Phosphorus fluxes and dynamics in P-deficient bedrock catchments: the anorthosites of Rogaland (SW Norway)

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Introduction and approach: Phosphorus (P) is an essential component of plant and animal life, a key regulator of ecosystem function and primary productivity and P availability can limit primary productivity in terrestrial or aquatic ecosystems (Schlesinger and Bernhardt, 2013). In most temperate environments, P flux through the Holocene has been driven by a combination of mineral (apatite) weathering, atmospheric aerosol inputs (dust, biotic particulates from biomass burning) and, more recently, anthropogenic inputs such as urban and agricultural runoff. In peatlands, variations in P accumulation have implications for N fixation and, in turn, rates of peat decomposition and the amount of carbon stored through time. As peatlands represent a globally-important component of the carbon (C) cycle, temporal and spatial changes in phosphorus deposition have major implications. In light of evidence suggesting 20th-century anthropogenic emissions have altered lake nutrient stoichiometry (Brahney et al. 2014), better-constrained lateral P flux estimates associated to each driver are clearly needed. However, inadequate spatial and temporal resolution of long-term biogeochemical data has meant quantifying the relative contribution of anthropogenic and natural fluxes remains a persistent challenge. It also represents a notable omission from estimates of global nutrient and carbon pools, Earth System models and projections of future carbon storage in lakes and peatlands.

An approach has recently been trialed to address these distinct uncertainties by analysing lake sediment records from Rogaland, southwestern Norway, a region underlain by bedrock dominated by P-deficient anorthosite. High-latitude, upland lakes with granitic catchments (i.e., P-rich bedrock) generally yield reliable records of long-term P accumulation, with a characteristic postglacial sediment profile: depletion of soil stores via apatite dissolution during early deglaciation produces a peak followed by a steady decline (Boyle et al., 2013). Lakes in regions of growing population density and/or agricultural intensification, a reversal occurs in recent centuries or millennia dependent on the length and intensity of land-use, representing a human-mediated flux (Boyle et al., 2014). Atmospheric nutrient deposition is a primary driver of productivity ombrotrophic (rain-fed) peatlands. A link between the anthropogenic atmospheric component and enhanced nutrient cycling in northern peatlands has been tentatively demonstrated (Schillereff et al., 2016) but the complexity of internal biogeochemical cycling makes it difficult to apportion relative contributions.

This studentship will build on preliminary work and conduct a comprehensive, high-resolution and multi-proxy investigation of lakes and peatlands in southwestern Norway to collate data that redress major uncertainties around nutrient dynamics. This research should ultimately produce well-constrained estimates of P flux associated to specific anthropogenic (agricultural dust, urban aerosols, biomass burning) and external and internal natural drivers. Such data will substantially improve our understanding of (i) the lateral transfer mechanisms of phosphorus and their spatial scales, e.g. contrasting hemispheric nutrient-rich dust circulation with short-distance transfers of airborne biotic material; (ii) the anthropogenic influence on lake and peatland nutrient stoichiometry and the effects on long-term carbon cycling and (iii) effects of anthropogenically-perturbed nutrient cycles on future global carbon sequestration in lakes and peatlands. Working in this P-deficient setting will also represent one of the first attempts globally to systematically evaluate Holocene landscape and vegetation development in mineral P-limited environments and lake acidification trajectories in the absence of apatite dissolution.

Unravelling the relative controls on long-term nutrient dynamics is hampered by inadequate data and the complexity of biogeochemical processes. This studentship will adapt a novel approach analysing lake sediments and peat sequences from Rogaland, southwestern Norway, a region dominated by P-deficient anorthositic bedrock. Biogeochemical characterisation of the lake and peatland sediments will involve a suite of techniques including XRF geochemistry, NIRS, CN elemental analysis [and C & N stable isotope measurements] as well as sequential P extractions to eludicate forms of available phosphorus. To understand the broader evolution of lakes and catchments in regions of P-deficient bedrock, other analyses will include pollen and diatom analyses.

Research training: The prospective PhD research will gain comprehensive training in palaeoenvironmental methods, sedimentology, and geochemistry. These data will be used to test an ensemble of process hypotheses. He/She will benefit from a supervisory team including Richard Chiverrell (geochemistry, NIRS, FTIRS, geochronology), John Boyle (Geochemistry), Daniel Schillereff (TCN analyses and sedimentology), Viv Jones (UCL: diatom analyses. He/She will benefit from training opportunities inherent to the Doctoral Training Partnership that joins expertise from Liverpool, Manchester and the National Oceanographic Centre, and be part of the 5th cohort of enthusiastic DTP PhD students and will develop strong interdisciplinary skills through specific training.

References:

Boyle JF (2007) Simulating loss of primary silicate minerals from soil due to long-term weathering using Allogen: comparison with soil chronosequence, lake sediment and river solute flux data. Geomorphology 83:121–135

Boyle J, Chiverrell R, Plater A, Thrasher I, Bradshaw E, Birks H et al (2013) Soil mineral depletion drives early Holocene lake acidification. Geology 41:415–418