Title: Fault distributions and seismic hazard in evolving normal fault networks

Supervisors Lara Kalnins (lara.kalnins@ed.ac.uk, University of Edinburgh), Richard Walters (Durham University) and Ian Main (University of Edinburgh)

Project Background

In plate boundary zones, brittle deformation in the upper crust occurs through progressive growth and linkage of a network of faults. The evolution of these networks over time has major implications for both the mechanics of crustal deformation and for seismic hazard. The connectivity of fault segments within a network exercises strong control on the likelihood of cascading rupture of multiple segments (Manighetti et al., 2007), which causes the largest magnitude earthquakes in these networks. Globally, this sort of rupture causes most earthquake fatalities (England & Jackson, 2011).

However, it is difficult to estimate how continental fault networks have grown and how the driving tectonic forces have changed through time, and, therefore, how existing fault systems may develop and change in future. Networks of extensional faults on the outer rise of subducting oceanic plates offer a unique opportunity to investigate how fault network evolution and growth relate to tectonic forcing, because the stress at the outer rise relates to bending of the plate as it approaches the trench. We can therefore use distance from the trench as a proxy for time (e.g. Boston et al., 2014) in order to relate a 'known' stress history to geometric observations of the fault network and spatio-temporal patterns of seismicity. A major unanswered question is how fault network maturity and geometry affects the likelihood of seismic sequences (e.g. the 2016 Central Italy seismic sequence) versus large multi-segment earthquakes (e.g. the 2016 Kaikoura, NZ earthquake).

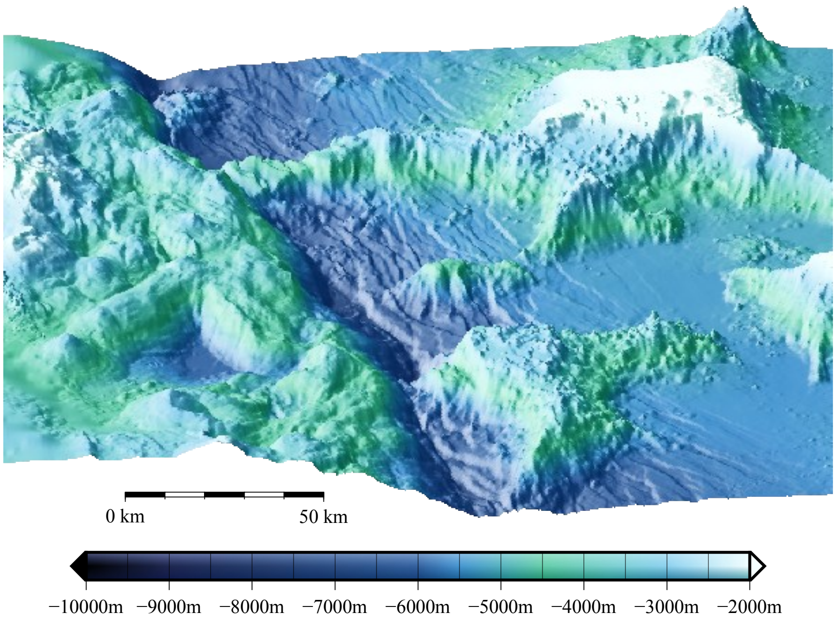

Figure 1: Normal faulting near Fryer Guyot, Marianas Trench

Key Research Questions

The fundamental research questions that would be addressed during this study are:

- How do networks of normal faults grow and evolve as the downgoing plate approaches the trench and bending increases?
- How is this growth influenced by factors such as plate strength (linked to age) and strain rate (linked to convergence rate and slab angle)?
- What patterns of seismicity are associated with fault networks at different stages of maturity, in particular the balance between large, multi-segment earthquakes versus smaller clustered events?

Methodology

The first objective will be to compile a global database of outer rise bathymetry, seismic reflection data, and earthquake locations, magnitudes, and mechanisms. This will be used to map normal fault networks on the downgoing plate and to estimate fault length, total displacements, displacement-length profiles, and strain histories. The second phase will examine the spatio-temporal development of the networks, comparing the history of finite strain and network maturity with the inferred history of tectonic stress. Networks from different outer rises will be used to explore the influence of factors such as plate strength and strain rate. The final stage will focus on how the proportion of clustered seismicity versus multi-segment earthquakes varies with fault network maturity and building simple probabilistic models to simulate seismicity records on varying types of fault network.

Preliminary Timeline	
0-12 months	Lit review, compile database, map and investigate 1 or 2 chosen outer rises, 1st year report
12-24 months	1st manuscript, extend mapping/development analysis globally
24-36 months	Analyse seismicity distribution, seismicity modelling
36-42 months	Preparation of thesis for submission and subsequent manuscripts

Training
A comprehensive training programme will be provided, comprising both specialist scientific training and generic transferable and professional skills. You will receive training in analysing geophysical data including bathymetry, seismic reflection data, and earthquake catalogues, as well as specialist computing packages (e.g., GMT, GIS packages, Petrel). Through Walters, you will become a member of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET), and will have the chance to attend COMET meetings and benefit from shared expertise in this area across several universities. You will also have the opportunity to present results at national and international conferences and will be encouraged to publish in leading scientific journals.

Requirements
Applicants should have a good first degree in Geology, Geophysics, or a related subject. The ideal candidate would be enthusiastic about earthquakes and faulting and have good numerical skills. Experience with GIS or Petrel would be advantageous, but is not essential.

References
1) Boston, B., Moore, G.F., Nakamura, Y. and Kodaira, S., 2014. Outer-rise normal fault development and influence on near-trench décollement propagation along the Japan Trench, off Tohoku. *Earth, Planets and Space*, *66*(1), p.135.
2) England, P. and Jackson, J., 2011. Uncharted seismic risk. *Nature Geoscience*, *4*(6), p.348.
3) Manighetti, I., Campillo, M., Bouley, S. and Cotton, F., 2007. Earthquake scaling, fault segmentation, and structural maturity. *EPSL*, *253*(3), pp.429-438.

Project Summary: Subduction zone outer rises: a natural laboratory for studying the development of normal fault networks and seismicity patterns