataset of the largest 707 events, of the same period, were manually located using data from 18 stations of the Hellenic Unified Seismic Network (HUSN) and the Corinth Rift Laboratory Network (CRL Net). Double difference relocation was applied using the HYPODD algorithm, incorporating catalogue differential traveltimes (Figure 3). Moment Tensor calculation of the largest events was performed using the ISOLA software. The results indicate an initial activation of the Psathopyrgos normal fault; afterwards the seismicity extended both towards East and West, while most events occurred at the western part of the study area. The seismicity distribution revealed a main activation of the North – dipping faults (Figure 4).

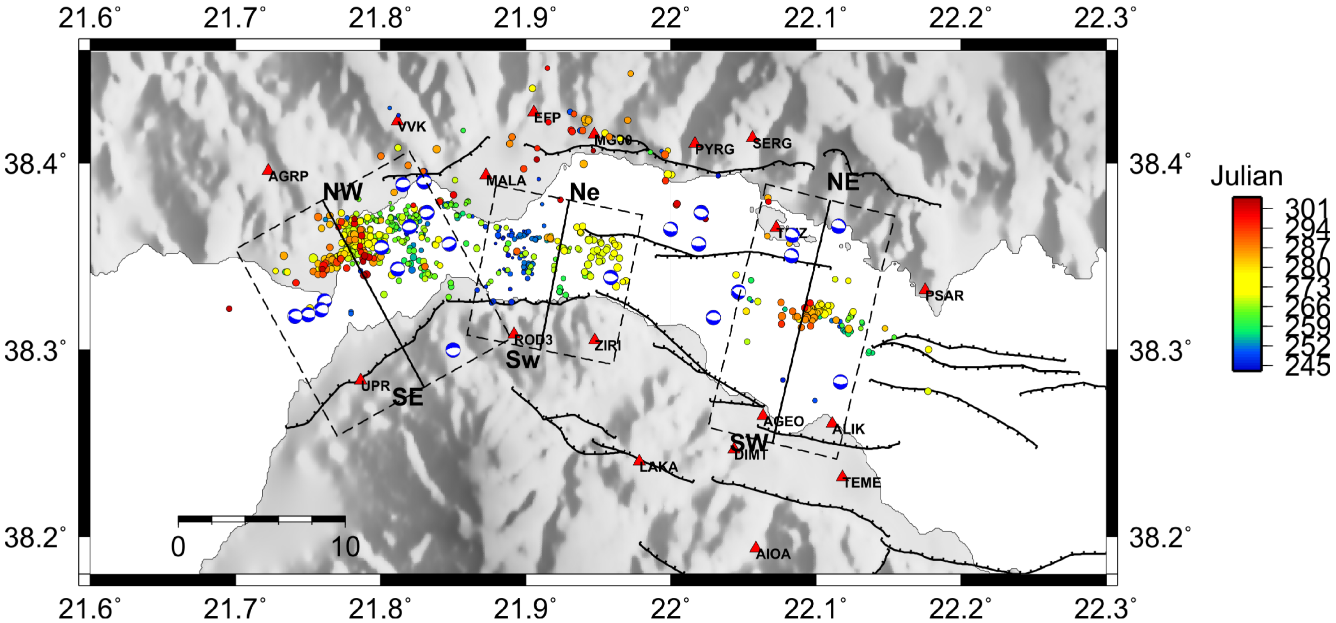

Figure 3. Distribution of the relocated events (initially manually located) and moment tensors of the largest events. The color scale refers to the Julian day of occurrence.

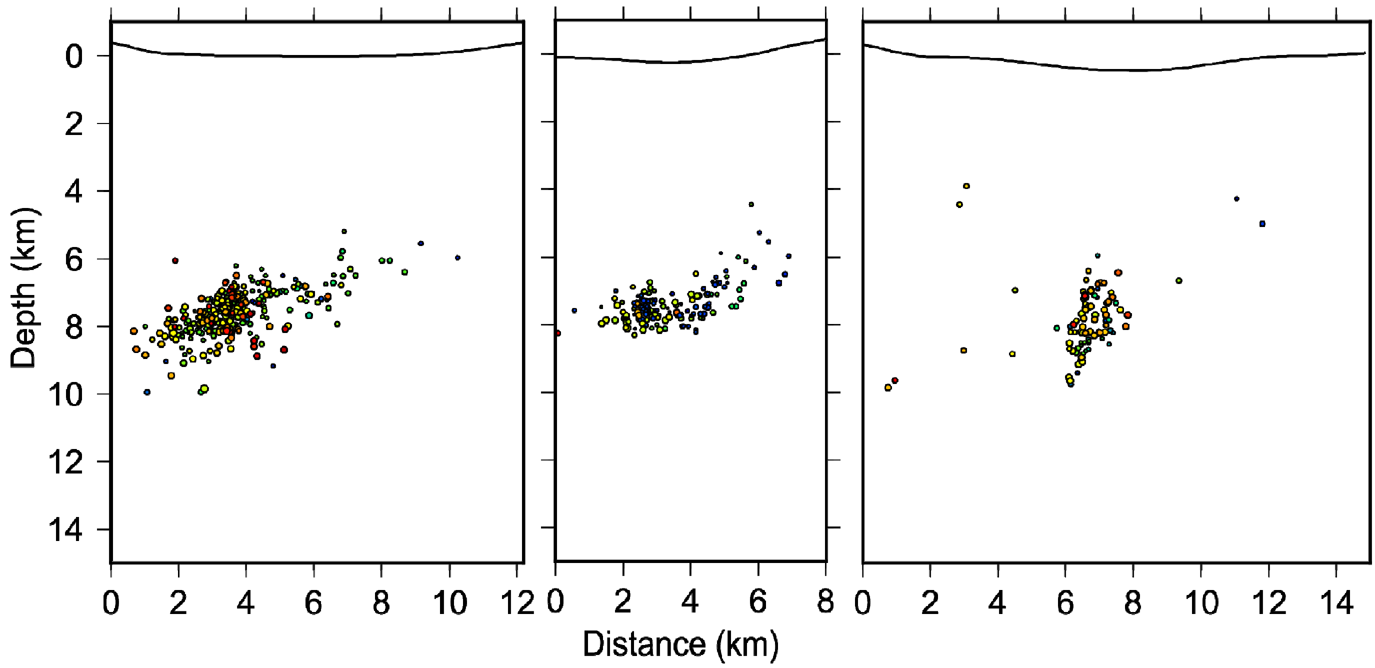

Figure 4. Distribution of the swarm's events on the cross sections shown in Figure 3.

Fluids role investigation

Fluids may play an important role in the mechanism of the rupture because they may reduce the friction coefficient, allowing seismic slip along the low-angle detachment.
Double difference relocation was applied to manually located events in order to investigate the Vp/Vs ratio variation, due to its sensitivity in pore fluids. Using the manual picks of the first P and S wanes' arrivals, the Vp/Vs ratio was calculated (Figure 5).The results show some differentiation from the standard 1.79 value used for the area. The velocity anomalies may be associated with the presence of a highly fractured zone at 8–12 km (Gautier et al., 2006). The presence of a highly fracturated zone can support the assumption of a circulation of deep fluids.

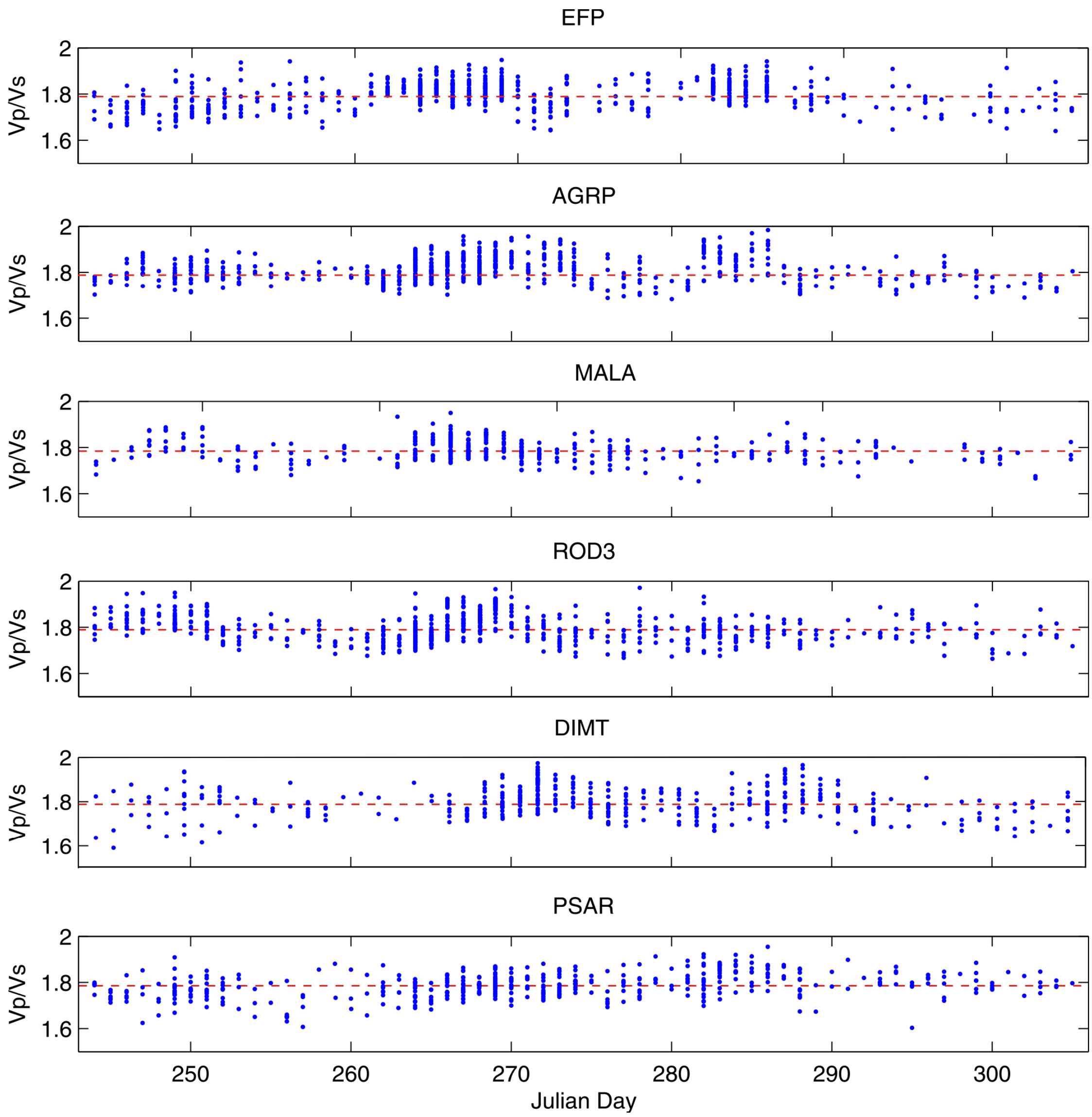

Figure 5. Calculated values of the Vp/Vs ratio using the manual picks of P and S waves first arrivals. The red dotted line represents the value 1.79 which is typically used for the study area.

Fluids role investigation

The seismicity migration with respect to pore pressure changes due to fluid movements was investigated through diffusivity calculations. The diffusivity value was found to be 4.5m2s-1, which is consistent with results of previous studies in the area(Figure 6). The results of the investigation of the fault- zone hydraulic behavior provide evidence for the fluid – triggered earthquake swarms and the related rock physical properties.

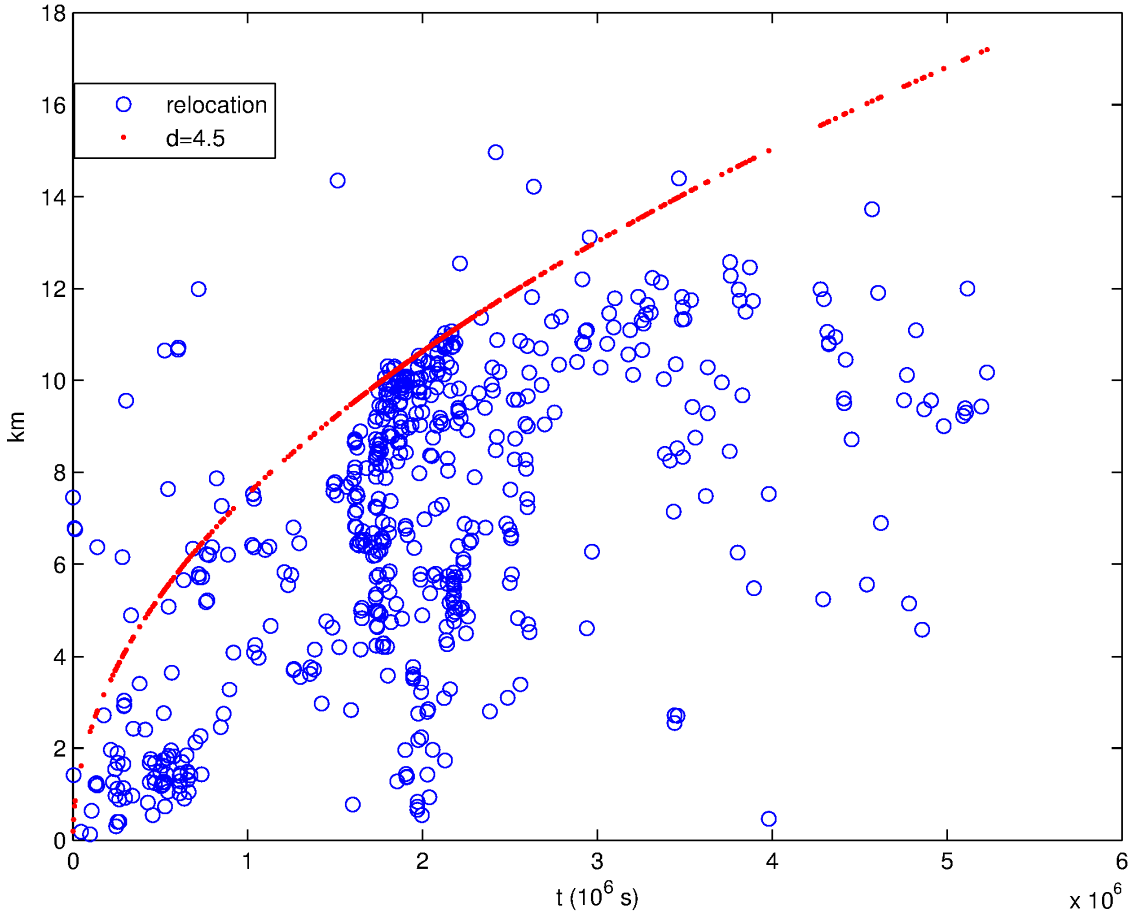

Figure 6. Distance variation r of the events (in reference to the first swarm's event) as a function of the occurrence time t.

Results – Conclusions

The moment tensors' solution indicated pure normal faulting accordingly to the seismotectonic setting of the Western Coring Gulf.

The results from the seismicity indicate an initial activation of normal faults in the vicinity of Psathopyrgos; afterwards the seismicity extended both towards East and West, while most events occurred at the western part of the Gulf.

The depth distribution ranges from 6 to 10km and revealed a main activation of the faults dipping towards the North while a minor South-dipping fault showed activation in the begging of the swarm.

The results of the investigation of the fault- zone hydraulic behavior provide evidence for the fluid – triggered earthquake swarms and the related rock physical properties. The variations in Vp/Vs values (higher than suggested) indicate a decrease of Vs value.

The diffusivity value D was found to be 4.5m2s-1; the value is consistent with results of previous studies in the area (Giannopoulos et al., 2015) and larger than the one calculated by Pacciani and Lyon-Caen, 2010, indicating higher hydraulic diffusivity and pore pressure at the western part of the Corinth Gulf.

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