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Spatial Variations of Seismic Anisotropy in the Western Gulf of Corinth

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The Western Gulf of Corinth (WGoC) is the most active rift in Europe, having hosted a large number of destructive earthquakes (Makropoulos *et al.*, 2012), as well as multiple swarms (Kapetanidis *et al.*, 2015). It comprises of fault systems striking approximately WNW-ESE, while the focal mechanisms in the area are almost exclusively normal in nature. This complicated structure characterizes the rift as a semi-graben, with the southern coasts of Northern Peloponnesus being uplifted (Armijo *et al.*, 1996). The intense seismic activity in the area has led to significant interest from researchers worldwide.

Seismic anisotropy refers to the wave velocity dependence from changes in the polarization direction. A widely studied branch of the above phenomenon is Shear-wave Splitting (SwS), which refers to velocity variations in shear-waves. Upon entering an anisotropic medium, shear-waves undergo splitting and two components of polarization can be distinguished; (a) the one propagating faster (S_{fast}) and (b) the one lagging behind (S_{slow}). SwS is quantified by determining two parameters, i.e. the polarization direction of the S_{fast} (φ) and the time-delay between the arrivals of the two split shear-waves (t_d). SwS is a featured phenomenon in areas where the crust is permeated by vertical fluid-filled microcracks. According to the Anisotropic Poro-Elasticity (APE) model (Crampin and Zatsepin, 1997; Zatsepin and Crampin, 1997), stress variations in a given rock volume and changes in the characteristics of the fluids affect the geometry of the microcracks. This affects SwS by altering both φ and t_d. Microcracks are usually controlled by the maximum horizontal compressive stress component (σ_{Hmax}). However, local structures can also have an effect on microcracks, leading to spatial differences in the distribution of φ (Li and Peng, 2017). In the WGoC, splitting has been previously studied, exhibiting polarization directions mostly aligned to σ_{Hmax}, i.e. WNW-ESE (e.g. Giannopoulos *et al.*, 2015; Kaviris *et al.*, 2017, 2018). However, deviations from this orientation have yet to be fully explored. The current study aims to clarify whether these outliers can be attributed to anisotropy controlled by structural factors.

The development and operation of dense seismological networks in the WGoC have a significant impact in the above, permitting the continuous recording of events by broadband seismological stations all around the rift. The Hellenic Unified Seismological Network (HUSN) is a joint venture of the operators of seismological networks in Greece and has been active since 2008, covering a significant portion of the gulf. The Corinth Rift Laboratory Network (CRLN) is the result of the partnership between Greek and French institutes with its main focus being the study of seismicity within the gulf. Data by both networks are used in the presented work.

The large dataset of event-station pairs was analyzed automatically. Initial locations of foci (acquired from the Seismological Laboratory of the National and Kapodistrian University of Athens) were used to determine candidate rays for analysis, i.e. ones with a maximum angle of incidence equal to 45°, in order to avoid converted and scattered phases. Then, two techniques were employed for the SwS analysis, through the Pytheas software (Spingos, 2019). The Eigenvalue (EV) method (Silver and Chan, 1991) utilizes a grid search approach, searching for the pair of φ and t_d that best minimizes the smallest eigenvalue λ_2 of the covariance matrix between the (corrected for anisotropy) horizontal components. To implement this, a signal window for analysis must be provided. Commonly, this is specified by the analyst. However, to fully automate the selection and accommodate a large number of recordings, the Pytheas software has followed a Cluster Analysis (CA) approach (Teanby *et al.*, 2004). Measurements with the EV method are repeatedly conducted for a range of candidate signal windows around the S-wave arrival. The outer bounds of the windows' range are defined by the S-P times and the period of the shear-waves. Thus, a population of measurements with coordinates (φ, t_d) is acquired, where clusters are formed, indicating stable solutions. A hierarchical agglomerative clustering is initially performed to determine the clusters. The optimal one is selected, based on the degree of constraint. The selected signal window is the one corresponding to the measurement with the smallest uncertainties, included in the most constrained cluster. Results from this analysis were then used to obtain the spatial variation of φ, with the use of the TESSA program (Johnson *et al.*, 2011). For a selected grid, the average of the polarization direction is calculated for each cell, by taking into account the φ value attributed to each passing ray and weighting their contribution according to t_d.

Results of the above analysis indicate that shear-wave splitting in the WGoC is mostly influenced by stress. While this was evident for the coastal areas (due to the stations being located on land), the spatial distribution of φ confirms this for the offshore region within the rift. However, the area surrounding the Mornos delta, to the NW, offers a different perspective, with polarization directions oriented NE-SW, perpendicular to σ_{Hmax}. While this could be interpreted as the microcracks reaching a critical state, where their aspect-ratio is inverted due to increased fluid pressure causing φ to flip by 90°, the time-independent nature of this change offers refuting evidence to the hypothesis. We attribute this difference in direction to local structures in the broader Mornos delta area, where both topographical and tectonic data indicate NE-SW trending structures. Distinguishing between the factors influencing SwS is a decisive step in seeking relations between fluid-related processes, such as diffusion/migration and splitting, enabling the latter to function as a monitoring tool.

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