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Tracing peatland geomorphology

Sediment and contaminant movements in eroding and restored areas

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Blanket peats face many pressures including anthropogenic disturbance and pollution, and large areas of blanket peat are significantly degraded and actively eroding as a direct result.

The consequences of erosion are diverse and often detrimental to ecosystem function, which can affect the economic and scientific value of these marginal areas.

In the last decade, blanket peats have been highlighted as important stores of soil carbon, and play a vital role in global carbon cycling. They can also act as sinks of atmospherically deposited heavy metals.

Erosion negatively impacts peat function, including carbon & pollutant storage.

THE IMPORTANCE OF GEOMORPHOLOGY

The physical rehabilitation of peatlands is of great importance in preventing the spread of erosion and restoring ecosystem function.

In intact peatlands, geomorphology is simply a boundary condition, whereby landscape position influences the type of bog that forms.

However, in severely eroded peatlands, the development of gully networks produces a highly variable landscape, and geomorphological form and process become key controls on how peatlands function.

An understanding of geomorphological controls on sediment release, carbon cycling and contaminant flux is therefore essential to identify and mitigate the negative impacts of peatland erosion.

THE PEAK DISTRICT NATIONAL PARK

The blanket peats of the Peak District, Southern Pennines, UK are amongst the most heavily managed, eroded and contaminated in the world.

The near-surface layer of the peat is contaminated by high concentrations of atmospherically deposited heavy metals.

Whilst not desirable, this legacy of lead pollution and its release offer a unique opportunity to trace peatland sediment movements and investigate the controls on sediment and contaminant movements.

Development of methods

A suite of established field, analytical, and modelling techniques have been modified and adapted for use in peatland environments.

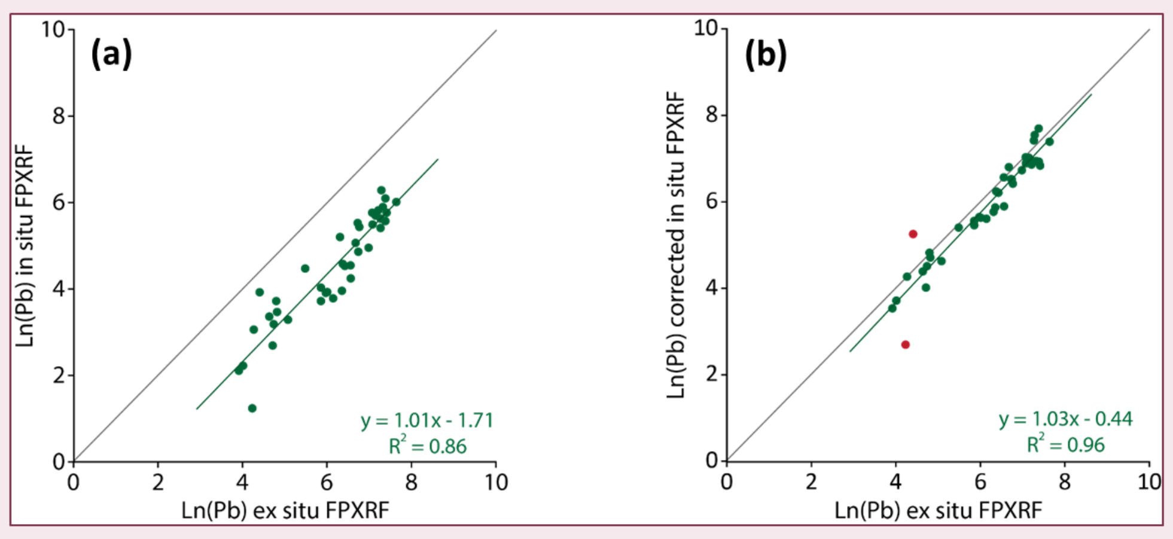

Figure 2: Relationships between (a) raw *in situ* and *ex situ* FPXRF, and (b) moisture corrected *in situ* and *ex situ* FPXRF (after Shuttleworth et al 2014).

When corrected for moisture content, in situ **field portable XRF (FPXRF)** Pb readings correlate strongly with results obtained by processing samples ex situ (Shuttleworth et al 2014).

FPXRF provides a cost-effective and rapid tool for assessing Pb contamination in peatlands.

The **time integrated mass-flux samplers (TIMS)** first described by Owens et al (2006) can be adapted for deployment at multiple remote field sites by replacing the standard gravel filling with a light-weight polystyrene alternative.

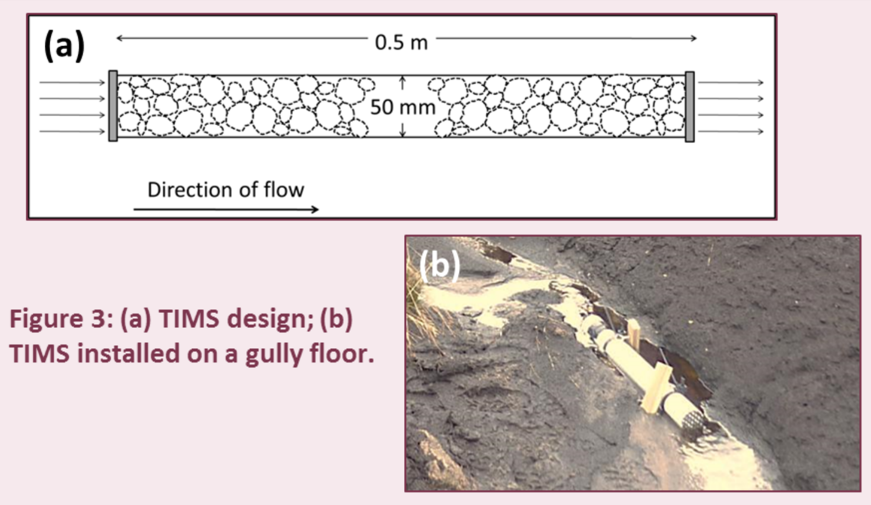

Figure 3: (a) TIMS design; (b) TIMS installed on a gully floor.

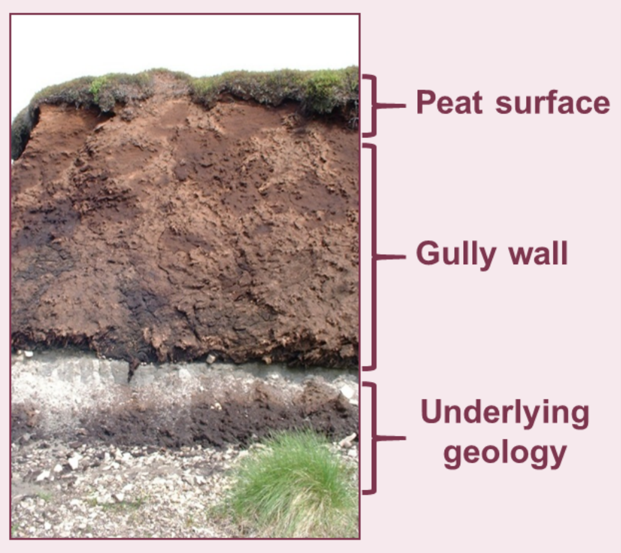

Figure 4: Distinguishable sources of suspended sediment in eroding contaminated peatlands.

Sediment **source fingerprinting** and numerical mixing models traditionally used in minerogenic systems can be applied to contaminated peatland catchments.

By exploiting the pollutants as a distinctive fingerprint of surface derived material, sediment from interfluve surfaces can be distinguished from material eroded from gully walls.

Controls on sediment dynamics

Vegetation and sediment production are closely linked. Vegetation plays an important role in stabilising the peat's surface and trapping mobilised sediment.

Sediment 'preparation' by desiccation and frost action dictates the timing of POC and Pb release.

Figure 7: Freshly deposited peat accumulating behind tussocks of *Eriophorum* on a gully floor.

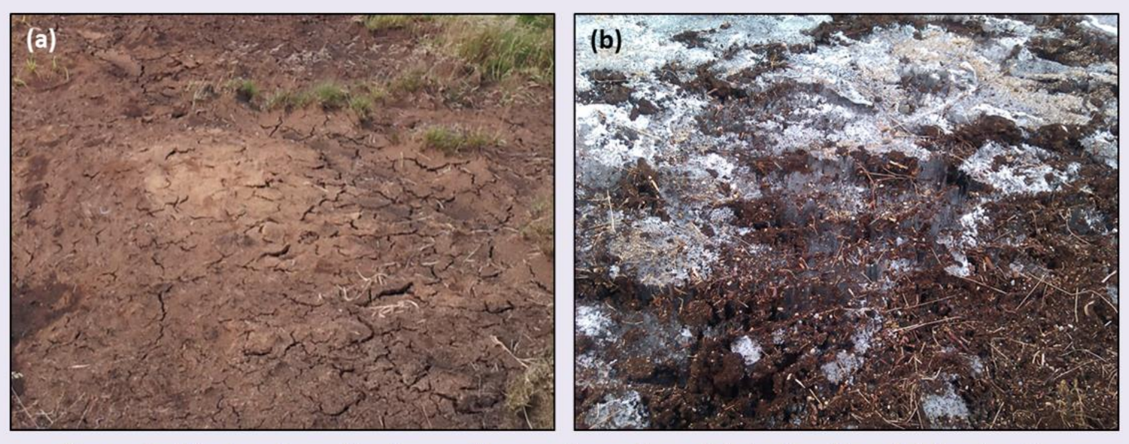

Figure 8: Effects of weathering on the peat's surface: (a) desiccation, (b) frost action (needle ice).

The degree of degradation influences Pb storage and release, and determines the dominant source of suspended sediment.

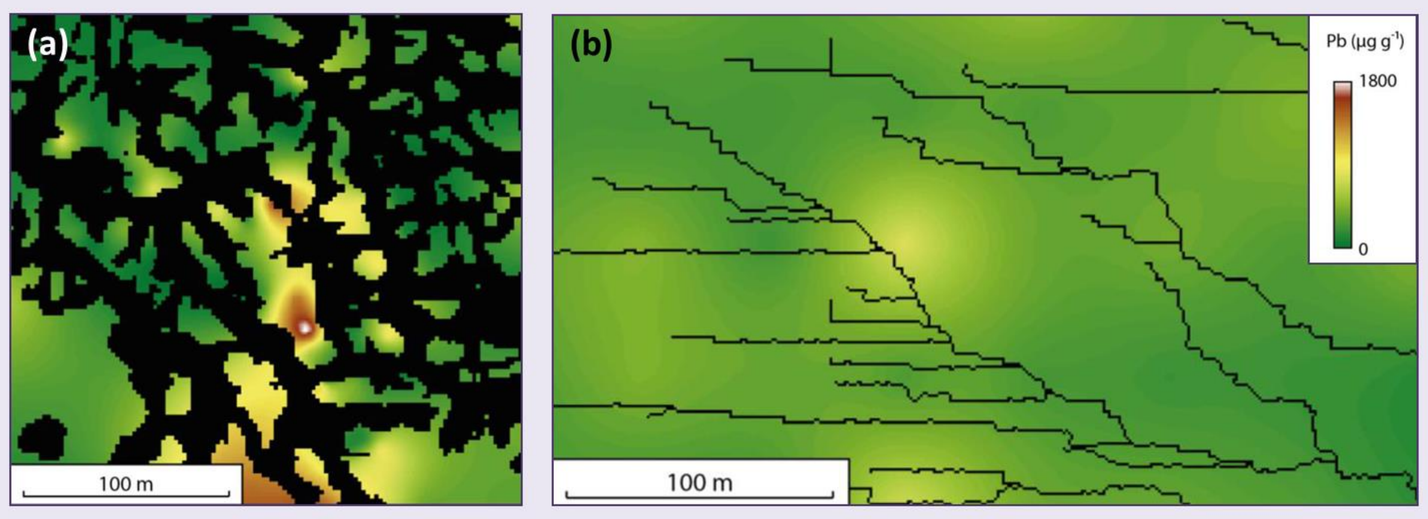

Figure 9: Surface Pb concentration at (a) eroding and (b) intact sites. Removal of surface material at the eroding site has exposed the peak in Pb deposition in some areas, creating 'hot spots' of exposed contamination which is subsequently mobilised to the fluvial system.

Antecedent water tables influence the timing and the nature of sediment entering the fluvial system during storm events.

Sediment dynamics at different spatial scales

When looking at sediment dynamics at the **landscape scale**, the presence or absence of vegetation appears to be the dominant control on sediment and contaminant release (Shuttleworth et al 2015a). Pb and C export following re-vegetation is comparable to an intact peatland, while fluxes are two orders of magnitude greater in areas with little or no vegetation cover.

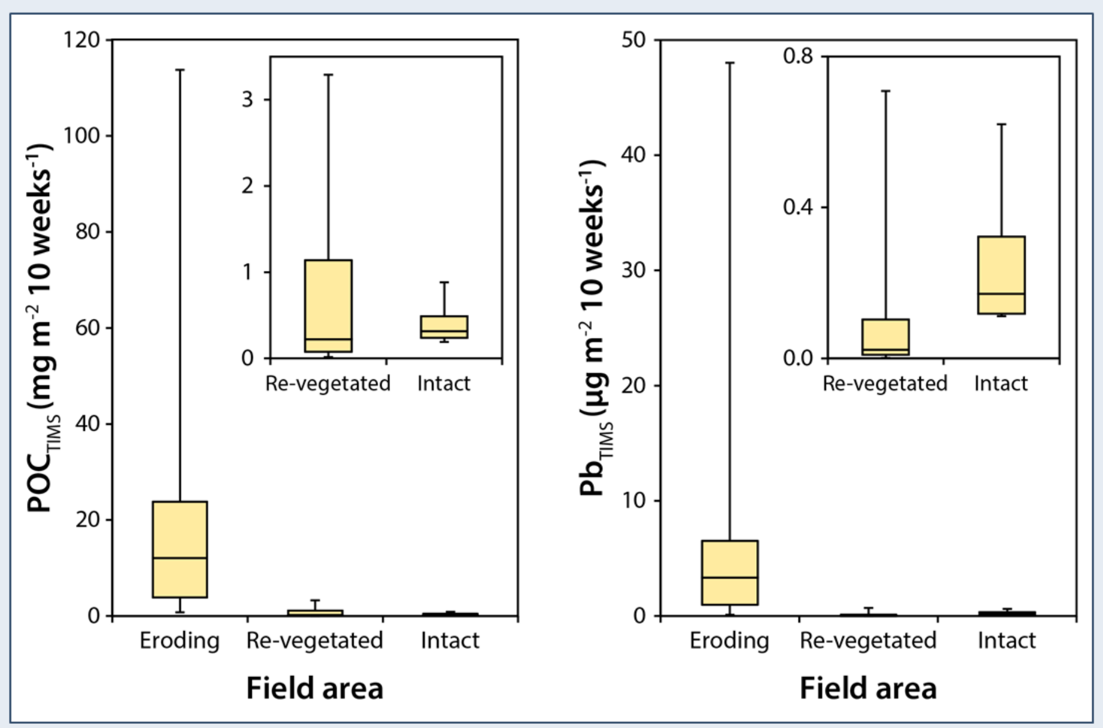

Figure 5: Relative fluxes of POC and Pb at eroding, restored, and intact field sites (after Shuttleworth et al 2015a).

Figure 6: Desiccated peat collecting on gully floor after a prolonged dry period.

At the **catchment scale**, sediment supply dictates suspended sediment composition (Shuttleworth et al 2015b). This is controlled by the physical availability of erodible organic sediment produced through weathering, and the degree of hydrological connectivity which governs the time scale at which ephemeral headwaters release higher Pb concentrations become linked to the main channel.

Plot scale analysis highlights the variety of mechanisms controlling Pb release and storage on different catchment surfaces: Wind erosion may be driving patterns of Pb storage on interfluve surfaces, aspect is key in controlling sediment preparation and Pb storage on gully walls, and gully depth and distance from gully head influences Pb concentrations found in gully floor sediments.

Implications for restoration and management

Shuttleworth et al (2015a) offer the first time-integrated assessment of the effect of peatland re-vegetation on sediment production at the landscape scale, and provide a **strong theoretical justification for peatland re-vegetation techniques**.

Current estimates of suspended sediment associated Pb export (Rothwell et al 2010) in eroding peatlands do not take into account areas of bare peat exposed on interfluve surfaces, and may be too low. **Bare interfluves should be the focus of peatland restoration** as a matter of priority to reduce sediment associated Pb export.

Gully floor vegetation intercepts POC at the slope-channel interface, which has the potential to oxidise to CO_2 and contribute to the overall greenhouse gas emissions from the area. **Further research into the magnitude and longevity of POC storage by gully floor vegetation is needed to fully understand the impact of restoration on the overall carbon balance** (e.g. Evans et al 2013).

Increasing catchment wetness will increase hydrological connectivity, linking ephemeral headwaters to the main channel (Goulsbra et al 2014). This **may release more contaminated sediment into the main channel** and should be considered and accounted for in future restoration initiatives (Shuttleworth et al 2015b).

Pb is preferentially released in pulses following dry or frosty conditions which may have implications for downstream water quality.