Imperial College London

Natural Environment Research Council

2024_31_ESE_AW: Reconstructing erosion and sediment supply from the continents: palaeo-topography, climate models and palaeo-hydrology

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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 (and will be) 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 identifying mineral resources and carbon capture and storage (CCS).

One way to address this problem is to use paleo-digital elevation models (pDEMs) coupled to climate models and palaeohydrological techniques to predict the locus, magnitude and variability of erosional fluxes across the Earth's surface in the past. This PhD will develop novel strategies to reconstruct erosional sediment fluxes from the continents, focusing initially on time-slices within the Cretaceous and Eocene. For the key study areas selected the student will:

(1) Compute palaeo-catchments and sediment routing systems from pDEMs to estimate erosion rates and sediment fluxes using: (i) a suite of temperature, rainfall estimates coupled to a BQART model (e.g., Lyster et al., 2020); ii) catchment scaling relationships; (iii) Landscape evolution modelling.

2) Investigate the potential effect of climate variability using predictions from palaeo-climate model data including rainfall in the wettest month and ratios of wettest to average precipitation.

3) Use field-based observation to calculate water discharge rates and instantaneous sediment fluxes to estimate water discharge and supply intermittency in the past.

4) Ground-truth predictions using field observations, estimates of preserved geological volumes of sediments in key depocentres and bedrock exhumation data from thermochronology to give insight into the geological applicability of the various sediment supply models tested, and to evaluate the sensitivity of landscape systems at the Earth's surface to environmental change.

5) Use these insights to how the Earth's surface may respond to well-documented climate scenarios in the past and future.

The outcome of this study will enhance our ability to use pDEMs to predict sediment fluxes, erosion rates from the continents, and to reconstruct depocentre characteristics for applications such as CCS. The work will also enable us to estimate supply intermittency, a major unknown in predictive modelling of landscape sensitivity to future climate change.

Ref: Lyster et al., 2020. Predicting sediment discharges and erosion rates in deep time – examples from the late Cretaceous North American continent. Basin Research, 32, 1547–1573, https://doi.org/10.1111/bre.12442