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Bayesian integration of radioisotope dating (210Pb, 137Cs, 241Am, 14C) and an 18-20th century mining history of Brotherswater, English Lake District

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Lake sediment records are often a useful tool for investigating landscape evolution as geomorphic changes in the catchment are reflected by altered sediment properties in the material transported through the watershed and deposited at the lake bed. Recent research at Brotherswater, an upland waterbody in the Lake District, northwest England, has focused on reconstructing historical floods from their sedimentary signatures and calculating long-term sediment and carbon budgets from fourteen sediment cores extracted from across the basin. Developing accurate chronological control is essential for these tasks.

One sediment core (BW11-2; 3.5 m length) from the central basin has been dated using artificial radionuclide measurements (210Pb, 137Cs, 241Am) for the uppermost sediments and radiocarbon (14C) for lower sediments. The core appears to span the past 1500 years, however a number of problems have arisen. We present our explanations for these errors, the independent chronological techniques used to generate an accurate age-depth model for this core and methods for its transferral to the other 13 cores extracted from the basin.

Two distinct 137Cs markers, corresponding to the 1986 Chernobyl disaster and 1960s weapons testing, confirm the 210Pb profile for sediment deposition since ∼1950, but calculations prior to this appear erroneous, possibly due to a hiatus in the sediment record. We used high-resolution geochemical profiles (measured by XRF) to cross-correlate with a second 210Pb-dated chronology from a more distal location, which returned more sensible results.

Unfortunately, the longer 14C sequence exhibits two age-reversals (radiocarbon dates that are too old). We believe the uppermost two dates are erroneous, due to a shift in inflow location as a flood prevention method ∼1900 A.D., dated using information from historical maps. The lower age-reversal coincides with greater supply of terrigenous material to the lake (increased Zr, K, Ti concentrations), pointing to a hillslope clearance event. A widespread concurrent hillslope gullying phase in northwest England triggering enhanced soil erosion is thus the most likely explanation, as the presence of old carbon is a known issue for lakes in the region at this time.

Applying a Bayesian age-depth modelling protocol is able to account for these age-reversals with some success. However, the greatest uncertainty in the model occurs across the 1700 -1900 A.D. time window as the radiocarbon percentages offer multiple age solutions due to fluctuating atmospheric 14C concentrations from fossil fuel emissions. We address this issue by incorporating into the model geochemical markers in the sediment core related to local point-source Pb mining of known-age; the most-likely age-depth curve is subsequently much more definitively resolved. Usefully, these mining-derived chronological markers bridge the temporal gap between artificial radionuclide and conventional radiocarbon dating which is a common problem in palaeolimnology.

These distinctive geochemical mining profiles (Pb, Zn, Cu) have been mapped across all cores, enabling precise core correlation and confident transferral of the age-depth model, and reveal highly spatially variable sediment accumulation rates. This has enabled more accurate sediment and carbon budgets to be calculated and some insight into palaeoflood frequency to be obtained from the Brotherswater sediment sequence.