IMPERIAL

Reconstructing erosion rates and sediment supply from mountain belts using palaeo-topographic and palaeo-hydrological constraints

Supervisors

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Research Group

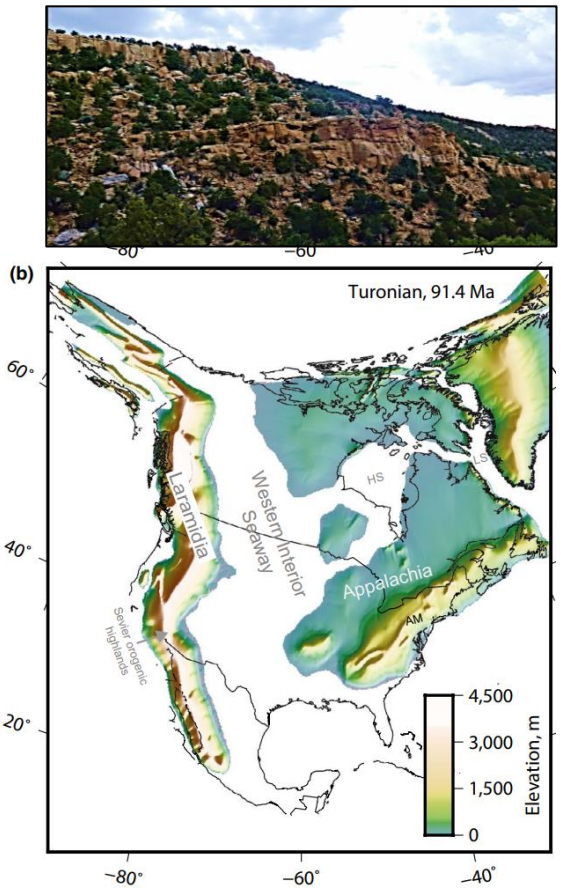
Landscapes and Basins Research Group (LBRG)

Project Summary

New methods to reconstruct the palaeohydrology, flow regimes and sediment fluxes from ancient rivers can give important new insights into the evolution of mountain belts and basins, particularly when coupled with digital elevation models of landscapes in the past (pDEMs). This project leverages both to understand the supply of water and sediment across the Earth in deep time, a critical challenge in the Earth Sciences.

Research Context and Objectives

Geological stratigraphy is the only physical record we have of mass movement across the surface of the Earth as a result of past environmental conditions. Consequently, siliciclastic sedimentary deposits represent the time-integrated product of erosional fluxes from terrestrial catchments to depositional basins, as a result of the tectonic and climatic boundary conditions prevailing at the time. Understanding how, when and where sediment was delivered from the continents to oceans therefore represents a major research challenge in the Earth Sciences and is also of importance for applications such as resource identification and carbon capture and storage (CCS).



One way to address this problem is to use paleo-digital elevation models (pDEMs) coupled with field-based palaeo-hydrological techniques to predict the locus, magnitude and variability of erosional fluxes across the Earth's surface in the past. An example of preserved fluvial channels (upper panel) and a pDEM of North America from Lyster et al., 2020 (lower panel), is shown in the figure, right. This PhD will develop novel strategies to reconstruct erosional sediment fluxes from mountain belts in the past using these tools, focusing on well-constrained time-slices within the upper Carboniferous of the Appalachian foreland basin, USA, and Oligocene-Miocene deposits of the Spanish Pyrenees.

For the two key study areas selected the student will:

(1) Use field-based observations, combined with novel palaeo-hydrological methods developed at Imperial, to calculate palaeo-river morphology, water discharge rates and instantaneous sediment fluxes. These will be used to constrain supply rates from source catchments for key time intervals.

(2) Use pDEMs to reconstruct catchments and palaeo-sediment routing systems at larger scale and use these to independently estimate erosion rates and sediment fluxes from a range of climate estimates and model outputs, coupled to a BQART model (e.g., Lyster et al., 2020).

(3) Ground-truth predictions using field observations where possible, alongside estimates of preserved geological volumes of sediments in key depocentres and bedrock exhumation data from thermochronology.

(4) Use these insights to estimate sediment and water intermittency factors as a function of climate in the past.

The outcome of this study will enhance our ability to use pDEMs to predict sediment fluxes, erosion rates from the continents. The work will also enable us to estimate supply intermittency, a major unknown in predictive modelling of landscapes across time and space.

Collaborators and partners on the project:

Benjamin Greselle, Neftex-Halliburton, and Kentucky Geological Survey.

Further reading:

Lyster, S. J., A. C. Whittaker, P. A. Allison, D. J. Lunt, and A. Farnsworth. 2020. “Predicting Sediment Discharges and Erosion Rates in Deep Time—Examples from the Late Cretaceous North American Continent.” Basin Research 32: 1547–1573

Lyster, S. J., A. C. Whittaker, G. J. Hampson, E. A. Hajek, P. A. Allison, and B. A. Lathrop. 2021. “Reconstructing the Morphologies and Hydrodynamics of Ancient Rivers from Source to Sink: Cretaceous Western Interior Basin, Utah, USA.” Sedimentology 68: 2854–2886.

McLeod, J. S., J. Wood, S. J. Lyster, J. M. Valenza, A. R. T. Spencer, and A. C. Whittaker. 2023. “Quantitative Constraints on Flood Variability in the Rock Record.” Nature Communications 14: 3362

Who are we looking for?

We are looking for motivated students with a degree or masters in Earth Sciences, or a related discipline, who have a real interest in sedimentary geology and landscape dynamics. The project is ideally suited to a student who is passionate about field geology and quantitative Earth observation. The student will gain experience of integrating sedimentological, DEM-based and numerical data sets and will have the opportunity to visit key outcrops in the field. The candidate will have the opportunity to develop their career by presenting at international conferences and publishing in high-impact journals.