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Palaeohydrological significance of late Quaternary strontium isotope ratios in a tropical lake

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Abstract

Ostracods preserved in late Quaternary sediments of Wallywash Great Pond, a fresh coastal lake in SW Jamaica, record temporal variations in the strontium-isotope composition of lake water. Oxygen-isotope and Sr/Ca ratios in ostracods reveal temporal variations in the lake's hydrology, related to effective precipitation, and in its salinity related to varying marine-saline groundwater input from changes in relative sea level. Evaluation of isotopic and trace-element data indicates that the stratigraphic variations in $^{87}Sr/^{86}Sr$ ratios during the late Quaternary are best explained by climatically-controlled hydrological changes. During wetter periods, the lake's Sr budget was dominated by springwater input with relatively low $^{87}Sr/^{86}Sr$ ratio, whereas during drier times reduced springflow, possibly coupled with input of more-radiogenic Sr from other sources, such as sea-spray aerosols and perhaps Saharan dust, led to an increase in the Sr-isotope ratio of the lake water. Despite proximity of the lake to the sea and evidence for slight intrusion of marine saline groundwater in the past, however, the extent of marine input appears to have had limited influence on the lake's Sr-isotope ratios. Whereas the $^{87}Sr/^{86}Sr$ ratios cannot be used as a palaeosalinity proxy in this particular lake, they do provide valuable information about the mechanisms underlying hydrological change.

Keywords: Strontium isotopes; Oxygen isotopes; Ostracods; Palaeolimnology; Jamaica

1. Introduction

The water chemistry of coastal lakes is a complex function of inputs of marine saline and meteoric water, reflecting such factors as sea level and terrestrial hydrology. Significant changes in the water composition and ecology of coastal lakes may result from variations in climate and sea level on Quaternary timescales and their sediment records can provide a means of evaluating the limnological response to such changes.

Strontium isotope ratios are potentially valuable tracers of hydrological change in groundwater-fed lakes. The $^{87}Sr/^{86}Sr$ ratio of lake waters varies according to the flow path and residence time of groundwater through rocks and soils of differing Sr-isotope composition (e.g. Lent et al., 1997). The $^{87}Sr/^{86}Sr$ ratio of marine limestone has changed markedly during the Phanerozoic (e.g. McArthur et al., 2001): hence, the $^{87}Sr/^{86}Sr$ ratio of karst groundwater may reflect the age of the rocks through which it has passed. Additions of Sr to lakes from sources such as dust (e.g.

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Banner et al., 1996) may modify this signature. In coastal lakes with composition close to that of meteoric water, varying inputs of marine water will generally have a marked effect on the composition of lake water, since the $^{87}Sr/^{86}Sr$ ratio of meteoric waters is usually very different from that of seawater. Because the concentration of Sr in seawater is also much greater than in most non-marine waters, the input of the former into a freshwater lake has greatest influence on the latter's Sr chemistry close to the freshwater endmember of a hypothetical mixture of marine and meteoric water (Anadón et al., 2002). Biogenic carbonates provide a faithful record of the Sr-isotope signature of waters, with no reported vital effects (e.g. Reinhardt et al., 1999), providing they are *in situ* and have undergone no diagenetic change (e.g. Schmitz et al., 1997). Sedimentary biogenic carbonates are therefore potentially valuable palaeohydrological tracers in coastal lakes.

Several studies have successfully applied $^{87}Sr/^{86}Sr$ ratios of ostracods (e.g. McCulloch and De Deckker, 1989; McCulloch et al., 1989) and other microfossil and macroinvertebrate carbonate (e.g. Ingram and Sloan, 1992; Ingram and De Paolo, 1993; Reinhardt and Raban, 1999; Reinhardt et al., 1999) and vertebrate skeletal remains (e.g. Schmitz et al., 1991, 1997) to the reconstruction of past salinity, under the assumption that changes in Sr-isotope ratios are controlled primarily by the proportion of marine water in a mixture. In non-coastal environments, the Sr chemistry of lake waters and groundwaters is mainly controlled by water–rock interactions (e.g. Katz and Bullen, 1996; Lent et al., 1997) together with additions of Sr from sources such as dust (e.g. Banner et al., 1996). In such cases, Sr isotopes provide valuable information about water sources and water-source changes through time. In coastal lakes, these factors may also be important and may therefore complicate any palaeosalinity signature in Sr isotope records.

We present a late Quaternary $^{87}Sr/^{86}Sr$ record preserved in ostracod calcite from Wallywash Great Pond, a Jamaican coastal lake. By comparing the strontium isotope record with ostracod oxygen-isotope values and Sr/Ca ratios, which are proxies for hydrological and salinity change, respectively, we evaluate the relative importance of changes in climate and marine intrusion on the lake's strontium-isotope composition during the late Quaternary.

2. Study site, materials and methods

2.1. Study site

Wallywash Great Pond (17°57′ N, 77°48° W, 7 masl) is a small (area 0.76 m^2) karstic freshwater (salinity 0.33 ± 0.02 ‰) lake of Mg–Ca–HCO_3 type in southwestern Jamaica (Fig. 1) located in a fault-bounded trough in Oligo-Miocene limestone. Although it is currently unaffected by marine waters, two small waterbodies (Lakes P and P1) to the north of the Great Pond (Fig. 1) lie within the mixing zone of fresh and marine-saline groundwater (Wozab and Wiliams, 1967), as indicated by the fact that their salinity and chemical composition differ from the Great Pond (Street-Perrott et al., 1993; Holmes et al., 1995a).

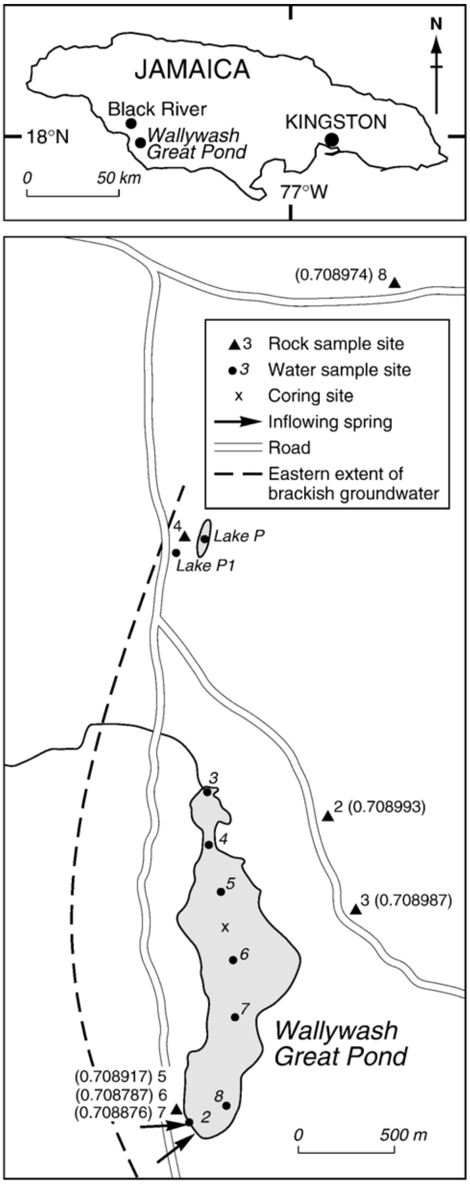

Fig. 1. Wallywash Great Pond and location of water and rock samples. Modern ostracod samples were from an integrated plankton tow across sites 4 to 8 inclusive, site 3 and Lake P1. $^{87}Sr/^{86}Sr$ ratios for rock samples are from acetic-acid leaches (see Table 1).