Imperial College London

Natural Environment Research Council

2023_27_ESE_Bell: Investigating subduction plate boundary earthquake hazards using controlled-source seismic data

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Subduction plate boundary faults are capable of generating some of the largest earthquakes and tsunami on Earth. However, in the last two decades a new type of seismic phenomena has been discovered at subduction zones globally: slow slip events (SSEs). These are transient episodes of aseismic slip faster than plate motion rates but too slow to incite seismic waves. The physical mechanisms that lead to SSEs remain poorly understood and their potential to trigger highly destructive earthquakes and tsunami on faults nearby is unknown, making slow slip a new and uncharted aspect of earthquake hazards. The growing concentrations of populations in regions prone to great earthquakes and tsunami makes resolving what controls whether a plate boundary fault ruptures in large earthquakes or slowly in SSEs one of the most urgent and societally important challenges in seismology today.

An ideal natural laboratory to investigate controls on subduction plate boundary fault seismic behaviour is the Hikurangi subduction zone in New Zealand. Geodetic data reveal that the portion of the plate boundary underlying Wellington City is interseismically locked (often considered a proxy for high earthquake potential) to depths of 30-50 km, but the northern part is predominately unlocked and slips in slow slip events. The physical properties and processes responsible for controlling the dramatic along-strike change in interseismic locking depth and fault slip behaviour are poorly understood. Given similarities in slab age and convergence velocities along the margin, these are unlikely to be the explanation. Other factors that may be responsible include: the roughness of the incoming plate; thickness, composition and physical properties of the incoming sediments, and over-riding plate fluid content and permeability (controlled by networks of faults and fractures).

The aim of this PhD is to characterise the nature of the incoming Pacific plate and structure of the overriding plate along the Hikurangi margin using new and existing 2D and 3D seismic reflection data, integrated with other geological and geophysical datasets (e.g. drilling data, tomography models, magnetic and gravity data), and to investigate correlations with interseismic locking and seismic behaviour. We will acquire a new seismic reflection dataset in April 2023 targeting the incoming plate and the student will be involved in interpreting these new data. In addition, the student will explore the application of machine learning techniques to automatically map faults within the deformed overriding plate in 3D seismic data to characetise its structure and fluid-flow pathways. The application of these technologies to identify reverse faults is novel and challenging.

This project suits a geophysicist interested in active-source seismic data and tectonic processes. The project will be based at Imperial College and the student will spend extended periods of time at GEOMAR, Germany and GNS Science, New Zealand.