IMPERIAL

Characterising the Importance of Aseismic Creep and Slow Slip Events on Normal Faults

Supervisors

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Research Group

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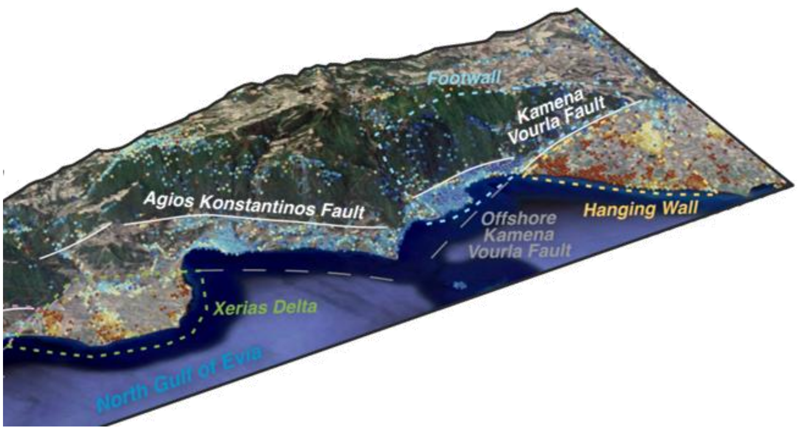
Project Summary

Understanding how faults slip represents one of the key challenges in the fields of structural geology and seismology. This project aims to characterise the importance of aseismic creep and slow slip events on normal faults, a mode of behaviour which is critical for understanding seismic hazard, but which to date has not been documented unambiguously for extensional structures. The outcome of the work will be new insights into the frequency and importance of aseismic slip behaviours on normal faults for the first time, and new insights into the modes of behaviours and seismic hazard for faults in Europe.

Research Context and Objectives

Classic models of fault behaviour use rate-and-state friction laws involving frictional weakening during slip, which enables discrete coseismic events to be modelled in between periods where the fault interface is locked ((Forsyth et al., 2009). However, an increasing number of geodetic, experimental and observational studies have shown that for thrust and strike slip faults, slip can in some cases occur aseismically (e.g. Avouac, 2015; Faure & Bayart, 2024). This process can occur as quasi-steady-state aseismic motion known as creep or during transient periods of elevated aseismic slip, now described as slow slip events (SSEs). Such events may last over time periods of days to months, or even over a few years. These behaviours can vary in space and time across faults, many of which may also host large earthquakes, raising important questions about how strain and seismic hazard is partitioned between slip modes across the seismic cycle.



While aseismic fault slip behaviours can now be identified at large subduction zones and on major strike-slip faults owing to high slip rates, to date creep or SSEs has not been unambiguously demonstrated on normal faults. This is owning to their generally smaller scale; yet these faults also can host extremely destructive earthquakes and in Europe are found in locations close to major population centres in countries including Greece and Italy. However, geodetic data, including InSAR based studies and the European Ground Motion Service (EGMS: *https://land.copernicus.eu/en/products/european-ground-motion-service*) now provides a key opportunity to detect and monitor the existence of aseismic slip, including SSEs, on normal faults for the first time. Recent work on Pisia-Skinos fault system, Greece, has interpreted the probable existence of transient normal fault slip on this structure using the EGMS data set, which is unaccompanied by any large earthquakes (Mildon et al., 2024). Very recently, work from Imperial suggests a variety of slip modes might occur on normal faults in the same region (Wood et al., 2025). An example of EGMS motion data for the Karmena Vourla Fault, Greece, from this latter paper is shown above, where blue is uplift and red is subsidence. Consequently, this project aims to exploit these new tools and insights to characterise aseismic slip for normal faults in space and time. The student will:

1. Use EGMS data in conjunction with GPS data and recorded seismicity to compile and document the existence of SSEs and aseismic creep for faults across Greece. The student will document the magnitude and rate of the events and the proportion of faults which are affected, compared to those that are locked.

2. Use existing GPS data in Greece where available to verify the potential existence of SSEs and simultaneously evaluate forensically the extent to which any ground motion could or could not be explained by other factors such as ground water extraction.

3. For potential SSEs, including for the Pisia fault, the student will compile and process InSAR data from sentinel 1 since 2014, using in-house algorithms at Imperial to determine the distribution of durations and return intervals

4. Use existing seismic data to search for any other signatures that have been associated with SSEs, including tremor and very low frequency earthquakes. For plausible SSEs, invert the EGMS ground motion data to find the SSE source area and equivalent moment magnitudes and and locate potential faults where high density geodetic observations could be carried out using in-situ installation of GNSS trackers.

Further reading:

Avouac, J.-P. (2015). Ann Rev Earth Planet Sci., 43(1), 233–271. https://doi.org/10.1146/annurev-earth-060614-105302; **Faure, Y., & Bayart, E.** (2024). Nat. Comms, 15(1), 8217. https://doi.org/10.1038/s41467-024-52492-2; **Forsyth, D., et al.,** (2009). Grand challenges for seismology. EOS Trans AGU, 90(41), 361–362. https://doi.org/10.1029/2009EO410001; **Mildon, Z. K. et al**. (2024). Transient aseismic vertical deformation across the steeply-dipping Pisia-Skinos normal fault, Tectonics, e2024TC008276. https://doi.org/10.1029/2024TC008276; **Wood, J., Whittaker, A. C., Bell et al**., (2025). Resolving coseismic and aseismic normal fault slip behaviors from InSAR time series of the European ground motion service (EGMS). Tectonics, 44, e2025TC008904. https://doi.org/10.1029/2025TC008904

Who are we looking for?

We are looking for motivated students with a degree or masters in Earth Sciences, or a related discipline, who have a real interest in structural geology and active faulting. The project is ideally suited to a student who is passionate about tectonics and Earth observation. The student will gain experience of integrating geodetic, seismological and structural data sets and may have the chance to visit candidate faults for SSEs in the field. The candidate will have the opportunity to develop their career by presenting at international conferences and publishing in high-impact journals.