Radiocarbon dating of mangrove sediments to constrain Holocene relative sea-level change on Zanzibar in the southwest Indian Ocean

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Abstract

Mangrove sedimentary deposits are sensitive to changes in sea level and can be used to reconstruct mid- to late Holocene sea-level fluctuations in intermediate and far-field locations, distant to the former polar ice sheets. However, they can be difficult to date using $^{14}$C because mangrove sediment can contain mixtures of carbon of different ages. The two main potential causes of error are younger mangrove roots penetrating down through the sediment column and bioturbation by burrowing animals which moves carbon up and down the sediment column. Both processes may introduce carbon not representative of the age of deposition of the layer being dated. This study reports new $^{14}$C dates on organic concentrates (10–63 $\mu$m) from mangrove sediments from Makoba Bay on Zanzibar (Unguja) where previous bulk sediment $^{14}$C age–depth profiles contained inversions and were therefore less useful for relative sea-level (RSL) reconstruction. Dates on organic concentrates provide a more coherent sequence of $^{14}$C ages compared with those from bulk sediments. These new data provide an improved environmental history and mid- to late Holocene RSL record for this site. Our reconstructions show that RSL rose during the mid-Holocene and reached within $\sim$3.5 m of present by c. 7900 cal. yr BP. RSL slowed as it reached present at or shortly after c. 7000 cal. yr BP, with falling and/or stable RSL from c. 4400 cal. yr BP to present. We are not able to determine whether there was a RSL highstand above present on Zanzibar during the mid- to late Holocene. The RSL reconstruction agrees broadly with changes predicted by the ICE-5G geophysical model, which includes 4 m of ice equivalent sea-level rise between 7000 and 4000 cal. yr BP. Our new dating approach has the potential to provide improved chronologies with which to interpret sea level data from this and other mangrove environments.

Keywords

far field, mangroves, pollen, radiocarbon dating, sea level, southwest Indian Ocean

Received 28 January 2014; revised manuscript accepted 7 January 2015

Introduction

The spatial and vertical distribution of mangrove vegetation and their associated deposits are sensitive to changes in sea level (Scholl, 1964a, 1964b; Woodroffe et al., 1985). Because of their widespread occurrence in tropical environments, mangrove deposits therefore provide potentially important sources of ‘intermediate’ and ‘far-field’ sea-level observations (i.e. from sites that are distant from the significant effects of glacio-isostatic adjustment (GIA) found close to former ice sheets) and can provide valuable constraints on ice-equivalent sea-level changes (e.g. Milne and Mitrovica, 2008; Milne et al., 2005). However, the potential of mangroves is difficult to exploit because of challenges when using the radiocarbon dating method.

Previous studies of fossil mangrove sediments show that where mangrove environments are present for any length of time, younger mangrove roots will penetrate the older underlying sediments and introduce young carbon into bulk $^{14}$C samples, which will be young compared with the age of their original deposition (e.g. Grindrod and Rhodes, 1984; Schofield, 1977; Smith and Coleman, 1967; Woodroffe, 1981, 1988b, 1990). Because mangrove roots can penetrate up to 2 m into underlying sediments (Hutchings and Saenger, 1987), this can be a significant problem when attempting to date mangrove sediment sequences. The problem is further compounded by bioturbation by a diverse fauna which may bring older organic material to the surface, increasing problems associated with obtaining reliable ages from these sediments.

We report a study designed to address the challenge of dating mangrove sediments by $^{14}$C AMS dating different size fractions of