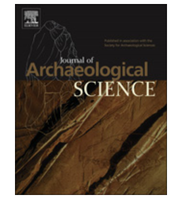
Journal of Archaeological Science 39 (2012) 2371–2384

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas



Spatial variation of biologically available strontium isotopes ($^{87}Sr/^{86}Sr$) in an archipelagic setting: a case study from the Caribbean

Jason E. Laffoon [a,*], Gareth R. Davies [b], Menno L.P. Hoogland [a], Corinne L. Hofman [a]

[a] Faculty of Archaeology, Leiden University, Reuvenplaats 3, 2311 BE Leiden, The Netherlands
[b] Faculty of Earth and Life Sciences, Free University, 1081 HV Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 28 November 2011
Received in revised form
1 February 2012
Accepted 2 February 2012

Keywords:
Strontium isotope
Bioavailable strontium
Caribbean
Antilles
Migration
Mobility

ABSTRACT

This paper presents the results of strontium (Sr) isotope analysis of modern and archaeological animal remains and modern plant samples from the Caribbean region. The goal is to assess if patterns of human mobility can be determined from the archaeological record in an archipelagic setting. The range of variability and spatial distribution of biologically available strontium isotope signatures is reported and data evaluated to determine if sufficient heterogeneity exists to permit the identification of mobility despite the presence of potentially large contributions of marine strontium in island and coastal ecosystems. The (is)landscape is divided into several sub-regions based on the age and lithology of underlying geology and the variability of $^{87}Sr/^{86}Sr$ ratios is reported as; mean $^{87}Sr/^{86}Sr \pm 2$ standard deviations, number of samples: 1) Volcanic and Intrusive rocks (0.7077 ± 0.0019; $n = 162$); 2) Cretaceous–Miocene Limestone (0.7085 ± 0.0009; $n = 50$); 3) Pliocene–Quaternary Limestone (0.7091 ± 0.0004; $n = 54$); 4) Sedimentary Deposits (0.7094 ± 0.0015; $n = 16$); 5) Metamorphic Deposits (0.7104 ± 0.0014; $n = 6$). There are substantial differences between expected $^{87}Sr/^{86}Sr$ values based on associated geology and measured $^{87}Sr/^{86}Sr$ in flora and fauna samples. These differences emphasize the importance of focusing on bioavailable strontium, as opposed to geological proxies, for estimations of Sr isotope ranges, especially in archipelagic environments. While some overlap exists between the $^{87}Sr/^{86}Sr$ ranges of certain sub-regions, other sub-regions possessed limited variation and could be distinguished based on strontium isotope data. This spatial patterning of biologically available strontium indicates that strontium isotope analyses can be successfully applied to the archaeological study of human mobility within the Caribbean region.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Analysis of strontium isotope ratios ($^{87}Sr/^{86}Sr$) in skeletal tissues has been effectively utilized to investigate migrations and mobility of humans and animals from a multitude of archaeological contexts (Bentley et al., 2007b, 2002, 2007a; Evans et al., 2006; Ezzo et al., 1997; Grupe et al., 1997; Hoppe et al., 1999; Knudson et al., 2004, 2005; Montgomery et al., 2003; Price et al., 2001, 2008, 1998, 1994, 2000; Schweissing and Grupe, 2003; Sealy et al., 1991), including the Caribbean region (Booden et al., 2008; Laffoon and de Vos, 2011; Laffoon and Hoogland, in press; Valcarcel Rojas et al., 2011). Strontium isotope ratios in skeletal tissues generally reflect the strontium isotope ratios of the biochemical environment in which they formed as strontium from the local environment enters the foodweb, is ingested and then incorporated into an individual's teeth and bones. Migration or mobility across isotopically distinct landscapes can be inferred when the $^{87}Sr/^{86}Sr$ in an individual's dental enamel differs substantially from the local range of biologically available $^{87}Sr/^{86}Sr$.

The Caribbean region is considered to be an ideal setting for the application of strontium isotope studies owing in part to the diversity of its geological terrains. The strontium isotope signatures from volcanic, marine limestone, metamorphic and continental regions are expected to be differ owing to broad differences in the ages and/or lithologies of their underlying geological substrates (Dengo and Case, 1990; Donovan and Jackson, 1994). In addition, archaeological research has revealed widespread movements of peoples, goods, and ideas evidencing complex and dynamic relationships of interaction and exchange within and between the Antillean archipelagos and between these islands and the surrounding mainland(s) of South and Central America (Boomert, 2000; Hofman et al., 2007, 2008; Hofman and Hoogland, 2011;

* Corresponding author. Tel.: +31 (0) 71 527 6459; fax: +31 (0) 71 5272429.
E-mail address: j.e.laffoon@arch.leidenuniv.nl (J.E. Laffoon).

0305-4403/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jas.2012.02.002

Hoogland et al., 2010; Knippenberg, 2007; Mickleburgh and Laffoon, 2011; Rodríguez Ramos, 2007).

Here we assess the spatial variation of $^{87}Sr/^{86}Sr$ within the Caribbean biosphere to determine if sufficient variation exists within this study region to allow human mobility to be inferred and to test the relationships between $^{87}Sr/^{86}Sr$ in biological samples and $^{87}Sr/^{86}Sr$ of underlying geological substrates. Spatial mapping of biologically available strontium is accomplished through the analysis of $^{87}Sr/^{86}Sr$ from archaeological and modern animal samples and modern plant samples from the Greater and Lesser Antilles, the Leeward Antilles, Trinidad and Tobago, and from coastal Venezuela. Our aim is to produce a database of bioavailable strontium isotope variation that can be utilized for archaeological, forensic, and ecological provenance studies within the Caribbean and we hope that this study represents an initial contribution to the development of a baseline or reference strontium isomap for the Caribbean Region.

Although strontium isotope analysis of human remains is a potentially powerful tool for the investigation of ancient migration and mobility, several caveats merit discussion. First is the assumption that the primary contributor of dietary strontium is locally derived (an assumption that can be validated based on archaeological evidence concerning local dietary and subsistence practices). The presumed relationship between geology and geography only holds under conditions of primarily local production and consumption. In cases where large quantities of imported foodstuffs are consumed, especially those that are disproportionately large contributors of strontium to local dietary budgets, the interpretation of strontium isotope data becomes rather more complex (Wright, 2005). Although in order to have an effect on the isotope composition of dental enamel, consumption would have to occur during mineralization of this tissue (i.e. during childhood). Second, the spatial scales of strontium isotope variation and the scales of human movements must have some degree of correspondence (Hodell et al., 2004). In other words, baseline strontium isotope ratios between the place of origin and the place of migration must be distinct and vary over the distances that people migrate within the area under study. For example, where large areas are homogenous in terms of strontium isotope ratios, mobility and migration within such a region, or between spatially separated but isotopically similar regions, will not be detectable.

We concur with Hodell et al. (2004: 587) that it is necessary to "evaluate local and regional variability before applying the technique to infer migration in the archaeological record". Strontium isotope analysis has been used to examine human mobility from a wide array of archaeological contexts over the last few decades, but until recently few maps of strontium isotope variation existed. Fortunately, local and regional databases of spatially explicit strontium isotope data are now being produced for several regions of the world (Aberg et al., 1998; Bentley and Knipper, 2005a; Evans et al., 2009, 2010; Frei and Frei, 2011; Hodell et al., 2004; Knudson and Torres-Rouff, 2009; Nafplioti, 2011; Porder et al., 2003; Price et al., 2010; Sjogren et al., 2009; Thornton, 2011; Voerkelius et al., 2010), with Mesoamerica and Europe extensively mapped in this regard. These large-scale, spatially explicit, datasets permit more refined interpretations of human strontium isotope data and investigations into potential origins.

2. Mapping bioavailable strontium isotopes

Various methods have been used to create reference databases of $^{87}Sr/^{86}Sr$. One simple method involves extrapolating isotope variation directly from the geological literature, including expectations of $^{87}Sr/^{86}Sr$ variation based on the ages and lithologies of associated geological substrates and/or direct $^{87}Sr/^{86}Sr$ measurements of geological materials. These approaches are based on the assumption that local geology is the primary contributor of strontium to local biological systems. The relationship between geological and biological strontium is rather more complex in reality with a number of factors (e.g., micro-scale variation, differential weathering and erosion, precipitation regimes, atmospheric deposition) contributing to differences between measured $^{87}Sr/^{86}Sr$ values in whole rocks and minerals relative to bioavailable $^{87}Sr/^{86}Sr$ values (Bentley, 2006; Hodell et al., 2007; Price et al., 2002). For example, in island and coastal settings, it has been demonstrated that contributions of marine-derived strontium, such as sea-spray, to terrestrial ecosystems can be substantial (Kennedy et al., 1998; Price and Gestsdottir, 2006; Vitousek et al., 1999; Whipkey et al., 2000). Although consumption of marine protein is not expected to be a large contributor to terrestrial dietary strontium, which tends to be dominated by plants (Burton and Wright, 1995), direct consumption of sea salt may influence the strontium isotope composition of skeletal tissues (Wright, 2005).

Owing to the aforementioned issues with the use of geological proxies, direct sampling of biosphere samples has been suggested as a more appropriate approach (Price et al., 2002; Sillen et al., 1998). Some approaches to mapping $^{87}Sr/^{86}Sr$ variation have relied on various 'environmental' proxies such as soils (Benson et al., 2003), water (Frei and Frei, 2011; Montgomery et al., 2006; Voerkelius et al., 2010); plants (Porder et al., 2003); or a combination of different sample types (Evans et al., 2009, 2010; Hodell et al., 2004). Alternatively, Price et al. (2002) have suggested the use of archaeological dental enamel from small, terrestrial, low mobility mammals as suitable bioavailable proxies. This latter technique benefits from the process of 'bioaveraging' (Price et al., 2002) by which animals tend to average out local variation in strontium isotope composition. Thus $^{87}Sr/^{86}Sr$ values of animal skeletal tissues tend to be relatively homogenous compared to the potential heterogeneity of local rock, soil, or even plant samples. Many recent archaeological approaches to mapping local or regional strontium isotope variation have utilized a wide array of faunal proxies including domestic animals such as pig, sheep, cattle, and guinea pigs (Bentley and Knipper, 2005a; Evans and Tatham, 2004; Knudson et al., 2004; Price and Gestsdottir, 2006); and various non-domestic animals such as deer, peccary, rabbit, and mice (Ezzo et al., 1997; Price et al., 2000; Sjogren et al., 2009; Thornton, 2011). However, the determination of suitable faunal proxies is dependent on the specific cultural, ecological, and geographical contexts of the study area as some studies have revealed the movement of animals based on strontium isotope evidence (Bendrey et al., 2009; Bentley and Knipper, 2005b; Shaw et al., 2009; Thornton, 2011) and thus sampling strategies may have to be tailored to local conditions (Evans et al., 2009; Price et al., 2002).

Our sampling strategy explicitly focused on animal and plant remains, as opposed to soil or whole rock samples owing to: 1) the potential heterogeneity of strontium isotope ratios within and between whole rocks and minerals, and the substantial variability in the solubility and weathering of various minerals within local soil matrices (Borg and Banner, 1996; Kennedy and Derry, 1995; Pozwa et al., 2000; Sillen et al., 1998); and 2) the high potential for substantial contributions of non-geologic strontium (i.e. seawater, rainwater) into terrestrial island ecosystems. The use of plant and animal proxies benefits from the effects of bioaveraging, and permits assessments of bioavailable strontium isotope ranges that inherently incorporate multiple sources of strontium (from the lithosphere, atmosphere, hydrosphere) into local terrestrial biospheres. This strategy is also informed by previous isotope research that has demonstrated substantial variability in the sources of strontium to terrestrial island

Download English Version:

https://daneshyari.com/en/article/10499161

Download Persian Version:

https://daneshyari.com/article/10499161

Daneshyari.com