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Cosmogenic dating of the evolution of rocky coastlines

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The study of the long-term dynamics of erosional rock coasts is inhibited by the destruction of geomorphic evidence of past cliff positions. This limits our understanding of the vertical foreshore platform erosion or down-wearing, and the lateral cliff retreat, to relatively short-term, often highly localised contemporary monitoring, historic map studies and poorly constrained empirical models. A recurrent problem is that rates of erosion and retreat are often comparable to measurement errors over short time scales and across representative spatial extents. The result is that long-term rates of retreat of rock coasts remain unknown and the magnitude and pattern of coastal change during the Holocene remains at best anecdotal. In multiplicative predictive models (e.g. the 'Brunn rule'), that combine retreat with sea-level change, small variations in contemporary rates of retreat derive large variations in modelled foreshore platform ages and future predicted shoreline positions. Recently, high-precision direct monitoring of cliff retreat rates has provided improved control on (present) rates of foreshore formation where virgin rock is exposed as the cliff face retreats. Critically contemporary erosion rates commonly appear at odds with the coastal erosion during the Holocene. We present an example from the North Yorkshire UK coast. Here, contemporary cliff retreat at rates of ∼0.02 myr-1 do not account for the ∼400 m of horizontal cliff movement exposing the shore platform, postulated to have occurred since the end of the Pleistocene (∼10,000 yrs) by Robinson (1977). This implies periods of increased cliff recession during the Holocene, presumably in response to variable environmental boundary conditions, notably relative sea level change.

Here we present a model in which erosion rates are constrained by modelling monitored rockfall magnitude frequency distributions, and validated over the long-term by cosmogenic radionuclide (CRN) exposure dating across the foreshore. Dating on actively eroding rock coastlines is inhibited by complex shielding in this environment. Here we model CRN concentrations as a function of local relative sea level change which is locally constrained by palaeolimnology, foreshore platform down-wearing constrained by long-term MEM monitoring, monitored cliff retreat and variable wave and tidal climate. The treatment of relative errors of contiguous samples using CRN dating is hypothesized to give new levels of detail on the erosion history of this coastline, and potentially permits foreshore platforms to be used to provide long-term erosion histories. More widely, in the UK there is a statutory requirement to predict shoreline positions up to 100 years into the future; a period effectively equal to the longest available mapping datasets, yet we lack any quantitative measure of longer-term (millennia) erosion rates as control, which we seek to obtain here.