PROJECT TITLE: How do large earthquakes start? Illuminating the nucleation phase from seismology and geodesy

DTP Research Theme(s): Dynamic Earth
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Project keywords: earthquakes, seismology, geophysics, geodesy, crustal deformation, hazards

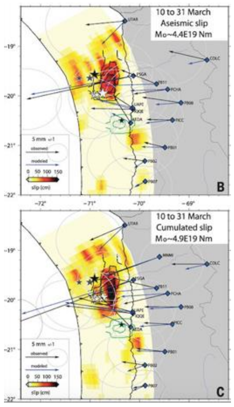

Fig 1. Slip distribution preceding the 2014 Iquique (Chile) earthquake, inverted from surface GPS displacements observed during the preseismic phase. (B) Aseismic slip for the period ranging from 10 to 31 March 2014. (C) Cumulative slip model for displacements observed from 10 to 31 March 2014. Black and green contours are the slip distributions for the mainshock and the main aftershock, respectively. Mo, seismic moment.

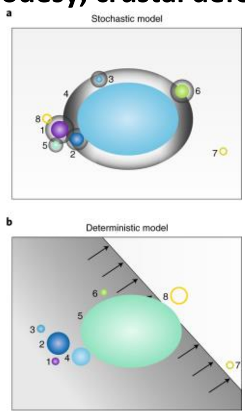

Fig 2. A fault surface contains strong patches (ellipsoids) that ultimately fail and slip so rapidly that they radiate seismic waves. a, In a stochastic model, the timing and size of any seismic failure is independent of the initiating perturbation. Grey shaded regions surrounding each failed strong patch indicate resulting stresses that can trigger failure on nearby patches. b, A propagating slow-slip front triggers failure of strong patches as it passes. From Gomberg (2018).

Project Background

How do large earthquakes start? The answer to this simple question might enable improved early warning and earthquake forecasting. In one endmember model (Fig 2), small tremors randomly redistribute stresses that can trigger more quakes, and some of these grow unpredictably into large events. In this 'cascade model', the processes during the pre-earthquake phase are stochastic, and the eventual size of a quake is determined by the random barriers to continued rupture. The cascade model underlies current operational earthquake forecasting systems around the world and provides useful but limited predictive skill. In another endmember model, aseismic creep sweeps across a fault, generating seismic events where the aseismic slip encounters asperities, and leading to large earthquakes when the asperities are big or connected. In this 'pre-slip model', foreshocks may obey discernible patterns that betray the aseismic slip, such as a spatial migration of foreshocks or repeating tremors that re-break asperities continually reloaded by slow slip. Such patterns might help to forecast impending quakes better. Recent geodetic observations prior to some giant earthquakes in subduction zones, such as the 2011 Tohoku (Japan) and the 2014 Iquique (Chile) earthquake (Fig 1), seem to support the pre-slip model, but some onshore events occurred without discernible pre-slip. How large earthquakes start is of immense scientific and practical interest.

Project Aims and Methods

The goal of this project is to gain new insights into how large earthquakes start and to determine the extent to which quakes in different tectonic settings start by cascading foreshocks or aseismic slip. The project will primarily draw on methods from observational earthquake seismology and statistical seismology to make inferences in the context of constraints from space geodesy (GPS/GNSS), fault mechanics and earthquake geology. Depending on the student's interests, empirical, statistical or computational work can be emphasised. Seismology includes searching for more foreshocks and repeaters via machine learning or template-matching techniques. GPS/GNSS can identify pre-slip or document its absence. Statistical approaches can compare foreshock patterns across tectonic settings with predictions from the pre-slip and cascade models. Geological evidence of the interplay between aseismic and seismic slip provide clues about the mechanics of the preparatory phase. A crucial question is how frequently patterns emerge without leading to large earthquakes in order to determine the practical value for seismic hazard analysis.

Candidate requirements

We seek an enthusiastic student with broad interests in solid-earth geophysics, with a first degree in geophysics, physics, (quantitative) geology, maths, statistics, engineering, computer science, or other quantitative subject. The ideal candidate will have experience in programming and a strong interest in earthquakes and their hazards. The candidate will communicate effectively in verbal and written form and present their work at international conferences. We seek a person that is highly motivated to work independently as well as in a team. We welcome and encourage student applications from under-represented groups. We value a diverse research environment.

Training

Students will be trained in data analysis, seismology, numerical modelling, space geodesy and earthquake geology. Main supervisor Dr Max Werner will support the student in seismology, seismicity analysis and earthquake modelling. Software will include Python, Matlab, R and C. Co-supervisor Dr Juliet Biggs will provide training in GPS geodesy, including data collection, processing and analysis. Co-supervisor Dr Ake Fagereng will train the student in earthquake geology. The Bristol Doctoral College provides a wide range of training opportunities for postgraduate researchers, including personal and professional development.

Background reading and references

Gomberg, J. (2018). Unsettled earthquake nucleation. *Nature Geoscience*. Brodsky, E. E., & Lay, T. (2014).
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Improving physics-based aftershock forecasts during the 2016–2017 Central Italy Earthquake Cascade. *Journal of Geophysical Research: Solid Earth*.

Useful links

http://www.bristol.ac.uk/earthsciences/courses/postgraduate/

NERC GW4+ DTP Website:

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The application deadline is Friday 8 January 2021 at 2359 GMT.
Interviews will take place during the week commencing 8th February 2021.

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