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Using optical dating of beachrock for sea-level reconstruction

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Coastal sites in mid to low latitudinal environments often provide sedimentary material described as 'beachrock'. Beachrock is formed in the intertidal zone where sediment lithifies very rapidly (sediment is turned into rock within the span of only 10–20 years) due to the interplay of photosynthesis of algae, respiration of biomass and supersaturation of sea water with respect to $CaCO_3$. A beachrock is a sea-level index point for the maximum sea level if its age is known. Optically stimulated luminescence (OSL) is the suitable technique to determine the age of this sea-level indicator because most beachrocks contain sand-sized quartz grains which are sufficiently exposed to daylight in the intertidal area. After burial, i.e. during formation of the beachrock, the grains are sheltered from daylight and acquire a luminescence signal by exposure to environmental radioactivity. This environmental activity is not only low but also heterogeneously distributed in the sediment due to post-depositional precipitation of carbonate in the sediment pores and post-mortem Uranium uptake in molluscs shells. Recent innovations allow modelling these non-linear processes; the dose rate over time is constructed as a series of values where the water content is gradually replaced by carbonate and proportionately reduced until it reaches a new constant level. The age of the sample is estimated as the length of time needed for the integrated dose rate to equal the equivalent dose. Uncertainties in the dose rate and ages are estimated using a Monte Carlo approach. However, the carbonate model simplifies the true sedimentary process by assuming (i) interstitial carbonate is inert so the number of decays within a unit volume is constant; (ii) the growth of carbonate cement is linear over time and it is inversely correlated with the moisture content; uptake of Uranium is linear over time; (iv) there is no migration of radioisotopes within the sediment; and (v) the sediment is homogeneous at any particular time and the ionising radiation is in charged particle equilibrium.

In this study we examined 10 beachrock samples for which we have no independent age control but age constraints derived from glacio-isostatic adjustment models which provide a time window during which a sample should have been deposited. We tested the sensitivity of the carbonate model first to all input data and secondly to changes of water, carbonate and uranium in the sediment. In addition, we tested the effect of multi-grain averaging on the equivalent dose of the well-bleached quartz samples and how this, in turn, affects the age.

Test results indicate that the impact of uptake of unsupported Uranium in mollusc shells upon the effective dose rate is masked by the attenuation of radiation energy in the sediment when the carbonate matrix is inert. The dose rate then effectively depends on the amount of water/carbonate occupying the pore space during burial. The dose distribution changes drastically between 1 mm and 3 mm aliquot size revealing the presence of heterogeneously distributed radionuclides in the sediment. The larger aliquot size compensates to a certain extent for the attenuating carbonate body. The ages of 3 samples are in the expected time interval while the ages of all other samples seem to be slightly over- or underestimated. These inaccuracies reflect the non-linear and spatially diverse relationship between water and carbonate which is not fully accounted for neither by the carbonate nor by the conventional steady-state model available for dose-rate estimation.