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Strontium Isotope Investigation of Paleosalinity in the Great Estuarine Group, Jurassic, Scotland

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Introduction

The Great Estuarine Group is a classic example of salinity controlled ecological diversity among benthic molluscan fauna. Different assemblages of molluscs are interpreted to reflect nearly the full salinity spectrum from marine to freshwater. An absolute calibration of these ecologically inferred paleosalinities was performed previously using oxygen isotope compositions of aragonitic molluscs. To advance the original calibration, we have undertaken a study of the Sr isotope paleohydrology of the Great Estuarine Group to test for concordance between O and Sr isotope paleosalinities. Our initial results, however, casts doubt on the interpretation that O isotope variations recorded in the molluscs result from seawater-freshwater mixing. Rather, the Sr isotope systematics indicates that the ecologically inferred paleosalinities are controlled by evaporation of freshwater in coastal lagoons.

Original δ^{18}O-Salinity Calibration of *Praemytilus*

Tan and Hudson (1974) and Hudson et al. (1995) used δ^{18}O analyses of the aragonitic bivalve *Praemytilus strathairdensis* from Bed 5e of the Kildonnan member to construct an absolute paleosalinity scale for that part of the Great Estuarine Group (GEG). Specimens of *Praemytilus* show good correlation between δ^{18}O and δ^{13}C, consistent with an origin by seawater freshwater mixing. The δ^{18}O-Salinity calibration was based on this assumption. *Praemytilus* δ^{18}Oshell values range between -2.4 and -6.1 per mil (PDB). Hudson et al., (1995) assumed δ^{18}O of -1 per mil for Jurassic seawater, freshwater input as -6 per mil, and a temperature of -25ºC. Assuming, furthermore, that δ^{18}O and salinity were linearly correlated, this corresponds to calcification of Praemytilus in waters varying from 8 to 34 ppt salinity, which is in agreement with paleoecology.

Strontium Isotope Variations in *Praemytilus*

Strontium isotopes behave conservatively in the seawater-freshwater mixing zone. Accordingly, if the O and C isotope variations in *Praemytilus* genuinely reflect salinity variation in the mixing zone, their Sr isotope compositions should also record this mixing (Holmden et al., 1997). The results, presented on a ^{87}Sr/^{86}Sr-Ca/Sr diagram (Figure 1), show that ^{87}Sr/^{86}Sr in *Praemytilus* is very radiogenic (0.710) compared to Bathonian seawater (approx. 0.7070). Samples of *Unio andersonis*, normally held to be a freshwater taxon, yielded similar isotopic compositions, (0.7095-0.7105), which emphasizes the importance of freshwater contributions to Kildonnan member environments. The correlation between ^{87}Sr/^{86}Sr and Ca/Sr is indicative of two-component mixing between end-member waters with greatly contrasting Ca/Sr ratios and slightly differing ^{87}Sr/^{86}Sr ratios. Neither of the potential end-member waters can be reconciled with Bathonian seawater. The strontium concentrations measured in *Praemytilus* range from about 2000 to 6000 ppm. Considering strontium distribution coefficients in modern molluscs of between 0.2 and 0.3, calculated 1000Sr/Ca_{water} atom ratios for the lagoonal waters inhabited by *Praemytilus* are about 8 to 34, much higher than modern seawater (8.5).

Implications for Depositional Environments in the Great Estuarine Group

The *Praemytilus* mixing line is interpreted to reflect a depositional environment consisting of hydrologically closed (or partially closed) coastal lagoons, in a climate setting that was, at least, seasonally dry. The radiogenic ^{87}Sr/^{86}Sr reflect dominantly freshwater inputs, and the high Sr/Ca ratios are indicative of closed basin precipitation and preservation of biogenic $CaCO_3$ in GEG sediments. Importantly, a hydrologic connection to the sea is not evident in the Sr isotope systematics of *Praemytilus* from Bed 5e. Consequently, the co-varying trend between δ^{18}O and δ^{13}C which was originally used to calibrate the δ^{18}O-salinity scale, would have originated from O and C isotope effects that are known to operate in closed basins; including, evaporation, CO_2 exchange between the atmosphere and lagoonal waters, biotic productivity, and organic carbon burial. The challenge ahead is to reconcile the present results with paleoecological inference of marine connection from parts of the Kildonnan member (Hudson et al., 1995; Patterson et al., 1999) and the GEG generally (Tan and Hudson, 1974). We can now use a multiple isotope approach to differentiate ecological assemblages of fossils that record episodes of evaporatively induced salinity variation in closed basins, from episodes of open basin mixing with marine waters. Such detailed investigations may also be used to test assumptions regarding the salinity tolerances of extinct molluscan species, and the concept of taxonomic uniformitarianism.

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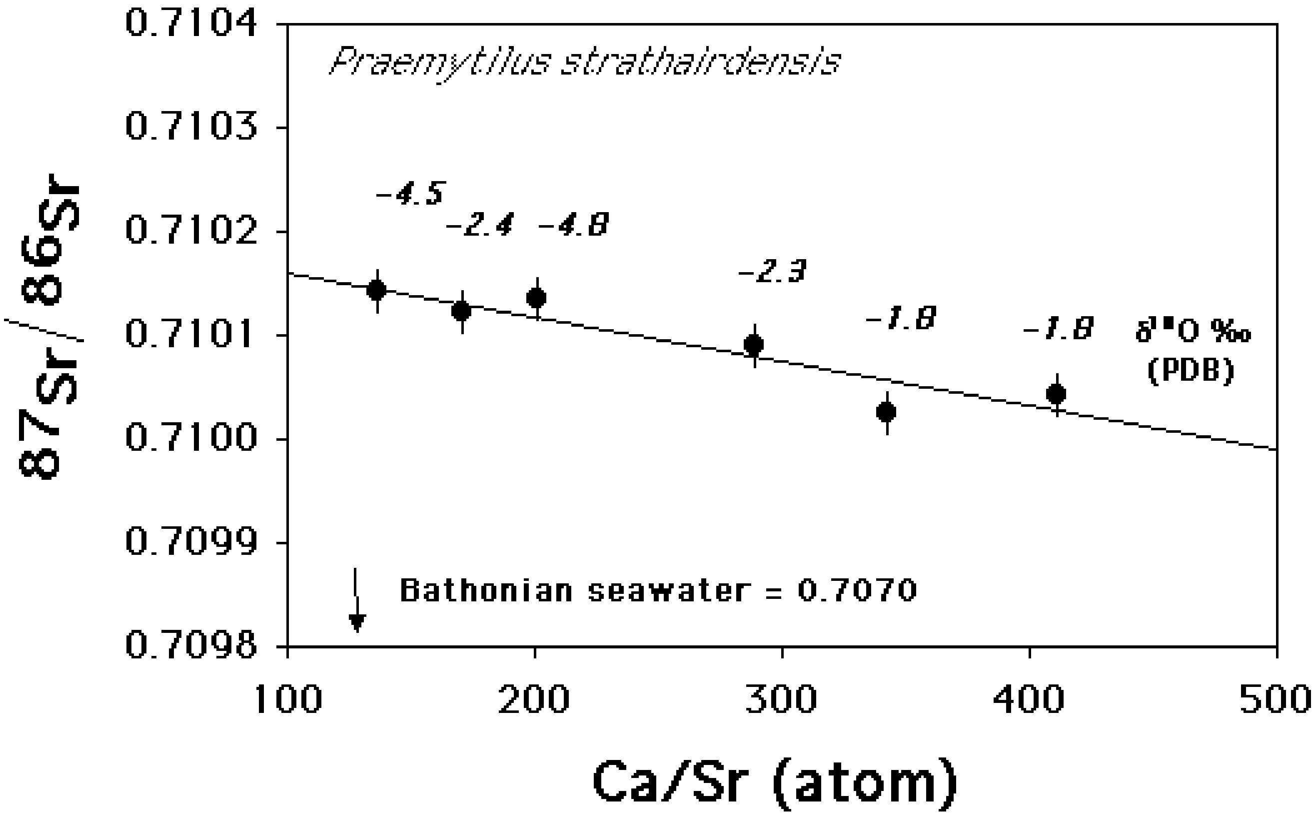

Figure 1: $^{87}Sr/^{86}Sr$ vs. Ca/Sr (atom) for *Praemytilus strathairdensis* from Bed 5e of the Kildonnan member of the Great Estuarine Group.

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