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Bioavailable $^{87}Sr/^{86}Sr$ in different environmental samples — Effects of anthropogenic contamination and implications for isoscapes in past migration studies

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ABSTRACT

$^{87}Sr/^{86}Sr$ reference maps (isoscapes) are a key tool for investigating past human and animal migrations. However, there is little understanding of which biosphere samples are best proxies for local bioavailable Sr when dealing with movements of past populations. In this study, biological and geological samples (ground vegetation, tree leaves, rock leachates, water, soil extracts, as well as modern and archeological animal teeth and snail shells) were collected in the vicinity of two early medieval cemeteries ("Thuringians", 5–6th century AD) in central Germany, in order to characterize $^{87}Sr/^{86}Sr$ of the local biosphere. Animal tooth enamel is not appropriate in this specific context to provide a reliable $^{87}Sr/^{86}Sr$ baseline for investigating past human migration. Archeological faunal teeth data (pig, sheep/goat, and cattle) indicates a different feeding area compared to that of the human population and modern deer teeth $^{87}Sr/^{86}Sr$ suggest the influence of chemical fertilizers. Soil leachates do not yield consistent $^{87}Sr/^{86}Sr$, and $^{87}Sr/^{86}Sr$ of snail shells are biased towards values for soil carbonates. In contrast, water and vegetation samples seem to provide the most accurate estimates of bioavailable $^{87}Sr/^{86}Sr$ to generate Sr isoscapes in the study area. Long-term environmental archives of bioavailable $^{87}Sr/^{86}Sr$ such as freshwater bivalve shells and tree cores were examined in order to track potential historic anthropogenic contamination of the water and the vegetation. The data obtained from the archeological bivalve shells show that the modern rivers yield $^{87}Sr/^{86}Sr$ ratios which are similar to those of the past. However, the tree cores registered decreasing $^{87}Sr/^{86}Sr$ values over time towards present day likely mirroring anthropogenic activities such as forest liming, coal mining and/or soil acidification. The comparison of $^{87}Sr/^{86}Sr$ of the Thuringian skeletons excavated in the same area also shows that the vegetation samples are very likely anthropogenically influenced to some extent, affecting especially $^{87}Sr/^{86}Sr$ of the shallow rooted plants.

1. Introduction

Over the past decade, strontium (Sr) isotope analysis has become an increasingly powerful tool in present-day and past animal ecology, for determining habitat use and mobility/migration (Blum et al., 2001; Britton et al., 2011; Feranec et al., 2007; Hoppe et al., 1999; Hoppe and Koch, 2007; Radloff et al., 2010; Tütken et al., 2011), in tracing food provenance (Almeida and Vasconcelos, 2001; Barbaste et al., 2002; Fortunato et al., 2004; Montgomery et al., 2006; Swoboda et al., 2008; Techer et al., 2011; Voerkelius et al., 2010), in hydrological and forest ecosystem investigations (Böhlke and Horan, 2000; Dijkstra et al., 2003; Drouet et al., 2005b, 2007; Poszwa et al., 2004; Shand et al., 2009), as well as in forensic sciences (Beard and Johnson, 2000; Juarez, 2008).

In archeology, the Sr isotopic composition can be used to identify migrants and to examine movements of individuals (Bentley et al., 2002, 2003; Knudson et al., 2004, 2005; Kusaka et al., 2011; Montgomery et al., 2007; Müller et al., 2003; Price et al., 2000, 2006a, 2006b; Schweissing and Grupe, 2003; Tafuri et al., 2006; Tung and Knudson, 2008; Wright, 2005). Such information, in turn, provides insight into the dynamics and economy of past populations.

Strontium has four stable isotopes (^{88}Sr, ^{87}Sr, ^{86}Sr and ^{84}Sr) of which ^{87}Sr is radiogenic, resulting from the long-lived radioactive decay of ^{87}Rb, and is therefore variable in nature. The $^{87}Sr/^{86}Sr$ ratio

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