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Establishing an Ecuadorian Isoscape: The Importance of Baseline Strontium Data in a Volcanic Landscape

Estableciendo un Iso-Paisaje Ecuatoriano: La Importancia de los Datos de Referencia de Estroncio en un Paisaje Volcánico

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ABSTRACT

Objectives: Strontium isotopes ($^{87}Sr/^{86}Sr$) have been used worldwide to track migrations and identify nonlocal individuals in the past. In South America, these studies often use comparative baseline maps, or isoscapes, established by samples from archaeological fauna and geologic formations. However, baseline research has focused on coastal Peru and the Central and South Andean Highlands. Currently, no comparable isoscape exists for Ecuador. Thus, scholars approximate baselines from predictive models and geologic studies, which may not accurately reflect the biologically available strontium in archaeological samples. This study tested the accuracy of predictive archaeological and geologic models for Ecuadorian strontium.

Materials and Methods: We collected 11 faunal samples from eight archaeological sites across three coastal regions and the northern highlands to test for $^{87}Sr/^{86}Sr$. All samples were collected from animals with narrow home ranges. Samples were processed at the University of North Carolina at Chapel Hill.

Results: Strontium values ranged from 0.704226 to 0.709764, with significant regional distribution. The lowest values came from highland samples (mean = 0.704296) and clustered by coastal region from north to south (central coast mean = 0.707561; south coast mean = 0.7064118; far south coast mean = 0.709764).

Discussion: This pilot study reveals two trends: First, strontium values cluster regionally despite stratigraphic volcanic influences, and second, values do not correspond to predictive models, particularly along the coast. We suggest that the unique geology of Ecuador means that predictive models based on Peruvian baselines are inappropriate for Ecuadorian strontium studies. There is a need for a large-scale baseline study of biologically available strontium in Ecuadorian archaeological samples.

RESUMEN

Objetivos: Los isótopos de estroncio (87Sr/86Sr) rastrean migraciones e identifican individuos no locales en el pasado. En Sudamérica, los estudios utilizan "isoscapes" basados en fauna arqueológica, agua moderna y formaciones geológicas. Sin embargo, estos se centran en Perú, los Andes Centrales y Sur. Ecuador carece de isoscapes específicos, obligando a los investigadores a usar modelos predictivos que no reflejan el estroncio biológicamente disponible.

Materiales y métodos: Se analizaron 11 muestras de fauna de ocho sitios arqueológicos de la costa y la sierra ecuatoriana en busca de $^{87}Sr/^{86}Sr$. Los animales estudiados tienen territorios limitados y las muestras se procesaron en la Universidad de Carolina del Norte en Chapel Hill.

Resultados: Los valores de 87Sr/86Sr oscilan entre 0.704226 y 0.709764, con diferencias regionales significativas. Las muestras de la sierra presentan valores bajos (media = 0.704296). En la costa, los valores varían por región: costa centro-norte (media = 0.707561), costa centro-sur (media = 0.7064118) y costa sur (media = 0.709764).

Discusión: Los resultados muestran que los valores de estroncio se agrupan por región, a pesar de las influencias volcánicas, y no coinciden con modelos predictivos, especialmente en la costa. Esto resalta la necesidad de desarrollar isoscapes específicos para Ecuador, ya que los modelos peruanos no son adecuados dada la geología única del país. Un estudio más amplio es esencial para crear líneas de base precisas en el futuro.

1 | Introduction

In South America, strontium isotopes have been used to track migrations, evaluate access to resources, and identify nonlocal individuals in the past (e.g., Knudson 2008; Knudson and Torres-Rouff 2009; Turner et al. 2009). These studies often use comparative baseline maps, or isoscapes, established by samples from archaeological fauna and geologic formations (Barberena et al. 2021; Bataille et al. 2020; Scaffidi and Knudson 2020). However, baseline research has primarily focused on Peru, Argentina, and Chile. Currently, no comparable isoscapes have been created for Ecuador; thus, scholars must approximate baselines from predictive models. While geologic or predictive models are a useful starting place, variation in geologic histories, erosion, and water flow can significantly impact local strontium baselines, making sampling from local plants and animals critical for studies specific to a region (Holt et al. 2021; Kootker et al. 2016). In this brief communication, we present preliminary evidence that shows that predictive models of Ecuadorian $^{87}Sr/^{86}Sr$ distribution do not accurately reflect the biologically available $^{87}Sr/^{86}Sr$ ratios found in archaeological samples. Therefore, the creation of baselines or base intervals (Vaiglova et al. 2023) from archaeological and modern fauna is necessary to accurately use strontium isotopes in Ecuadorian archaeology.

2 | Strontium Isotopes and South American Bioarchaeology

Strontium isotope ratios ($^{87}Sr/^{86}Sr$) vary according to local geology. ^{87}Sr is a product of ^{87}Rb decay; therefore, the $^{87}Sr/^{86}Sr$ ratio in a rock is a function of the initial $^{87}Sr/^{86}Sr$, the Rb/Sr ratio, and the age of the rock. In general, continental rocks such as shales and granites tend to have high Rb/Sr and high $^{87}Sr/^{86}Sr$ ratios (typically above 0.710), in contrast to volcanic rocks such as basalts and andesites that have low Rb/Sr and low $^{87}Sr/^{86}Sr$ ratios (typically below 0.707). Local geologic strontium leaches into water and is incorporated into producer (plants) and consumer (animal) tissue, including bone and tooth enamel, by substitution of strontium for calcium in biogenic hydroxyapatite. If an animal or human consumes predominantly local water and food over their lifetime, their dental and skeletal strontium ratios should reflect the local bioavailable strontium (Åberg et al. 1998; Ericson 1985; Fahy et al. 2017; Knudson 2008; Knudson et al. 2004; Price et al. 2002).

Strontium is the most commonly used radiogenic isotope system in archaeological studies of migration in South America, since the original Andean use of the method by Knudson et al. (2004). Recent studies have created predictive models for the western South American coast based on previously published samples and underlying geology (Barberena et al. 2021; Bataille et al. 2020; Scaffidi and Knudson 2020). Based on these models, local $^{87}Sr/^{86}Sr$ ratios for southern coastal Ecuador are predicted to be between 0.70840 and 0.70945 (Scaffidi and Knudson 2020) or greater than 0.70900 (Bataille et al. 2020), values that reflect older continental bedrock. However, comparatively young volcanic bedrock occurs throughout Ecuador, and soils developed over such bedrock are likely characterized by lower strontium isotope ratios (Bernal et al. 2012; Longo and Baldock 1982). Additionally, volcanic eruptions may artificially lower strontium isotope ratios, as newly formed volcanic soils and drifting ash have $^{87}Sr/^{86}Sr$ ratios between 0.704 and 0.706 (Hodell et al. 2004; Serna et al. 2020). Similarly, sea spray contributes to local soil chemistry as far as 200 m inland from the coast and may change values derived from bedrock alone (Evans et al. 2010; Snoeck et al. 2020). Finally, preliminary studies of human samples (Cruz 2022; Juengst et al. 2021) show variability by region and lower strontium isotope ratios than predicted by the models. Since these studies were based on human samples, we cannot exclude the possibility that human migration or consumption of nonlocal foods led to disparate results. However, it is clear that there remains a discrepancy between archaeological models and geologic expectations for the Northern Andes, and these unexpected results from human samples may reflect larger problems.

3 | Materials and Methods

Faunal bone and dental samples were collected from museums and archaeological repositories in coastal and highland Ecuador. We prioritized remains of small rodents or territorial animals with small home ranges over roaming animals or modern plants to ensure a narrow range of isotope values and to control for changes to soil over time (Castelló 2018; Cueva-Hurtado et al. 2024) (see Holt et al. 2021 for a full discussion of the advantages of using plants vs. animals). Since dental enamel is less likely to be contaminated by leaching of local soils (Budd et al. 2000; Garvie-Lok et al. 2004), we preferentially selected animal teeth over bone, although bones were selected when teeth were unavailable. Diagenesis of bone samples was possible; however, since we are establishing local isoscapes (rather than trying to detect migration or place of origin), these local soil contributions would not skew the baseline (Holt et al. 2021).

Twenty-seven samples were exported to Juengst's lab at UNC Charlotte under permit DAAPPS-INPC-Z1/2–013-2024 from the Instituto Nacional de Patrimonio y Cultura of Ecuador. Eleven samples from eight archaeological sites were selected for preliminary analysis (Table 1, Figure 1). Three sites (Rumicucho, NADQ, and Yachay) were located in the highlands, two on the central coast (Rio Chico and La Isla Jaramijo), two on the south coast (Loma los Cangrejitos and Samanes 1), and one on the far south coast (El Dornajo). Highland samples were from northern Ecuador to verify if local volcanic eruptions, that reportedly had important consequences in archaeological settlements, also impacted strontium isotope values. Coastal sites were located both within (Rio Chico, La Isla Jaramijo) and outside (Loma los Cangrejitos, Samanes 1, El Dornajo) the sea spray zone to similarly investigate if there was an impact on strontium isotope values.

Enamel samples were polished and cleaned with a Dremel drill to remove contaminants on the surface and outer layer of enamel, and then manually crushed with an agate mortar and pestle. Prepared enamel and powdered bone samples were processed in the Department of Geological Sciences isotope geochemistry clean laboratory at the University of North Carolina at Chapel Hill, following their standard protocol (Macheridis et al. 2024). Approximately 7–10 mg of sample was dissolved in distilled 3.5 M HNO_3. Strontium was isolated using ion-exchange column chromatography with EiChrom Sr-Spec resin using 3.5 M HNO_3 to wash the columns and H_2O to elute the Sr. Approximately 20 μL of 0.03 N H_3PO_4 was added to the sample and evaporated to dryness. The Sr samples were loaded on single Re filaments with TaF_5 and analyzed in triple-dynamic multicollector mode with $^{88}Sr = 3\,V$ ($10^{11}\,\Omega$ resistor) on the VG Sector-54 thermal ionization mass spectrometer. All data are normalized to $^{86}Sr/^{88}Sr = 0.1194$, assuming exponential fractionation behavior. Data are reported relative to a value for NBS-987 of $^{87}Sr/^{86}Sr = 0.710250 \pm 0.000020$.

4 | Results

Samples returned values that ranged from 0.704226 to 0.709764 (Table 1, Figure 2). Highland samples ($n = 3$) had a narrow range of values from 0.704226 to 0.704400 with a mean of 0.704296. Coastal values ranged more broadly from 0.706232 to 0.709764, with a mean of 0.7071225. However, separating the coast into smaller regions revealed a clustering of values between central, southern, and the far southern coast. The sample from El Dornajo in the El Oro province (the most southern coastal region) had the highest strontium value at 0.709764. Samples from Loma los Cangrejitos and Samanes 1 ($n = 5$) in the Guayas province on the southern coast had a narrow range from 0.706232 to 0.706615, with a mean of 0.7064118. Finally, samples from Rio Chico and La Isla Jaramijo ($n = 2$) on the central coast returned values of 0.707526 and 0.707596, respectively, with a mean of 0.707561.

5 | Discussion

This pilot study demonstrates two important findings, with implications for future isotopic work in Ecuador. First, there are strong regional trends in baseline $^{87}Sr/^{86}Sr$ ranges. The results obtained from the northern highlands samples show that, for Ecuador, volcanoes do not create hyperlocal significant changes in isotopic ratios in Pichincha and Imbabura. On the contrary, the relatively young bedrock and drifting ash associated with volcanoes may have created lower strontium baselines across the region, as predicted by the geologic baselines and studies on volcanic ash (Bernal et al. 2012; Hodell et al. 2004; Serna et al. 2020). This effect seems to have resulted in lower-than-average $^{87}Sr/^{86}Sr$ ratios across the highland region, rather than being isolated to sites directly located on volcanic slopes.

For the coastal samples, river basins and potentially sea spray correspond highly with the changes in isotopic values for the Manabi, Guayas, and El Oro samples. The river basin clustering is somewhat surprising, as the underlying geology does not shift by river valley (Jackson et al. 2019). Perhaps the silts carried by these rivers and deposited broadly throughout valleys during floods, occasional ENSO events, and other alluvial depositions drive these values more than the underlying bedrock. The central coast samples may have been additionally altered by sea spray, as both of these sites are located within 200 m of the ocean unlike—the southern and far southern sites, which are further inland.

However, this pattern could also be caused by an averaging effect of bedrock along the coast. The far southern coast is on bedrock that primarily formed during the Cretaceous Period (145–66 million years ago), whereas the Guayas Basin and Santa Elena Peninsula sit on bedrock from the Neogene (23–2.6 million years ago) and Paleogene (66–23 million years ago). The Manabi province contains all three, as the Piñon formation of Cretaceous volcanic bedrock cuts through Neogene and Paleogene sediments (Jackson et al. 2019; Longo and Baldock 1982; Reynaud et al. 1999). The oldest Cretaceous layers, thus, bookend the younger Neogene and Paleogene bedrock, perhaps creating the patterning of strontium values identified by these preliminary samples. Nevertheless, further samples from the northern coast and the central and southern Andes need to be analyzed to confirm the regional variation seen in the pilot study.

Second, baseline values for the coast in particular do not correspond well with predictive models such as Bataille et al. (2020); Barberena et al. (2021); Scaffidi and Knudson (2020). These models predicted that coastal strontium values would be higher than the data returned here (0.708400–0.709450), with the exception of the El Dornajo value (0.709764), which is higher than predicted. This shows the importance of collecting local faunal

TABLE 1 | Samples included in the preliminary round of testing and initial results.

Sample code	Region	Province	Site	Coordinates	Sample type	Species	Weight (g)	$^{87}Sr/^{86}Sr$	±(1 s%)	±2 s abs.
B1-8	South coast	Guayas	Loma los Cangrejitos	2°21′49.6″S 80°39′27.5″W	Enamel	*Cavia* sp.	0.2	0.706615	0.0008	0.000011
B5-F1	South coast	Guayas	Loma los Cangrejitos	2°21′49.6″S 80°39′27.5″W	Enamel	*Cervid* sp.	0.3	0.706232	0.0006	0.000008
D2-8	South coast	Guayas	Loma los Cangrejitos	2°21′49.6″S 80°39′27.5″W	Enamel	*Cervid* sp.	0.6	0.706261	0.0007	0.00001
D2.5.1/A	South coast	Guayas	Loma los Cangrejitos	2°21′49.6″S 80°39′27.5″W	Enamel	*Canis* sp.	0.2	0.706666	0.0007	0.00001
UA N12	South coast	Guayas	Samanes 1	2°06′11.5″S 79°53′47.1″W	Enamel	*Dusicyon* sp.	0.3	0.706320	0.0009	0.000013
UB2 S2 N5	Central coast	Manabi	Rio Chico	1°52′00.1″S 80°44′14.0″W	Enamel	*Canis* sp.	0.4	0.707526	0.0008	0.000011
U4 R14/A	Central coast	Manabi	La Isla Jaramijo	0°56′36.3″S 80°36′52.6″W	Enamel	*Cavia* sp.	0.2	0.707596	0.0006	0.000008
U9 NA-1	Far south coast	El Oro	El Dornajo	3°29′40.2″S 80°13′45.6″W	Enamel	*Cervid* sp.	0.4	0.709764	0.0008	0.000011
Z3B1–075	Highlands	Pichincha	N.A.D.Q.	0°07′22.5″S 78°21′41.5″W	Bone	*Cervid* sp.	0.5	0.704263	0.0006	0.000008
517U8 R80-90	Highlands	Pichincha	Rumicucho	0°00′43.0″N 78°25′52.1″W	Bone	*Cavia* sp.	2	0.704226	0.0007	0.00001
4503	Highlands	Imbabura	Yachay	0°24′17.2″N 78°10′36.6″W	Bone	*Cavia* sp.	2	0.704400	0.0008	0.000011

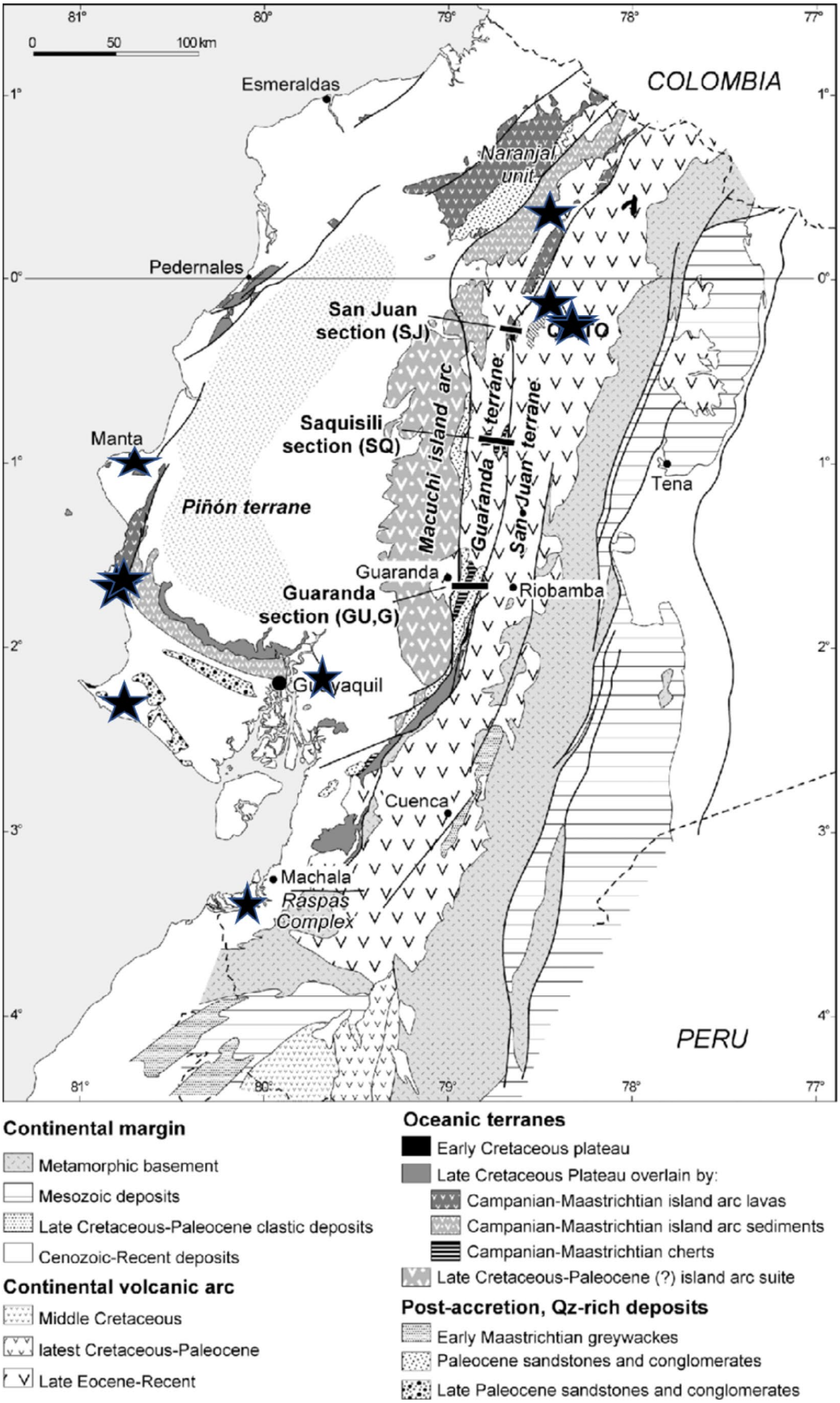

FIGURE 1 | Map of Ecuador showing the locations of archaeological sites from which samples were selected and the underlying geology of the country. Base geologic map from Longo and Baldock (1982).

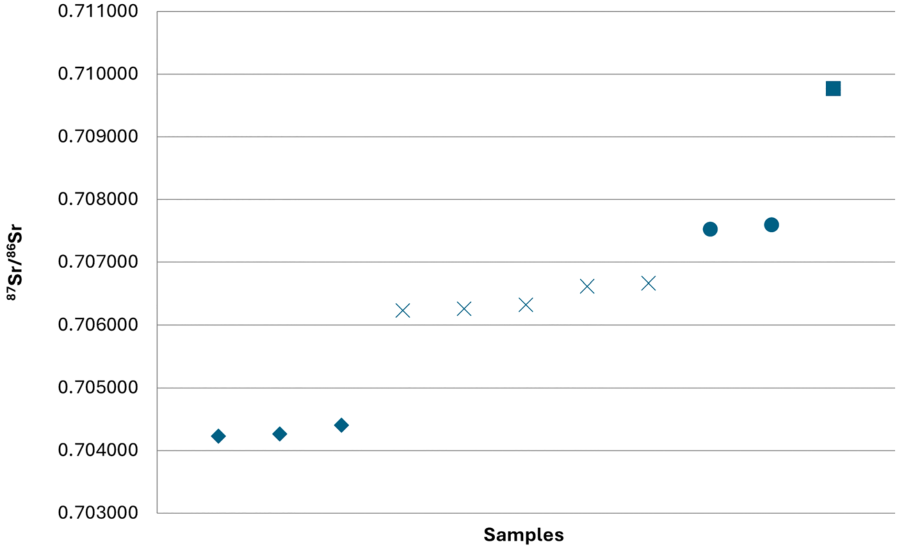

FIGURE 2 | ^{87}Sr/^{86}Sr values from low to high. Samples from the highlands are represented by diamonds, south coast are represented by X, central coast are represented by circles, and the far south coast sample is represented by a square.

samples to establish baselines, as the geology and other modeled values may not accurately reflect how strontium is biologically embodied in tooth and bone.

This pilot study underscores the need for detailed isoscapes for Ecuador (and likely other regions of South America). How local geological strontium is reflected in archaeological remains is not necessarily straightforward. Future research should test additional samples from within and outside the sea spray zone to further elucidate sea spray impact and should consider incorporating plant materials into the analysis as an additional line of evidence. These types of studies will provide the necessary tools for further research on archaeological migratory patterns and allow for more detailed comparisons with other known areas in South America.

Author Contributions

Sara L. Juengst: conceptualization (equal), data curation (equal), formal analysis (equal), funding acquisition (equal), investigation (equal), methodology (equal), project administration (equal), visualization (equal), writing – original draft (equal), writing – review and editing (equal). **María Patricia Ordoñez Alvarez:** conceptualization (equal), funding acquisition (equal), investigation (equal), methodology (equal), project administration (equal), resources (equal), supervision (equal), writing – review and editing (equal).

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Åberg, G., G. Fosse, and H. Stray. 1998. "Man, Nutrition and Mobility: A Comparison of Teeth and Bone From the Medieval Era and the Present From pb and Sr Isotopes." *Science of the Total Environment* 224, no. 1–3: 109–119.

Barberena, R., A. Tessone, M. Cagnoni, et al. 2021. "Bioavailable Strontium in the Southern Andes (Argentina and Chile): A Tool for Tracking Human and Animal Movement." *Environmental Archaeology* 26, no. 3: 323–335.

Bataille, C. P., B. E. Crowley, M. J. Wooller, and G. J. Bowen. 2020. "Advances in Global Bioavailable Strontium Isoscapes." *Palaeogeography, Palaeoclimatology, Palaeoecology* 555: 109849.

Bernal, C., F. Christophoul, J. C. Soula, et al. 2012. "Gradual Diversions of the Rio Pastaza in the Ecuadorian Piedmont of the Andes From 1906 to 2008: Role of Tectonics, Alluvial Fan Aggradation, and ENSO Events." *International Journal of Earth Sciences* 101, no. 7: 1913–1928.

Budd, P., J. Montgomery, B. Barreiro, and R. G. Thomas. 2000. "Differential Diagenesis of Strontium in Archaeological Human Dental Tissues." *Applied Geochemistry* 15, no. 5: 687–694.

Castelló, J. R. 2018. *Canids of the World: Wolves, Wild Dogs, Foxes, Jackals, Coyotes, and Their Relatives*. Princeton University Press.

Cruz, Z. Y. 2022. "Did They Belong: A Preliminary Study on Strontium Isotopic Analysis of the Guangala Culture Located at Salango, Ecuador (Master's Thesis, the University of North Carolina at Charlotte)."

Cueva-Hurtado, L., A. Jara-Guerrero, R. Cisneros, and C. I. Espinosa. 2024. "Activity Patterns of the White-Tailed Deer (*Odocoileus virginianus*) in a Neotropical Dry Forest: Changes According to Age, Sex, and Climatic Season." *Therya* 15, no. 2: 242–252.

Ericson, J. E. 1985. "Strontium Isotope Characterization in the Study of Prehistoric Human Ecology." *Journal of Human Evolution* 14, no. 5: 503–514.

Evans, J. A., J. Montgomery, G. Wildman, and N. Boulton. 2010. "Spatial Variations in Biosphere ^{87}Sr/^{86}Sr in Britain." *Journal of the Geological Society* 167, no. 1: 1–4.

Fahy, G. E., C. Deter, R. Pitfield, J. J. Miszkiewicz, and P. Mahoney. 2017. "Bone Deep: Variation in Stable Isotope Ratios and Histomorphometric Measurements of Bone Remodelling Within Adult Humans." *Journal of Archaeological Science* 87: 10–16.

Garvie-Lok, S. J., T. L. Varney, and M. A. Katzenberg. 2004. "Preparation of Bone Carbonate for Stable Isotope Analysis: The Effects of Treatment Time and Acid Concentration." *Journal of Archaeological Science* 31, no. 6: 763–776.

Hodell, D. A., R. L. Quinn, M. Brenner, and G. Kamenov. 2004. "Spatial Variation of Strontium Isotopes (87Sr/86Sr) in the Maya Region: A Tool for Tracking Ancient Human Migration." *Journal of Archaeological Science* 31, no. 5: 585–601.

Holt, E., J. A. Evans, and R. Madgwick. 2021. "Strontium (87Sr/86Sr) Mapping: A Critical Review of Methods and Approaches." *Earth-Science Reviews* 216: 103593.

Jackson, L. J., B. K. Horton, and C. Vallejo. 2019. "Detrital Zircon U-Pb Geochronology of Modern Andean Rivers in Ecuador: Fingerprinting Tectonic Provinces and Assessing Downstream Propagation of Provenance Signals." *Geosphere* 15, no. 6: 1943–1957.

Juengst, S. L., B. L. Hundman, J. Krigbaum, and G. Kamenov. 2021. "Exploring Dental Modification From Coastal Ecuador From an Unprovenienced Museum Collection." *Bioarchaeology International* 5, no. 3–4: 99–123. https://doi.org/10.5744/bi.2020.0012.

Knudson, K. J. 2008. "Tiwanaku Influence in the South Central Andes: Strontium Isotope Analysis and Middle Horizon Migration." *Latin American Antiquity* 19, no. 1: 3–23.

Knudson, K. J., T. D. Price, J. E. Buikstra, and D. E. Blom. 2004. "The Use of Strontium Isotope Analysis to Investigate Tiwanaku Migration and Mortuary Ritual in Bolivia and Peru." *Archaeometry* 46, no. 1: 5–18.

Knudson, K. J., and C. Torres-Rouff. 2009. "Investigating Cultural Heterogeneity in San Pedro de Atacama, Northern Chile, Through Biogeochemistry and Bioarchaeology." *American Journal of Physical Anthropology* 138, no. 4: 473–485.

Kootker, L. M., R. J. Van Lanen, H. Kars, and G. R. Davies. 2016. "Strontium Isoscapes in The Netherlands. Spatial Variations in $^{87}Sr/^{86}Sr$ as a Proxy for Palaeomobility." *Journal of Archaeological Science: Reports* 6: 1–13.

Longo, R., and J. Baldock. 1982. "National Geological Map of the Republic of Ecuador (including Galápagos Province)." https://esdac.jrc.ec.europa.eu/content/national-geological-map-republic-ecuador-including-gal%C3%A1pagos-province.

Macheridis, S., M. Sandstrom, A. Svensson, H. Wilhelmson, Å. Berggren, and P. Wranning. 2024. "Preliminary Strontium Isotope ($^{87}Sr/^{86}Sr$) Baselines for the Bjäre Peninsula and Halland in Southern Sweden." *Frontiers in Environmental Archaeology* 3: 1379055.

Price, T. D., J. H. Burton, and R. A. Bentley. 2002. "The Characterization of Biologically Available Strontium Isotope Ratios for the Study of Prehistoric Migration." *Archaeometry* 44, no. 1: 117–135.

Reynaud, C., E. Jaillard, H. Lapierre, M. Mamberti, and G. H. Mascle. 1999. "Oceanic Plateau and Island Arcs of Southwestern Ecuador: Their Place in the Geodynamic Evolution of Northwestern South America." *Tectonophysics* 307, no. 3–4: 235–254.

Scaffidi, B. K., and K. J. Knudson. 2020. "An Archaeological Strontium Isoscape for the Prehistoric Andes: Understanding Population Mobility Through a Geostatistical Meta-Analysis of Archaeological 87Sr/86Sr Values From Humans, Animals, and Artifacts." *Journal of Archaeological Science* 117: 105–121.

Serna, A., L. Prates, E. Mange, D. C. Salazar-García, and C. P. Bataille. 2020. "Implications for Paleomobility Studies of the Effects of Quaternary Volcanism on Bioavailable Strontium: A Test Case in North Patagonia (Argentina)." *Journal of Archaeological Science* 121: 105198.

Snoeck, C., S. Ryan, J. Pouncett, et al. 2020. "Towards a Biologically Available Strontium Isotope Baseline for Ireland." *Science of the Total Environment* 712: 136248.

Turner, B. L., G. D. Kamenov, J. D. Kingston, and G. J. Armelagos. 2009. "Insights Into Immigration and Social Class at Machu Picchu, Peru Based on Oxygen, Strontium, and Lead Isotopic Analysis." *Journal of Archaeological Science* 36, no. 2: 317–332.

Vaiglova, P., N. A. Lazar, E. A. Stroud, E. Loftus, and C. A. Makarewicz. 2023. "Best Practices for Selecting Samples, Analyzing Data, and Publishing Results in Isotope Archaeology." *Quaternary International* 650: 86–100.