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Stochastic Modelling of Anomalous Earthquake Diffusion in the 2001 Agios Ioannis Earthquake Swarm (Corinth Rift)

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The Corinth Rift (central Greece) is one of the most seismically active areas in Europe due to rapid continental extension that reaches the rate of ~15mm/year in its western part. In contrast to the eastern part, the western part of the rift presents intense microseismic activity and frequent earthquake swarms that have been associated with pore-fluid pressure diffusion at depth (Bourouis & Cornet, 2009). Such an earthquake swarm occurred on 2001 in the SW margin of the rift, in the area of Agios Ioannis, near the city of Aigion. The swarm initiated on 2001 March 28 with a sudden increase in the regional seismicity rate and involved more than 2900 events over a period of 100 days. The largest event of the swarm occurred on 2001 April 8, 10 days after the initiation of the swarm, with the moderate size of M_w4.3. The spatial distribution of the swarm and the focal mechanism of the largest event indicated the activation of a SW–NE fault plane dipping at ~40◦ to the north-west, which coincides with the unexposed Kerinitis fault (Pacchiani & Lyon-Caen, 2010). The spatiotemporal evolution of the swarm indicated the spatial migration of activity towards the surface with time. This migration pattern is consistent with a pore-fluid pressure diffusion mechanism, where the initial pore-fluid pressure perturbation occurred at some point near the early events of the swarm and progressively migrated at negative pressure gradients towards the surface along the active fault structures.

According to the Mohr-Coulomb failure criterion, increased pore-fluid pressure can reduce the effective normal stress along a fault zone triggering earthquakes. Here we investigate the diffusion properties of the Agios Ioannis earthquake swarm and the applicability of such mechanism in triggering the earthquake activity. We consider a probabilistic approach and a stochastic framework that generates the key properties of earthquake diffusion. Within this context, a well-established stochastic framework for modelling anomalous diffusion phenomena in complex heterogeneous media, where linear diffusion equations and Fick's second law might no longer be applicable, is the continuous-time random walk (CTRW) model (Berkowitz *et al*., 2006). Within the CTRW context, we consider earthquake occurrence as a point-process in time and space and we map earthquake diffusion with a joint probability density function of spatial jumps and waiting times between successive earthquakes. The analysis of the swarm within this context indicates a broad probability density of waiting times with asymptotic power-law behavior, as well as the power-law growth of the mean square displacement of seismicity with time, with a diffusion exponent well below unity that marks normal diffusion (Fig.1). Such properties are intrinsic characteristics of anomalous diffusion and indicate the slow propagation of seismicity according to a sub-diffusive process.

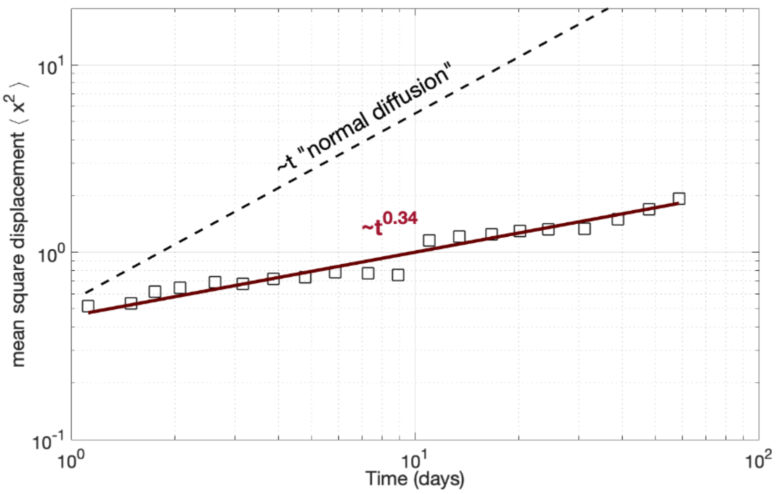

Figure 1. Mean square displacement of the earthquake swarm with time (squares) in logarithmically spaced bins and in double logarithmic axes. The solid line indicates the best-fitting solution of ~t^a for the value of a = 0.34 ± 0.04, while the dashed line indicates ~t that marks normal diffusion (modified after Michas & Vallianatos, 2018).

In addition, we combine the CTRW model with fractional kinetics and the time-fractional diffusion equation to provide an analytic description of the spatial migration of seismicity with time. According to the results for various time periods, the derived stochastic model can successfully predict the main features of anomalous earthquake diffusion, indicating a peak of earthquake concentration close to the origin and a stretched exponential decay for the concentration of distant events. Our results are consistent with pore-fluid pressure diffusion as the triggering mechanism of the earthquake swarm. In this case, our results can be understood as a ‘non- Fickian’ relaxation of an initial pore-fluid pressure perturbation that reduces the effective normal stress along the active fault structure triggering the seismicity. The results further indicate that the CTRW model and the fractional diffusion equation can efficiently be used to model anomalous earthquake diffusion in the highly heterogeneous crust.

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References

Berkowitz, B., Cortis, A., Dentz, M., Scher, H., 2006. Modeling non-Fickian transport in geological formations as a continuous time random walk,.Rev. Geophys. 44, RG2003.

Bourouis, S., Cornet, F.H., 2009. Microseismic activity and fluid fault interactions: some results from the Corinth Rift Laboratory (CRL), Greece. Geophys. J. Int. 178, 561–580.

Michas G., Vallianatos F., 2018. Modelling earthquake diffusion as a continuous-time random walk with fractional kinetics: the case of the 2001 Agios Ioannis earthquake swarm (Corinth Rift). Geophys. J. Int. 215, 333–345.

Pacchiani, F., Lyon-Caen, H., 2010. Geometry and spatiotemporal evolution of the 2001 Agios Ioanis earthquake swarm (Corinth rift, Greece). Geophys. J. Int. 180, 59–72.