IAPETUS

NERC DOCTORAL TRAINING

The topographic signature of earthquake-triggered landslides

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Durham University, Dept of Geography
In partnership with British Geological Survey

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Key Words	**Landslides, earthquakes, erosion, topography, sediment**

Overview

It is well-established that landslides in general, and bedrock landslides in particular, play a critical role in shaping mountainous topography and controlling the efflux of sediment from orogens (Hovius et al. 1997; Densmore et al. 1998; Egholm et al. 2013). It is equally well-established that large earthquakes are one of the dominant triggers of landsliding in mountain belts, causing landslides and sediment transfer over large areas (Keefer, 1984; Pearce and Watson, 1996; Dadson et al., 2004). Densmore and Hovius (2000) hypothesised that, at the scale of individual hillslopes, earthquake-triggered landslides should be clustered at ridge crests because of topographic focusing of seismic waves, a pattern that was documented by Meunier et al. (2007, 2008). More recently, Parker et al. (2011) and Hovius et al. (2011) argued that earthquake-triggered landslides may partly or completely counteract the material added to an orogeny by coseismic slip, raising fundamental questions about how mountainous topography is built and maintained by active faulting across multiple earthquake cycles.

All of these investigations of the interactions between landsliding and topographic form suffer from important limitations, however. Meunier et al. (2007, 2008), like Densmore and Hovius (2000), focused on landslide position on individual hillslopes, amalgamating landslides from different portions of the mountain belt into a single distribution. Hovius et al. (2011) addressed landsliding within a single catchment in Taiwan, while Parker et al. (2011) considered only the bulk volumes of landslide material and coseismic rock uplift, rather than their spatial distribution.

Fig. 1. Coseismic landslides near the epicentre of the 2008 M_w 7.9 Wenchuan earthquake, China

These limitations mean that we cannot currently answer a number of important research questions related to the growth of mountainous topography, including:

1) What is the topographic fingerprint of earthquake-triggered landsliding across an entire mountain belt?

2) In orogens where the locus of active faulting has shifted over time, does the locus of landsliding shift as well? How do such shifts affect the morphology of the landscape and the distribution of sediment storage within the orogen?

3) Using the outcomes of (1) and (2), can we use the topography as a robust indicator of landslide occurrence, and thus hazard, over short to medium time scales (e.g., one or several earthquake cycles)?

This PhD studentship sets out to answer these outstanding questions in a range of different orogens worldwide. The proposed research sits equally under the Geodynamics and Earth Resources (crustal processes) and Hazards, Risk, and Resilience (landsliding) research themes within IAPETUS. The studentship takes full advantage of several recent advances that now make this problem tractable at the orogen scale, including (1) the advent of consistent, robust global data sets for topography (e.g., filled SRTM or the upcoming Tandem-X), active faulting (e.g., GEM Active Faults Database), climatic data (e.g., APHRODITE for Asia; Yatagai et al. 2009); (2) new process-based understanding of landslide area-volume scaling relationships (Larsen et al., 2010), hillslope form in areas of rapid erosion (Hurst et al., 2012), and sediment storage in mountain belts (Straumann and Korup, 2010; Bloethe and Korup 2013); (3) compilation of available earthquake-triggered landslide databases (Parker, 2013); (4) growing archives of published erosion-rate and cooling-rate data from orogens worldwide; and (5) next-generation landscape evolution models that allow the interactions between rock uplift, landsliding, sediment storage, and fluvial incision to be explored (Egholm et al., 2013; Lague et al., in prep).

Methodology

The student will

1. Combine existing landslide distributions from recent earthquakes with SRTM (and, when available, WorldDEM) data and available data on erosion and cooling rates, to establish first-order correlations. The initial focus will be on the Southern Alps, New Zealand; the Central Range, Taiwan; and the Longmen Shan, China. These orogens span a range of scales and have widely varying spatial patterns of active faulting and rock uplift.
2. Use the outcomes of (1) to look for persistent geomorphic signals of earthquake-triggered landslides in other orogens, including the Himalayas, Peruvian Andes, and the Tien Shan. In particular, the student will compare and contrast topography across long-term seismic gaps, and across regions with different spatial distributions of active faulting (e.g., central Nepal vs. Bhutan and the Shillong Plateau), and where possible will attempt to compare the results with regions with few earthquakes (e.g., South Africa, Rocky Mountains).
3. Establish the degree of correlation between landslide location and areas of sediment storage or accumulation in multiple orogens.
4. Adapt an existing landscape evolution model to include earthquake-triggered landsliding, and use the model to simulate patterns of landsliding and sediment production across different portions of a mountain belt (e.g., headwaters/upper drainage basins due to slip on an out-of-sequence thrust, versus foothills/lower drainage basins due to slip on a frontal fault).
5. Place constraints on a topographic signature of landsliding as an indicator of short to medium term landslide hazard.

The work will involve periods spent at both Durham and the British Geological Survey in Keyworth, as well as collaborative visits to project partner Lague at the University of Rennes, France.

Timeline

Year 1
Literature review and compilation of existing landslide datasets
Compilation and analysis of topographic and erosion-rate data from initial orogens
Year 2
Extension to other orogens
Field work to examine field evidence for patterns of landsliding and sediment storage in the Southern Alps, building on work in year 1
Begin adaptation of numerical model, in collaboration with project partner Lague
Year 3
Analysis of sediment storage and correlations with landslide locations and topographic characteristics
Numerical experiments
Conference and manuscript preparation
Year 4
Integration of results into comprehensive topographic signature of landsliding, with emphasis on hazard identification
Manuscript and thesis preparation

Training & Skills

The student will undergo specialist training in the specific techniques and approaches to be used in the project. This will include GIS analysis, manipulation of large spatial data sets, quantitative topographic analysis using Matlab and other software packages, and numerical modelling using an existing landscape evolution code provided by project partner Lague. The precise balance between these different aspects of the project will depend on the skills, aptitude, and interest of the candidate.

References & Further Reading

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Further Information

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