University of BRISTOL COMET British Geological Survey CARDIFF UNIVERSITY

Unravelling the Geological Controls on Shallow Fault Mechanics

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Project Themes: Fault Mechanics, Space Geodesy, Structural Geology.

Funding: **The project is fully funded for 3.5 years by COMET-BGS** and is available to students eligible for UK/home fees. The funding includes a stipend that is in line with UKRI rates (£19,162 p/a) and a research grant that covers fieldwork, consumables and conference visit costs.

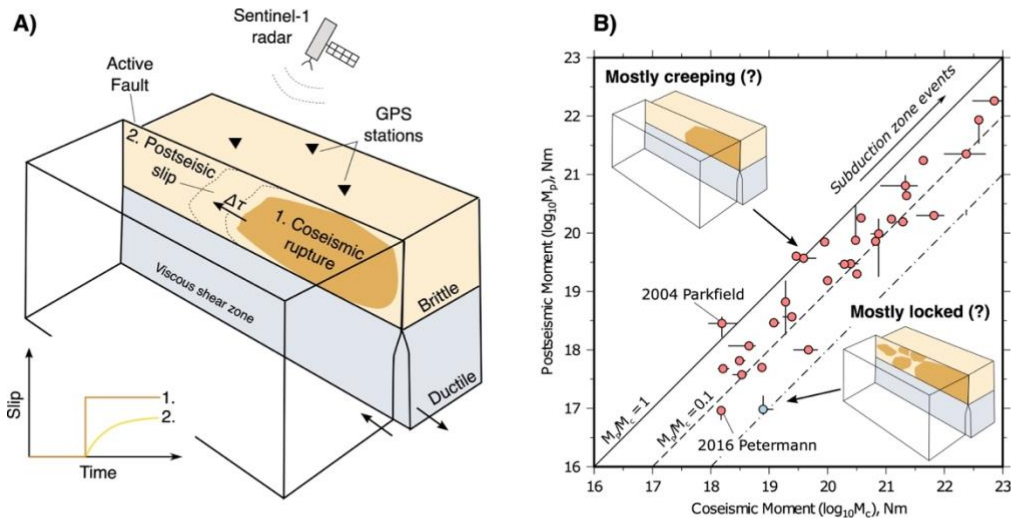

Figure 1: (a) Sketch showing the relationship between earthquake slip and post-earthquake creep. (b) Measurements of the amount of earthquake slip relative to post-seismic creep on different faults.

Project Background

Active faults move in a variety of different ways – some faults creep slowly at speeds of mm/yr, whilst others slip rapidly at speeds of m/s generating seismic waves. Understanding what controls these different modes of fault slip remains one of the major unresolved questions in Earth Sciences and is a key barrier to determining the hazard that large faults pose to communities and infrastructure.

Advances in both the quality and sampling frequency of satellite remote-sensing data mean it is now possible to measure how the ground deforms during and after earthquakes in most of Earth's tectonically active regions. These measurements have revealed that some faults experience extensive shallow creep following moderate-sized earthquakes, whilst others experience hardly any at all [Wimpenny et al., 2017]. This variation in "post-seismic creep" between faults provides a way of interrogating the controls on their frictional properties and has been attributed to varying geological structure and history [Thomas et al., 2012; Floyd et al., 2016]. Intuitively this makes sense, as the grain-scale processes that accommodate the deformation of fault rocks depends on their composition and structure. However, exactly how the grain-scale processes operating within active faults relate to the slip styles on faults observed at the metre-to-kilometre scale remains unclear.

In this multi-disciplinary project, you will work with a team of world-leading scientists to combine geophysical measurements of the frictional properties of active faults, with geological observations of the structure and composition of fault zones, to develop new insights into how the geology and grain-scale structure of a fault zone controls its kilometre-scale frictional properties.

Project Aims

1. Create systematic satellite-based measurements of the ground deformation in the near-field around a subset of continental earthquakes in a range of different geological settings. Some example targets include the 2020 Mw 6.4 Petrinja earthquake in Croatia, which is cross-cut by a series of fault-perpendicular rivers and is well-exposed, and the 2017 Mw 6.5 Jiuzhaigou earthquake that occurred in a region of highly dissected topography.

2. Use the deformation measurements to constrain numerical models of fault slip in response to earthquake stress changes and thereby determine frictional properties within the top 1-2 km of these fault zones. You will apply state-of-the-art, open-source numerical models to simulate the creep of fault zones in response to earthquake stress changes [Wimpenny et al., 2022], and search for models that match the ground deformation measurements made in Aim 1.

3. Collect samples of the deformed fault rocks from a sub-set of these fault zones and characterise their microstructures to infer the grain-scale processes accommodating the observed deformation. You will design fieldwork to sample two of the faults studied in Aims 1 and 2 that show contrasting behaviour (stick-slip versus creep), and establish what microstructural evidence there is for differing deformation processes within each fault zone using optical microscopy and other analytical techniques (scanning electron microscopy, x-ray diffraction).

4. Compare the mechanical properties inferred from the modelling with the grain-scale processes accommodating the deformation. You will apply novel micro-mechanical descriptions of rock friction to link the grain-scale deformation mechanisms with the fault-scale frictional properties.

Candidate Requirements

The project would be suitable for a candidate with a background in geology and/or geophysics. There is the option for the candidate to undertake fieldwork to sample and map some of the faults they may study, though this is not essential, and the sampling can be carried out by the supervisors.

Training

You will receive training in a wide-range of geological and geophysical techniques, including: (1) creating and interpreting satellite remote-sensing (InSAR, optical) measurements of ground deformation, (2) modelling ground deformation caused by earthquakes, (3) mapping and sampling natural fault zones, and (4) studying and interpreting fault-rock microstructure. You will also be a member of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics – a world-leading centre with expertise across satellite remote-sensing, volcanology and tectonics.

References & Further Reading:

Wimpenny S., et al., 2017, *Fault Mechanics and Post-seismic Deformation at Bam, Iran*, Geophysical Journal International, **209(2)**, 1018-1035, https://doi.org/10.1093/gji/ggx065.

Floyd M., et al., 2016, *Spatial variations in fault friction related to lithology from rupture and afterslip of the 2014 South Napa, California, earthquake*, Geophysical Research Letters, **43(13)**, 6808-6816, https://doi.org/10.1002/2016GL069428.

Thomas M., et al., 2014, *Lithological control on the deformation mechanism and the mode of fault slip on the Longitudinal Valley Fault, Taiwan*, Tectonophysics, **632**, 48-63, https://doi.org/10.1016/j.tecto.2014.05.038.

Wimpenny S., et al., 2022, *Time-dependent decrease in fault strength in the 2011–2016 Ibaraki–Fukushima earthquake sequence*, **232**, 788-809, https://doi.org/10.1093/gji/ggac368.