Environmental Archaeology

The Journal of Human Palaeoecology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/yenv20

Mapping Strontium Isotope Geographical Variability as a Basis for Multi-regional Human Mobility: The Sybaris Region (S Italy) in the Early 1st Millennium BC

Céline Zaugg, Martin A. Guggisberg, Werner Vach, Matthew J. Cooper & Claudia Gerling

To cite this article: Céline Zaugg, Martin A. Guggisberg, Werner Vach, Matthew J. Cooper & Claudia Gerling (09 Oct 2023): Mapping Strontium Isotope Geographical Variability as a Basis for Multi-regional Human Mobility: The Sybaris Region (S Italy) in the Early 1st Millennium BC, Environmental Archaeology, DOI: 10.1080/14614103.2023.2260622

To link to this article: https://doi.org/10.1080/14614103.2023.2260622

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

Published online: 09 Oct 2023.

Submit your article to this journal

Article views: 206

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at https://www.tandfonline.com/action/journalInformation?journalCode=yenv20

ENVIRONMENTAL ARCHAEOLOGY
https://doi.org/10.1080/14614103.2023.2260622

Association *for* Environmental Archaeology
Routledge Taylor & Francis Group
OPEN ACCESS Check for updates

Mapping Strontium Isotope Geographical Variability as a Basis for Multi-regional Human Mobility: The Sybaris Region (S Italy) in the Early 1st Millennium BC

Céline Zaugg[a], Martin A. Guggisberg[a], Werner Vach[b], Matthew J. Cooper[c] and Claudia Gerling[a,b]

[a]Department of Ancient Civilizations, Classical Archaeology, University of Basel, Basel, Switzerland; [b]Department of Environmental Sciences, Integrative Prehistory and Archaeological Science, University of Basel, Basel, Switzerland; [c]School of Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton, UK

ABSTRACT

Archaeological findings from the 8th c. BC settlement at Francavilla Marittima (CS) and its necropolis on the nearby Macchiabate plateau point to multi-regional interactions and the emergence of new identities in connection with the establishment of the Greek colony Sybaris. Strontium isotope analysis ($^{87}Sr/^{86}Sr$) is an efficient method to reconstruct human mobility and provides new insights into the Iron Age and Archaic period in the Calabria region. A successful interpretation of Sr isotope compositions in human tissues requires a baseline of the bioavailable strontium in the landscape of Francavilla Marittima and its surroundings. This study presents $^{87}Sr/^{86}Sr$ values of modern vegetation and water from North Calabria to establish the first finely resolved Sr isotope baseline map of this region. Sr isotope compositions vary between 0.7082 and 0.7127 and reflect the geological and lithological diversity of the study region. The regional $^{87}Sr/^{86}Sr$ variability exceeds the baseline of bioavailable $^{87}Sr/^{86}Sr$ at Francavilla Marittima and enables the integration of past regional interaction in data interpretation of the human remains. Several mapping and prediction methods were tested to produce surface models of the isotopic landscape, and the isotope group map is proposed as a suitable representation of the bioavailable Sr in the studied region.

ARTICLE HISTORY
Received 9 September 2022
Revised 6 July 2023
Accepted 12 September 2023

KEYWORDS
Bioavailable strontium; GIS isoscape modelling; Magna Grecia; Sybaris; cultural interaction; mobility

Introduction

Between the 8th to 6th c. BC Greek seafarers, traders and settlers expanded their activities to the West and East of their homeland and numerous Greek settlements and cities arose all around the Mediterranean Sea as well as in the Black Sea region. From the resulting contacts with the non-Greek population new cultural identities emerged in the respective areas (Hodos 2006; Petropoulos 2015; Donnellan 2016; Murray and Lucas 2019). Research into the interactions between Greek settlers and the native population in the Iron Age (ca. 950/25–730/25 BC, Pacciarelli 2005) and the Archaic period (ca. 700 – 490/89 BC; Hölscher 2002) in Southern Italy has so far been mainly based on the study of archaeological findings and ancient literary traditions (Giangiulio 2001; Burgers and Crielaard 2016; Donnellan 2016; Murray and Lucas 2019). Bioarchaeological methods like isotopic analysis on human skeletal remains, however, have only been used sporadically to investigate this dynamic epoch in the Mediterranean region (Stallo et al. 2010; Gigante et al. 2017).

Strontium isotope analysis ($^{87}Sr/^{86}Sr$), depending on geological variations, is the most common method to reconstruct human mobility in the past (e.g. Ericson 1981; 1985). Since the 1980s, but especially since the early 2000s (for an overview, see Salesse et al. 2018), radiogenic and stable isotope analyses have been an increasingly popular archaeological tool for understanding past populations in the Mediterranean (e.g. Prowse et al. 2004; 2007; Nafplioti 2008; 2009a; 2009b; 2011; 2016; Killgrove 2013; Killgrove and Montgomery 2016; Emery et al. 2018; Milella et al. 2019; Stark et al. 2020; Frank et al. 2021a; 2021b; Lugli et al. 2022). Isotopic studies of the Greek colonial world have so far been conducted in Apollonia (Keenleyside, Schwarcz, and Panayotova 2006; Stallo et al. 2010; Keenleyside, Schwarcz, and Panayotova 2011; Kwok and Keenleyside 2015), Syrakus (Tanasi et al. 2017), Metapont (Henneberg and Henneberg 2001; 2003), Pithekoussai (Gigante et al. 2017), and Francavilla Marittima (Colombi, Villa, and Guggisberg 2018; Villa 2021).

Mapping $^{87}Sr/^{86}Sr$ values of modern water, soil, plants, and archaeological human and faunal skeletal

CONTACT Céline Zaugg celine.zaugg@bl.ch Archäologie Baselland, Amtshausgasse 7, 4410 Liestal, Switzerland; Claudia Gerling claudia.gerling@unibas.ch Department of Ancient Civilizations, Prehistory, Early History and Archaeology of the Roman Provinces, University of Basel, Petersgraben 51, 4051 Basel, Switzerland; Department of Environmental Sciences, Integrative Prehistory and Archaeological Science, University of Basel, Spalenring 145, 4055 Basel, Switzerland

Supplemental data for this article can be accessed http://doi.org/10.1080/14614103.2023.2260622.

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (http://creativecommons.org/licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

remains provides the framework to interpret ancient mobility and places of origin (e.g. Price et al. 1994; Sillen et al. 1998; Bentley and Knipper 2005; Evans et al. 2010; see Britton et al. 2020 also for an evaluation of various modern reference datasets). Different methods have been used to model the biologically available strontium in the landscape, e.g. simple plotting of the collected isotope data to a geology map (Bentley and Knipper 2005; Nafplioti 2011; Blank et al. 2018; Brönnimann et al. 2018; Cavazzuti et al. 2019), assigning average isotope values to geological or lithological units and thus creating isotope groups (e.g. Evans et al. 2010; Willmes et al. 2018), or using interpolation methods (e.g. Blank et al. 2018; Willmes et al. 2018; Britton et al. 2020; Lugli et al. 2022), as well as machine-learning approaches (e.g. Beard and Johnson 2000; Bataille et al. 2018) to generate smooth surface models. The first strontium isotope map for Italy was published by M. Emery and colleagues (2018; data points n = 333). Recently, Lugli et al. (2022) presented several Kriging modellings using Emery's dataset of bioavailable and non-bioavailable Sr isotope values with added novel data (n = 1920, database available at https://www.geochem.unimore.it/sr-isoscape-of-italy/). The limited number of data points in the Calabria region make both maps less reliable for more regional and small-scale studies, however, and prompts the creation of more detailed isoscape maps.

In this study, we present the first strontium isotope baseline data and isoscape modelling of the Sibaritide region, Calabria (S Italy), which will serve as a basis to interpret the $^{87}Sr/^{86}Sr$ values of human skeletons (dating from mid 8th to early 7th c. BC) from the Iron Age cemetery at Francavilla Marittima (Colombi, Villa, and Guggisberg 2018; Billo-Imbach et al., 2020; Gerling et al. 2021). We attempt three different, but conventionally used mapping approaches. The various map models highlight different aspects of the bioavailable Sr isotopic landscape. A distribution map (cf. Brönnimann et al. 2018) emphasises measured datapoints in context with the geolithological units, but there is no prediction of $^{87}Sr/^{86}Sr$ between the known data. In an isotope group map (cf. Evans et al. 2010; Willmes et al. 2018), an estimation of the mean $^{87}Sr/^{86}Sr$ of a geolithological unit is presented. It is a surface model that respects the geological variation and its impact on the bioavailable Sr. However, Sr heterogeneity within geolithological formations in a surface model is presented by interpolation processes, e.g. Kriging (cf. Blank et al. 2018; Willmes et al. 2018). Kriging predicts values of unknown points in a continuous manner. By comparing the different approaches, we explore the best-suited method for the Sibaritide dataset.

Francavilla Marittima and the Sibaritide in the 1st Millennium BC

Before the foundation of the Greek colony Sybaris on the Gulf of Taranto (Figure 1), the area was already characterised by a dynamic settlement process. Until the Iron Age (ca. 950/25–730/25 BC, Pacciarelli 2005), various 'central settlements' were established on the marine terraces around the plain, which from then on dominated the Sibaritic settlement system (Peroni 1994). These 'central settlements' controlled territories of 12–15 km^2 each, limited by the Sibaritic rivers. The territory attributed to the settlement on the Timpone Motta plateaus at Francavilla Marittima lies between the Satanasso and Raganello rivers. The hamlets and farm buildings found in the Contrada Damale and Contrada Portieri further north may also have belonged to the settlement's territory (Peroni 1994; Kleibrink 2004; Attema, Burger, and van Leusen 2010; Vanzetti 2013; De Neef 2016). In addition, the settlement's burial grounds serve as an important source for the reconstruction of the demographic developments in the Sibaritide during both pre-colonial and colonial times. Recent research by the University of Basel following earlier investigations by P. Zancani Montuoro in the 1960s at the Macchiabate necropolis near the settlement on the Timpone Motta focuses on three Iron Age and one Archaic burial areas (Guggisberg and Colombi 2021). The previously uncovered burials in the Strada, De Leo and Est areas can be dated mainly to the 8th c. BC, while in the area Collina the majority of graves date from the Archaic period (ca. 700 – 490/89 BC; Hölscher 2002). Typical elements of these Iron Age fossa graves are the positioning of the body in a lateral, flexed position, a rich kit of local ceramic vessels as well as of jewellry, tools, and weapons made mostly of bronze or iron. In addition to these Oinotrian grave goods, objects that were clearly imported or locally imitated under Greek and Near Eastern influences have also been found in various graves. The large number of contemporaneous burials in the Macchiabate necropolis compared to the small settlement area of Timpone Motta (Elevelt 2012; Colombi, Villa, and Guggisberg 2018), may suggest that people living in Timpa del Castello, Timpone Motta di Cerchiara, Contrada Damale, Contrada Portieri, and Terra Masseta were also buried in Francavilla Marittima.

Around 720 BC, Achaean settlers from Helike, Boura and Aigai, founded the colony Sybaris (Strabo V.4.13 in Rainey and Lerici 1967; Petropoulos 2015). Sybaris quickly developed into a powerful city and cultivated lively trade relations with the Greek world (Petropoulos 2015). In the second half of the 8th c. BC, around the time of the establishment of the colony, many of the Iron Age settlements in the Sibaritide were abandoned or destroyed (Kleibrink 2004; Peroni and Vanzetti 2008). However, some Oinotrian settlements in the Crati basin (Cozzo Michelicchio, Cozzo la Torre Castello Torano, Bisignano) and the settlements of Timpone Motta, Castrovillari, and Amendolara continued to exist (Figure 1; Peroni and Vanzetti

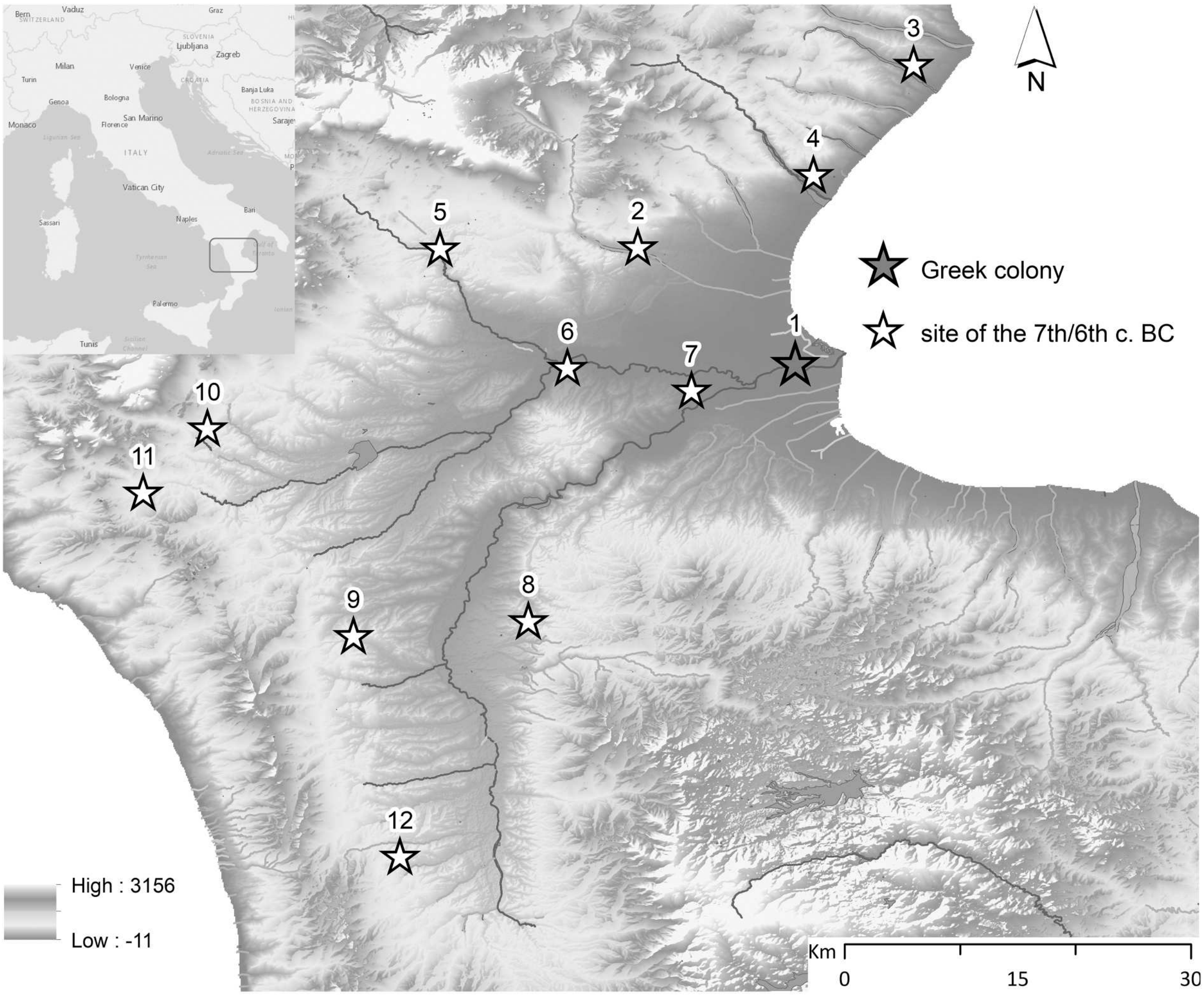

Figure 1. 7^{th}/6th c. BC sites in the Sibaritide (after Peroni 1994; Peroni and Vanzetti 2008; D'Alessio and Taliano Grasso 2014; Carloni and Pacciarelli 2021; Marino and Colelli 2021). 1: Sybaris; 2: Timpone della Motta; 3: Amendolara; 4: Broglio di Trebisacce; 5: Castrovillari; 6: Torre Mordillo; 7: Cozzo Michelicchio; 8: Bisignano; 9: Cozzo la Torre Castello Torano; 10: San Sosti; 11: Grotta del Tesauro; 12: Rende. Map data: powered by Esri, HERE, Garmin, FAO NOAA, USGS, CIAT-CSI SRTM (https://srtm.csi.cgiar.org), and OpenStreetMap, ODbL 1.0.

2008). After the foundation of Sybaris, the settlement and sanctuary on the Timpone Motta seem to have gained a particular importance (Kleibrink 2011) and the Macchiabate necropolis was still in use until at least the 6^{th} c. BC (Kleibrink 2011). By that time, the former Oinotrian burial custom had been replaced by the tradition of extended supine skeletal positions and ceramic vessels in a predominantly Greek tradition as grave goods. These changes indicate complex and close cultural and economic relationships between the residents of Timpone Motta and Sybaris as well as their direct interactions in respect to ritual activities (Attema, Burger, and van Leusen 2010).

Strontium Isotope Analysis and the Geology of the Sibaritide

Strontium isotope analysis is a method to reconstruct human mobility in the past (e.g. Ericson 1981; 1985). The ratio of ^{87}Sr to ^{86}Sr isotopes in a geological formation depends on the age, geochemistry, type, and initial concentration of ^{87}Rb of the investigated bedrock (Beard and Johnson 2000; Price, Burton, and Bentley 2002; Bentley 2006). Thus, $^{87}Sr/^{86}Sr$ ratios serve as geochemical signatures of certain geological formations. Through weathering of the bedrock, soluble strontium gets into the overlying soil layers and groundwater (Bentley 2006). Through ingestion, Sr isotopes are absorbed into the nutrient cycle of plants, animals, and humans and stored in their tissues. Skeletal elements mineralise at different times of life (Ubelaker 1978). Human tooth enamel mineralises during childhood and does not undergo significant alteration afterwards; it is also relatively resistant to post-mortem diagenesis (Price, Schoeninger, and Armelagos 1985; Knipper 2004; Bentley 2006). Hence, $^{87}Sr/^{86}Sr$ values in tooth enamel can provide information on the geological area from where the food consumed during early life originated (Bentley 2006). Different $^{87}Sr/^{86}Sr$ values in the enamel of early forming teeth and biological reference samples from the last residence/burial place used as an approximation to the 'local' biologically available strontium, are usually interpreted as indicating changes in diet and, related to this, residence changes during life (Price, Burton, and Bentley 2002; Bentley 2006). For an improved assessment of the isotopic composition of the last residence/burial place and human lifetime mobility, a fundamental knowledge of the geochemical composition not only of the local but also regional environment is essential (Bentley 2006; Evans, Montgomery, and Wildman 2009; 2010). This can be achieved by analysing the biologically available strontium in and around the food catchment area of a community. Although strontium isotopes in the biosphere are primarily influenced by its geological underground, several atmospheric contributors add to the isotopic composition in plants and water. Thus, the local bioavailable strontium is a mixture of different strontium in– and outputs, e.g. mineral weathering, rivers, springs, rainfall, sea spray, dust, and anthropogenic contamination (Price, Burton, and Bentley 2002; Bentley 2006; Thomsen and Andreasen 2019).

The Sibaritide, located in the northeast of today's province of Cosenza (Calabria, Italy) at the Ionian Sea, is geologically diverse (Figure 2) and divided in different geomorphological zones: Ionian plain, marine terraces, Pollino and Sila massifs (Cucci 2005; Elevelt 2012; added zones 4–5, 7 see Figure 2). The plain is traversed by several rivers, which have deposited a several metres thick layer of clastic and alluvial sediments in the lowlands since the Pliocene leading to a continuous shift of the coastline to the east (Collella, De Boer, and Nio 1987; Cucci 2005; Vespasiano et al. 2019). Towards the north, north-west and south, the plain gradually rises to the foothills of the Pollino and Sila mountains with a band of marine terraces extending between the foothills and the alluvial plain (Cucci and Cinti 1998; Cucci 2005). Large parts of the Pollino mountain range north of the Sibaritide are characterised by Mesozoic carbonate complexes. The Sila and Catena Costiera mountain ranges south of the Sibaritide belong to the Paleozoic crystalline Complesso Calabride (Cotecchia 1993; Cucci 2005; Vespasiano et al. 2015).

Materials and Methods

Sampling

For a complete isotopic recording of the bioavailable strontium in the regions in and around the potential food catchment area of the Sibaritic settlements, modern vegetation and water samples were taken within a radius of approx. 50–70 km around Francavilla Marittima. Collecting strategy and spatial distribution of sample locations followed the approach published in Brönnimann et al. (2018). To avoid possible anthropogenic influences (e.g. fertilisers, industrial waste, dust, etc.), samples were taken in natural, old forests and avoiding constructed, industrial and agricultural areas whenever possible (Declerck et al. 2006; Britton et al. 2020).

Modern leaf (n = 33) and grass (n = 33) from 33 locations and water (n = 5) from 5 locations (Tables 1 and 2) were collected to characterise the bioavailable $^{87}Sr/^{86}Sr$ composition of the burial site and its catchment area. The 33 plant sample locations were selected (Figure 2) based on the geology of the sampling area. Water samples were taken from the five rivers Crati, Coscile, Raganello, Caldanello, and Satanasso, which flow at <15 km from Francavilla Marittima. All sampling locations were recorded using a GPS device and documented photographically. Grass and leaf samples of approx. 50–100 g each were collected and stored separately in zip lock bags and dried. 50 ml of river water was taken with a pipette and stored in acid-cleaned Teflon containers. For the contextualisation of the $^{87}Sr/^{86}Sr$ values measured in water and plants, general comparative data (McArthur, Howarth, and Bailey 2001; Voerkelius et al. 2010) were consulted.

Sample Preparation and Analysis

Sample preparation for strontium isotope analysis took place in the Integrative Prehistory and Archaeological Science (IPAS), Department of Environmental Sciences, University of Basel. Sample treatment followed established methods (Maurer et al. 2012; Gerling et al. 2017). Details of the sample preparation processes are provided in SI1. Following the chemical separation, the samples were analysed for $^{87}Sr/^{86}Sr$ on a Thermo Fisher TRITON Thermal Ionisation Mass Spectrometer at the University of Southampton. The samples were loaded onto Ta filaments with a Ta activator solution and run at an ^{88}Sr ion beam of 2 V. The standard international reference material NIST SRM 987 was run alongside the samples, the long-term $^{87}Sr/^{86}Sr$ average of SRM 987 for this instrument is 0.710243 ± 0.000021 (2σ) (n = 303). This is within the error of the reported $^{87}Sr/^{86}Sr$ ratios of NIST SRM 987 by Thirlwall (1991) and Avanzinelli et al. (2005). Five independent NIST SRM 987 samples, that had been through the chemical procedure along with the EFM (environment of Francavilla Marittima) samples, averaged 0.710240 ± 0.000013 (2σ).

GIS Modelling

ArcGIS Desktop Version 10.6 from ESRI was used to create all maps presented in this study. Every performed modelling method highlights unique aspects of an isotopic landscape. In order to get the best possible approximation of the isotopic composition of the

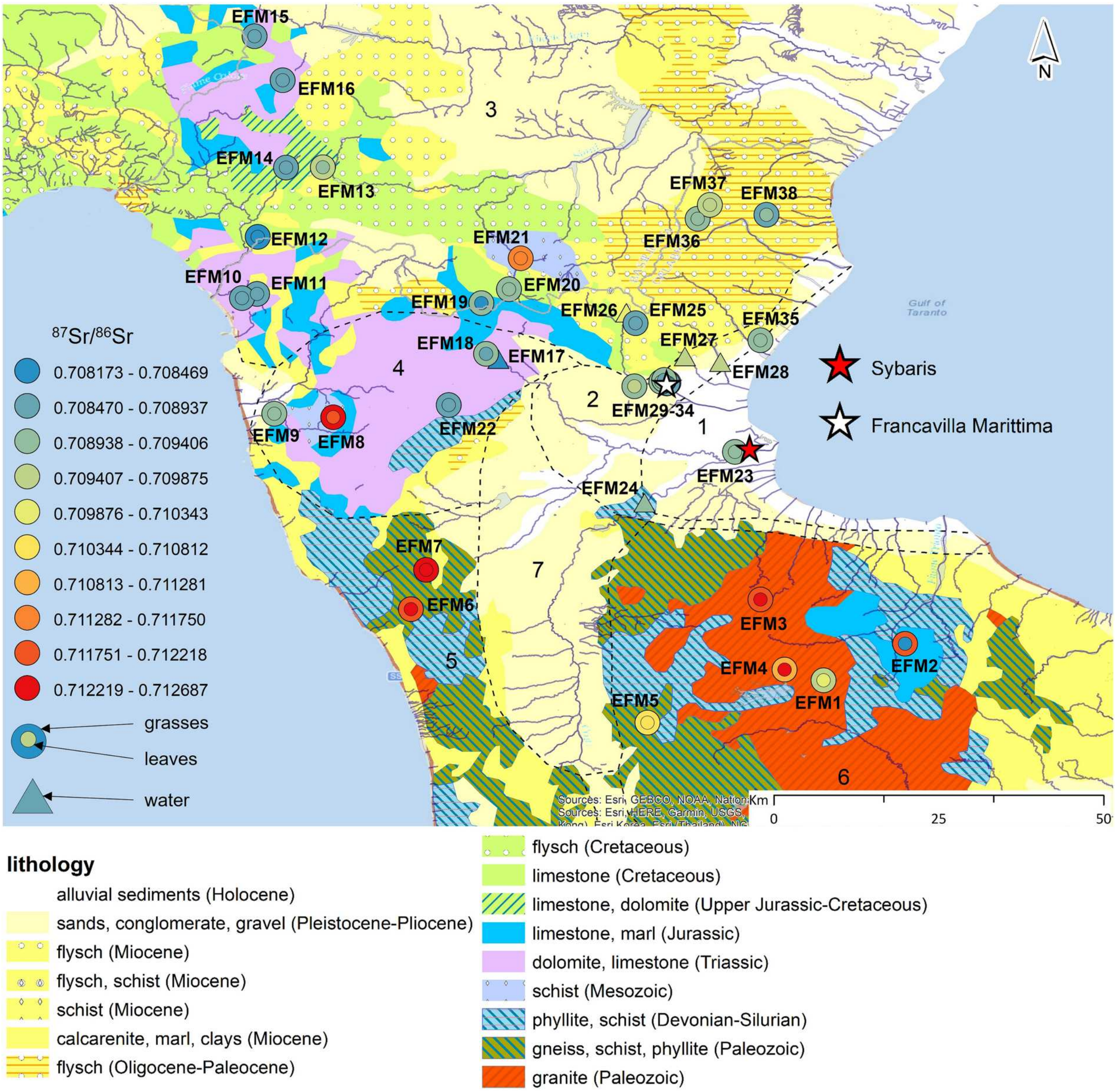

Figure 2. Geological map of the wider environment of Francavilla Marittima (EFM) in northern Calabria and southern Basilicata with $^{87}Sr/^{86}Sr$ ratios measured in plants (circles) and river water (triangles) in sampling locations EFM1–38 and geomorphological zones (expanded after Cucci 2005 and Elevelt 2012) 1: alluvial plain, 2: hill zone with marine terraces, 3: Pollino mountains, 4: hinterland of Castrovillari, 5: Catena Costiera mountains, 6: Sila mountains, 7: Crati basin. The $^{87}Sr/^{86}Sr$ ranges are calculated by equal intervals into 10 different classes. Geological map after IGK1500 D6 and Vari, 1970 (modified). Map data: powered by Esri, HERE, Garmin, FAO NOAA, USGS, and OpenStreetMap, ODbL 1.0.

landscape, several methodological approaches were tested: A distribution map of the $^{87}Sr/^{86}Sr$ values measured in plants and water according to Brönnimann et al. (2018), five isotope group maps with classifications of the $^{87}Sr/^{86}Sr$ data according to a) geological era (three groups), b) geological period (seven groups), c) main lithological properties (four groups), d) a combination of geological age, rock types, and geomorphological zone (21 groups) and e) lithological groups from Lugli et al. 2022 (using Isoclasses 2, 3, 7, and 8 which correspond with Calabrian geolithologies; approaches similar to Evans, Montgomery, and Wildman 2009; 2010; and Willmes et al. 2018) as well as a prediction model using the Ordinary Kriging method as in Willmes et al. (2018).

Kriging is a geostatistical process to estimate a continuous surface between sampled data points by considering spatial autocorrelation (Krige 1951). A Root Mean Square Error (RMSE) was calculated, and a Prediction Standard Error Map (PSEM) was created to check the performance and uncertainty of the generated Kriging model (Figure s1). For map modelling, the mean values of all plant samples per location and water values were used (see also SI7 and Table s3). Grass sample EFM2 was excluded from the mean value calculations due to its unusually high $^{87}Sr/^{86}Sr$ values (see also section 4.1). For the isotope group maps, the mean values of the samples from each group served as basis for the representation in the map (Figure 4).

Table 1. $^{87}Sr/^{86}Sr$ ratios of modern river water samples from the Sibaritide region including geological and geographical background information.

sample	river	location	geology (lithology) catchment area, location	GPS (WGS84) lat. (°N)	GPS (WGS84) long. (°E)	altitude m a.s.l.	date	$^{87}Sr/^{86}Sr$	± 2σ	Sr mg/l
EFM17	Fiume Coscile	Morano Calabro	Triassic (dolomite, limestone) > Pleistocene > Holocene	39.838422	16.148361	509	4/6/2019	0.708195	0.000015	–
EFM24	Fiume Crati	Terranova da Sibari	Paleozoic > Pleistocene > Holocene (alluvial sediments)	39.64255	16.347814	36	4/7/2019	0.7094	0.000012	–
EFM26	Torrente Raganello	San Lorenzo Bellizzi	Cretaceous/Miocene (limestone, flysch, schist, clay) > Pleistocene > Holocene	39.901503	16.322933	650	4/8/2019	0.710087	0.000013	4.02
EFM27	Torrente Caldanello	Cerchiara di Calabria	Cretaceous/Miocene (limestone, flysch, schist, clay) > Pleistocene > Holocene	39.842078	16.402747	177	4/8/2019	0.709701	0.000013	2.85
EFM28	Torrente Satanasso	Masseria Adduci	Cretaceous/Miocene (limestone-clay-complex) > Pliocene/ Pleistocene (alluvial and marine sediments) > Holocene	39.834253	16.451108	128	4/8/2019	0.709492	0.000015	4.12

Table 2. $^{87}Sr/^{86}Sr$ ratios of modern vegetation samples from the Sibaritide region including geological and geographical background information.

sample	location	geology (lithology)	GPS (WGS84) lat. (°N)	long. (°E)	altitude m a.s.l.	date	ground vegetation taxa	$^{87}Sr/^{86}Sr$	± 2σ	trees and shrubs taxa	$^{87}Sr/^{86}Sr$	± 2σ
EFM1	Fossiata	Permo-Carboniferous (granite; intrusive rocks)	39.399756	16.592042	1332	4/2/2019	grasses	0.709615	0.000021	Pinus nigra	0.709951	0.000014
EFM2	Ortiano	Jurassic (limestone, silicate minerals, carbonate)	39.449844	16.703308	776	4/2/2019	grasses	0.711773	0.000014	Malus sylvestris	0.708409	0.000014
EFM3	Bonia I	Permo-Carboniferous (granite; intrusive rocks)	39.510283	16.505881	941	4/2/2019	grasses	0.712116	0.000013	Quercus	0.712687	0.000013
EFM4	Cava di Melis		39.414342	16.538886	1277	4/2/2019	grasses	0.711276	0.000014	Pinus	0.712229	0.000012
EFM5	Fermata di Santo Janni	Paleozoic (gneiss, schist, phyllite; metamorphous rocks)	39.342031	16.351881	1108	4/2/2019	grasses	0.710796	0.000015	Crataegus	0.710729	0.000012
EFM6	Guardia Piemontese		39.497147	16.029175	674	4/3/2019	grasses	0.7121	0.000011	Sambucus	0.712226	0.000012
EFM7	Fagnano Castello		39.550778	16.049931	623	4/3/2019	grasses	0.712444	0.000013	Sambucus	0.712401	0.000014
EFM8	Verbicaro	Miocene (sandstone, claystone, limestone; schist of the Fiume Lao)	39.758942	15.923292	650	4/3/2019	grasses	0.712225	0.000013	Sambucus	0.711781	0.000012
EFM9	Marcellina	Pliocene (conglomerate, sandstone, clay)	39.763792	15.843028	57	4/3/2019	grasses	0.709254	0.000013	Pistacia lentiscus	0.709299	0.000014
EFM10	Aieta	Triassic (dolomite, limestone)	39.927133	15.819522	578	4/4/2019	grasses	0.70893	0.000014	Pinus	0.708723	0.000017
EFM11	Praia a Mare		39.921567	15.798975	494	4/4/2019	grasses	0.708705	0.000014	Fagus	0.708519	0.000013
EFM12	Fabbricato	Cretaceous (limestone, dolomite)	40.005111	15.820411	908	4/4/2019	grasses	0.708243	0.000013	Fagus	0.708173	0.000012
EFM13	Timparossa	Upper Jurassic-Cretacous (limestone, dolomite, flysch)	40.100008	15.909189	919	4/4/2019	grasses	0.709513	0.000012	Crataegus	0.709145	0.000012
EFM14	Masseria Viceconti		40.099581	15.858911	965	4/4/2019	grasses	0.708825	0.000012	Crataegus	0.70873	0.000011
EFM15	Tramutola	Triassic (dolomite, limestone)	40.278822	15.816003	910	4/5/2019	grasses	0.708735	0.000013	Fagus	0.708576	0.000012
EFM16	Moliterno		40.218719	15.854408	902	4/5/2019	grasses	0.708605	0.000015	Fagus	0.708606	0.000015
EFM18	Morano Calabro		39.845467	16.131697	720	4/6/2019	grasses	0.70894	0.000012	Fagus	0.708828	0.000014
EFM19	Piano di Ruggio Zaperna	Jurassic (limestone, silicate minerals, carbonate)	39.914531	16.125361	1554	4/6/2019	grasses	0.708941	0.000011	Pinus	0.708379	0.000012
EFM20	Colle dell' Impiso	Cretacous (limestone, breccia, conglomerate)	39.933539	16.162958	1583	4/6/2019	grasses	0.709011	0.000014	Fagus	0.709047	0.000013
EFM21	Mezzana Frido	Cretaceous (schist of the Torrente Frido)	39.975872	16.179114	1028	4/6/2019	grasses	0.711473	0.000012	Crataegus	0.711365	0.000014
EFM22	Lungro	Triassic (dolomite, limestone)	39.775558	16.080964	1361	4/7/2019	grasses	0.708923	0.000014	Abies	0.708702	0.000014
EFM23	Sibari	Holocene (alluvial sediments)	39.711722	16.471172	8	4/7/2019	grasses	0.709036	0.000013	Fagus	0.709047	0.000013
EFM25	San Lorenzo Bellizzi	Miocene (calcarenite, marl, clay, flysch)	39.887294	16.335739	954	4/8/2019	grasses	0.708621	0.000013	Fagus	0.70848	0.000014

(*Continued*)

Table 2. Continued.

sample	location	geology (lithology)	GPS (WGS84)		altitude	date	ground vegetation			trees and shrubs		
			lat. (°N)	long. (°E)	m a.s.l.		taxa	$^{87}Sr/^{86}Sr$	± 2σ	taxa	$^{87}Sr/^{86}Sr$	± 2σ
EFM29	FMM, Area Est	Pleistocene (terraced sands and conglomerate)	39.8059	16.380344	155	4/8/2019	grasses	0.708772	0.000013	Pistacia lentiscus	0.70868	0.000014
EFM30	FMM, Collina		39.804922	16.378444	158	4/8/2019	grasses	0.708969	0.000013	Pistacia lentiscus	0.708865	0.000012
EFM31	FMM, Area Strada		39.805478	16.379108	158	4/8/2019	grasses	0.708823	0.000013	Pistacia lentiscus	0.708748	0.000014
EFM32	Timpone della Motta	Pliocene (conglomerate, limestone, arenite, sandstone)	39.807256	16.370725	241	4/8/2019	grasses	0.709032	0.000013	Pistacia lentiscus	0.708971	0.00002
EFM33	Francavilla Marittima	Pleistocene (terraced sands and conglomerate)	39.809714	16.374783	231	4/8/2019	grasses,	0.708948	0.000012	Pinus	0.708877	0.000013
EFM34	Monte San Nicola	Pliocene-Pleistocene (terraced sands and conglomerate, limestone, arenite)	39.801172	16.334128	491	4/8/2019	grasses	0.709333	0.000013	Pinus	0.709524	0.000013
EFM35	Broglio di Trebisacce	Pleistocene (terraced sands and conglomerate)	39.864039	16.505903	173	4/9/2019	grasses	0.709011	0.000013	Pistacia lentiscus	0.708989	0.000014
EFM36	Farneta	Paleocene-Oligocene (sandstone, clays, marl, limestone, flysch)	40.0296	16.420439	653	4/9/2019	grasses	0.708988	0.000012	Fagus	0.708955	0.000012
EFM37	Oriolo		40.048728	16.437125	730	4/9/2019	grasses	0.709494	0.000013	Fagus	0.70945	0.000013
EFM38	Montegiordano		40.0351	16.514122	581	4/9/2019	grasses	0.70877	0.000013	Pinus	0.709038	0.000012

Results

$^{87}Sr/^{86}Sr$ Baseline Data from Modern Water and Vegetation

The $^{87}Sr/^{86}Sr$ ratios of the five river water samples ranged from 0.70820 to 0.71009 (mean 0.70938 ± 0.00071; n = 5; Table 1). The isotope ratios measured in plants ranged from 0.70817 to 0.71269 (n = 66; Table 2). The sampled river waters, grasses, and tree leaves (n = 71) gave heterogeneous Sr signals, which reflect the geological diversity of the study region. A more detailed examination of the analysis results is provided in SI3.

The differences between the $^{87}Sr/^{86}Sr$ values of grass and tree samples ($\Delta^{87}Sr/^{86}Sr_{grasses\text{-}leaves}$; Figure s2) of the same location vary between − 0.00095 and +0.00336 (n = 33). A tendency towards smaller $\Delta^{87}Sr/^{86}Sr_{grasses\text{-}leaves}$ (Brönnimann et al. 2018; Isaakidou et al. 2019) occurs more frequently in pairs of plants from younger, Cenozoic soils (Figure 3). A distinct association between the $^{87}Sr/^{86}Sr$ in grasses and trees/shrubs and the mean annual precipitation (Figure s3), as proposed in Crete (Isaakidou et al. 2019) and Israel (Hartman and Richards 2014), could not be observed.

Spatial Variation of the Biologically Available Strontium in Calabria

The $^{87}Sr/^{86}Sr$ distribution map (Figure 2) shows the isotope value ranges measured within the various geological units. $^{87}Sr/^{86}Sr$ ratios are in general low in the North (geomorphological zones 1–4) and high in the South (zones 5–6) of the study region. Geomorphological zone 1 (alluvial plain) has a narrow $^{87}Sr/^{86}Sr$ range of 0.7090–0.7094 (mean 0.70916 ± 0.00021, n = 3) due to its homogenous Holocene alluvial sediment layer. In zone 2 (hills and marine terraces), the measured $^{87}Sr/^{86}Sr$ ranges were narrow over Pleistocene and Pliocene ground with 0.7087–0.7095 and widened by schist influence at EFM27 up to 0.7097 (mean 0.70905 ± 0.00030, n = 15). Zone 3 (Pollino mountains) is characterised by an $^{87}Sr/^{86}Sr$ variability of 0.7082–0.7115 (mean 0.70904 ± 0.00077, n = 30), due to its heterogeneous geology, including two locations (EFM21, 26) with schist influence. This is very similar to zone 4 (hinterland of Castrovillari), which has an $^{87}Sr/^{86}Sr$ range of 0.7082–0.7122 (mean 0.70960 ± 0.00142, n = 9) due to the schist formation at EFM8. Paleozoic zone 5 (Catena Costiera) is characterised by a narrow $^{87}Sr/^{86}Sr$ range of 0.7121–0.7124 (mean 0.71229 ± 0.00016, n = 4). Zone 6 (Sila mountains) has an $^{87}Sr/^{86}Sr$ variability of 0.7084–0.7127 (mean 0.71087 ± 0.00134, n = 9) due to its heterogeneous geology.

$^{87}Sr/^{86}Sr$ ranges vary when grouped by geomorphological zones 1–7, depending on their geological age and lithological composition. When grouped by geolithology (Figure 3), however, more homogeneous isotope groups with only few outliers are obtained. In general, isotopic differences in the studied region are mainly based on geolithological units with occasional variations in different geomorphological zones, e.g. higher $^{87}Sr/^{86}Sr$ ratios in Paleozoic Catena Costiera vs. lower $^{87}Sr/^{86}Sr$ ratios in Paleozoic Sila (Figure 3, Table s1).

Generated Isoscapes

Several map models were generated to produce a Sr isoscape of the area according to various prediction methods. With respect to generating isotope groups, we compared five potential groupings of sites based on information on geology and lithology. The best explanation of the variation in the Sr ratio was given by the 21 groups (adjusted $R^2 = 0.799$), followed by the four groups based on main lithology (adjusted $R^2 = 0.719$). All other groupings lead to adjusted R^2 values of less than 0.53. However, we

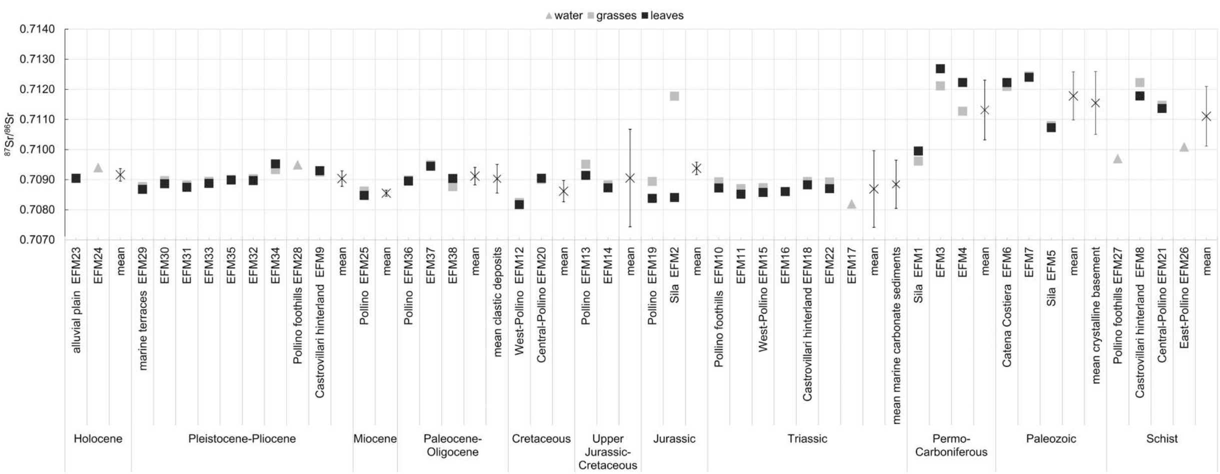

Figure 3. $^{87}Sr/^{86}Sr$ ratios of modern grass, shrub/tree leaf, and river water samples, grouped by geological periods, and subgrouped by lithological units and geomorphological regions. An additional schist group was separated (see also Table s1).

note that the best R^2 value observed for the 21 groups in part is likely driven by the effect of our sampling since in more than half of the classes the Sr values are based on only one study site. The corresponding isotope group maps are shown in Figure 4. Both isotope group maps characterise the Pollino mountains largely with the $^{87}Sr/^{86}Sr$ range 0.7085–0.7089, with the hinterland of Amendolara having a more radiogenic range between 0.7089 and 0.7094 on average and the western Pollino below 0.7085. This probably reflects the rough division of the massif into the eastern limestone-clay complex and the western limestone soil. Also clearly visible in both maps are the local schist formations in the Pollino mountains. Hill zone, Crati basin, and alluvial plain lie within the same $^{87}Sr/^{86}Sr$ range of 0.7089–0.7094. According to their isotope group, the Sila foothills have on average lower $^{87}Sr/^{86}Sr$ values between 0.7085 and 0.7089, whereby the extrapolated mean value for this region is uncertain due to the lack of measurements. Differences between the two isotope group maps are mainly seen in the southern mountain ranges: While in the map with only four isotope groups (Figure 4a, RMSE 0.000672) the crystalline basement is generally classified with means between 0.7112 and 0.7118, the map with 21 groups (Figure 4b, RMSE 0.000568) displays more heterogeneity. The Catena Costiera is more radiogenic than the Sila region with >0.7122 on average. Samples from the central highlands of the Sila massif have average values between 0.7113 and 0.7118 and in the west between 0.7103 and 0.7108.

After removal of point EFM21 with undue influence (Figure s4), the Kriging model (RMSE 0.000883) generally provided similar results (Figure 5): The lowest values are in the western Pollino massif. The highest $^{87}Sr/^{86}Sr$ ranges were modelled in the Catena Costiera throughout the Crati basin to the western Sila mountains. The alluvial plain downhill the Sila mountain range has slightly higher $^{87}Sr/^{86}Sr$ values than north of the Coscile and Crati rivers.

Discussion

$^{87}Sr/^{86}Sr$ Isotopic Outliers

As shown in Figure 3, EFM 2, EFM17, EFM1, EFM5, and EFM27 are identified as isotopic outliers within their geolithological groups. The ground vegetation of EFM2 has an unusually high $^{87}Sr/^{86}Sr$ value for calcareous underground (Voerkelius et al. 2010, 0.7070–0.7090), maybe due to an influence by atmospheric sources or gravel deposits from the surrounding crystalline Sila mountains (cf. Evans, Montgomery, and Wildman 2009). The Fiume Coscile (EFM17) is low in $^{87}Sr/^{86}Sr$, probably due to the river's spring in the Jurassic calcareous Pollino, however, still within the predicted Mesozoic Sr isotope range of 0.7070–0.7090 (Voerkelius et al. 2010). Plants from Fossiata (EFM1) have lower $^{87}Sr/^{86}Sr$ values than expected for its Paleozoic granite unit (>0.7100; Price, Burton, and Bentley 2002; Bentley 2006). Decreased isotope values might be an indication for the usage of fertilisers or agricultural lime (Thomsen and Andreasen 2019), but no signs of agricultural or other anthropogenic influences were observed. A possible explanation might be the influence of the snow cover (ca. 0.7092; Hess, Bender, and Schilling 1986) at the time of sampling. Although low in $^{87}Sr/^{86}Sr$, EFM5 is within the expected Paleozoic range >0.7100 (Price, Burton, and Bentley 2002; Bentley 2006), and the differences might be interpreted as regional variations between the Sila and the Catena Costiera mountains. River sample EFM27 has lower $^{87}Sr/^{86}Sr$ values as plant samples EFM8 and EFM21, although all are primarily influenced by the presence of schist, regardless of other mineral components within their geological formations or age. The Cretaceous catchment areas of the rivers may lead to a lower isotope signal despite the local presence of schist. Summing up, although geolithology is the main influencing factor on Sr isotope compositions, slight variations within geological units in different geographic or geomorphological regions occur.

Evaluation of the $^{87}Sr/^{86}Sr$ Isoscape Models

By comparing different groupings of site samples, we observed that lithological property-based classifications are more effective than those based on rock age. Therefore, within the sampled area, the lithological unit present is primarily impacting the strontium in the biosphere. The four lithological isotope groups defined rather connected areas with good agreement between many sites and the group specific values, but a few distinct exceptions. The main discrepancy described in Figure 4a of crystalline and schist is that the classification of mean group values is no longer in agreement with the majority of the measured values. The crystalline Catena Costiera and Sila are characterised with values between 0.7113–0.7118 by the model while the measured values have increased variability of 0.7096–0.7127. With 21 groups (Figure 4b) we have often a perfect match with the values of single sites, as many groups consist only of one site (cf. Table s1). For these 12 lithological units, the map may reflect rather the variation in Sr of the sites than of the areas. A substantial degree of averaging is only performed for one group with seven sites, and in this group the range from 0.7086–0.7095 was indeed limited.

The Ordinary Kriging model does not take into account the geolithological units, which leads to an unrealistic smoothing of the formation boundaries (Blank et al. 2018). This is particularly visible in the areas around Castrovillari and the Crati basin

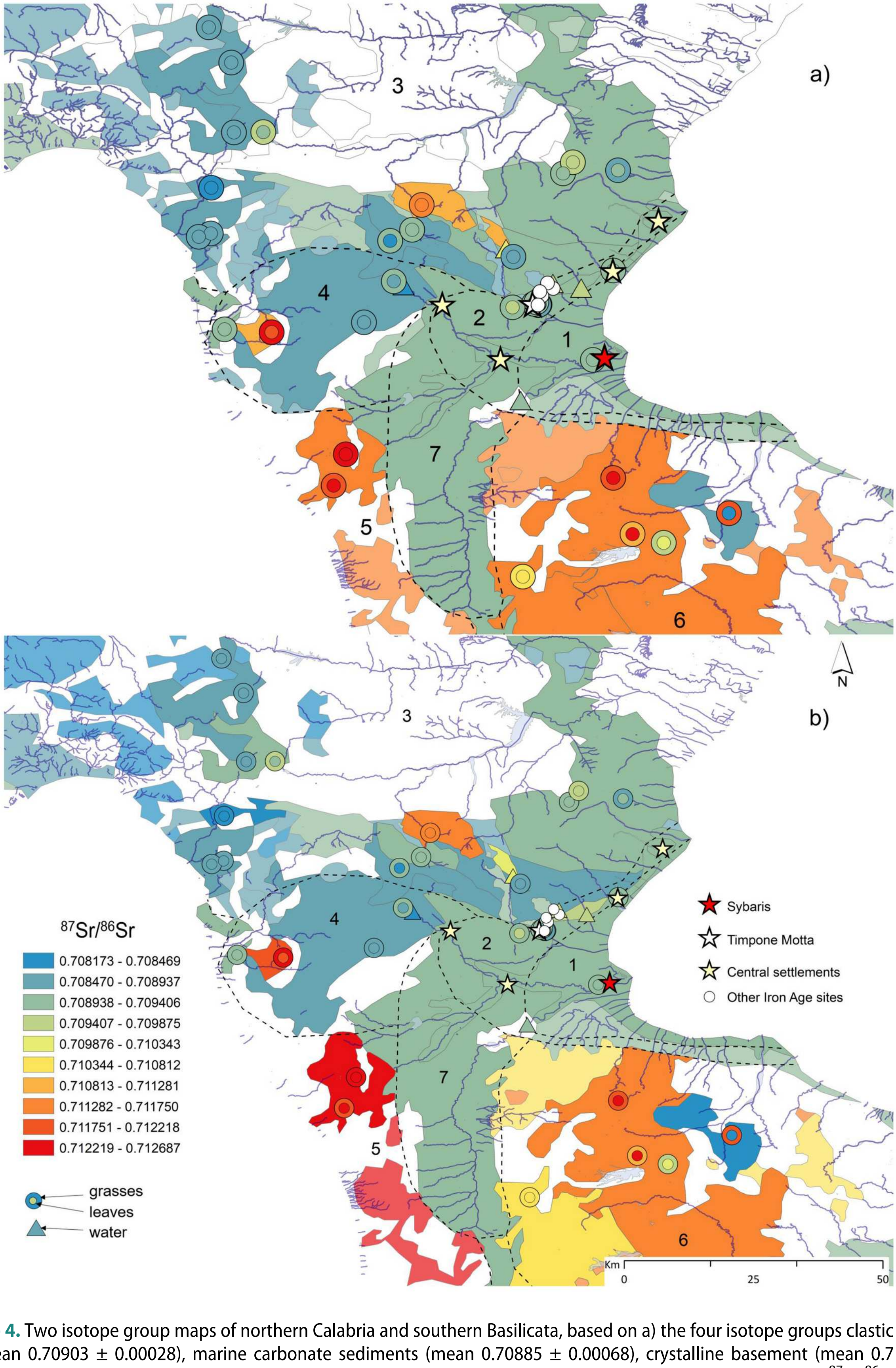

Figure 4. Two isotope group maps of northern Calabria and southern Basilicata, based on a) the four isotope groups clastic deposits (mean 0.70903 ± 0.00028), marine carbonate sediments (mean 0.70885 ± 0.00068), crystalline basement (mean 0.71155 ± 0.00104), and schist (mean 0.71111 ± 0.00099) and b) the 21 isotope groups shown in Figure 3 and Table s1. The $^{87}Sr/^{86}Sr$ ranges are calculated by equal intervals into 10 different classes. Units with similar geolithological characteristics but no sampled data were coloured in 40% transparency. Geological units with no comparative data were left white. Map data: OpenStreetMap, ODbL 1.0.

(Figure 5), with significantly more radiogenic $^{87}Sr/^{86}Sr$ ratios than expected based on geology. Simultaneously, the measured variations within the geolithological units were considered in the interpolation model compared to the isotope group maps (Figure 4). Generally, the Kriging model reflects local variations of the

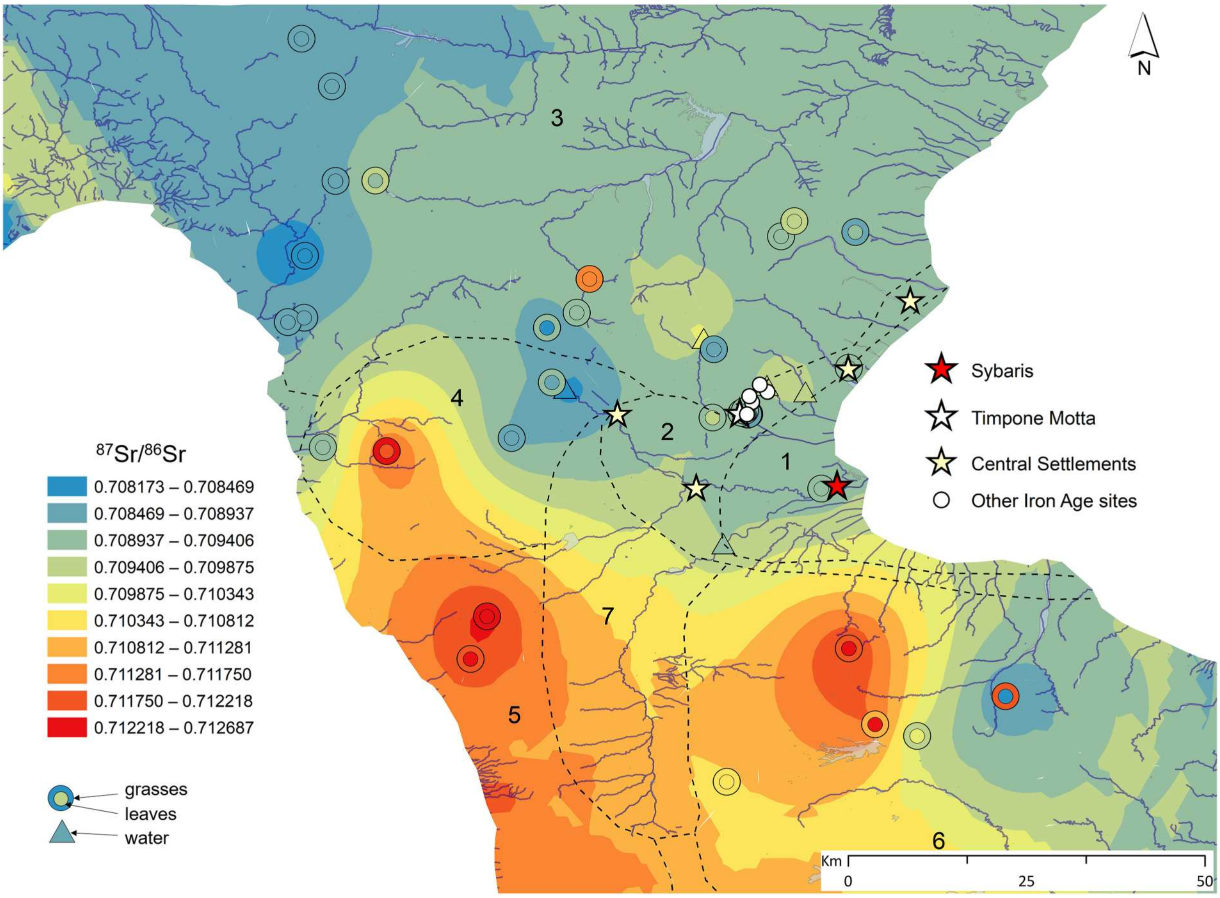

Figure 5. Isoscape map created with Ordinary Kriging (OK) interpolation function, excluding radiogenic point EFM21. The Kriging model was calculated with mean $^{87}Sr/^{86}Sr$ values per sampling locations. The $^{87}Sr/^{86}Sr$ ranges are calculated by equal intervals into 10 different classes. Map data: OpenStreetMap, ODbL 1.0.

bioavailable strontium and are better suited for small-scale analyses. However, as the evaluation of the analysed plant and water samples has shown, the main influencing factor for the bioavailable strontium is lithology. Kriging functions lead to spatially continuing surface models, which contrasts with the spatially discrete system of geolithological formations and therefore with the strontium isotopic landscape (Bowen and West 2019). Considering this, we propose the isotope group map with 21 groups (Figure 4b) as the most representative isoscape model for the regions in and around the Sibaritide. In addition, the plotted 38 data points are indicative of the isotopic variations within the 21 isotope groups (Figure 2).

Implications of Isotope Mapping on the Definition of the Local Bioavailable $^{87}Sr/^{86}Sr$ at Francavilla Marittima

Sampling locations were located up to 70 km from the archaeological site of the Timpone Motta, but the settlement's cultivation area in the 1st mill. BC, and thus the bioavailable strontium that entered the human food web, was much more restricted. Archaeobotanical (Nisbet 1984; Vallino and Ventura 1984; Nisbet and Ventura 1994; Coubray 2001), archaeozoological (Attema et al. 1998; Kleibrink 2006; Elevelt 2012; Post 2014), and archaeological land evaluation (Van Joolen 2003) data suggests that the protohistoric communities in the Sibaritide practiced a mixed subsistence economy based on transhumant livestock management, dry farming, gardening, gathering, and hunting. The marine terraces on and around Timpone Motta are considered as important areas for agriculture during the 8th c. BC (Elevelt 2012; De Neef 2016). Potential pastures for transhumant livestock include the highlands around Contrada Maddalena, Monte Sellaro, and San Lorenzo Bellizzi during summer (Van Joolen 2003; Kleibrink 2011; De Neef 2016) and the coastline between the rivers Raganello and Satanasso during winter. The latter is discussed as a hunting and foraging ground of the Iron Age settlement (Elevelt 2012). Natural springs are unknown in the settlement (Kleibrink 2011), making it likely that water of nearby rivers served as drinking water, e.g. the river Raganello. During the rainy season, rainwater (approx. 0.7092; Hess, Bender, and Schilling 1986) could also have been collected. Based on these considerations, the potential resources of the food catchment area of the Timpone Motta cover a range of up to 20 km from the site and include $^{87}Sr/^{86}Sr$ values ranging between 0.7085 and 0.7101.

Table 3. Estimated local $^{87}Sr/^{86}Sr$ signature of the Timpone Motta community based on average ± 2 SD of infant teeth enamel and bone samples from the Macchiabate cemetery and modern plant samples from Francavilla Marittima.

	samples	average $^{87}Sr/^{86}Sr$	local baseline $^{87}Sr/^{86}Sr$ ± 2SD	material
Baseline of the Timpone Motta community	49/2012, 51/2012, 45/2012, 75/2013, FMM2.1, 3.1, 28.1, 32.1, 33.1 (n=10)	0.70889	0.708886 ± 0.000248	infant enamel, human bones
	EFM29-33 (n=10)	0.70887		modern plants

The estimation of the local $^{87}Sr/^{86}Sr$ signature of a community is often based on using the $^{87}Sr/^{86}Sr$ mean ± 2SD of locally restricted living archaeological fauna or infant teeth (Price, Burton, and Bentley 2002; Bentley and Knipper 2005; Bentley 2006; Brönnimann et al. 2018). Due to the susceptibility of bone to diagenetic contamination, bone is considered to reflect the isotopic composition of the burial place (Beard and Johnson 2000; Knipper 2004; Bentley 2006). Published $^{87}Sr/^{86}Sr$ data from the Macchiabate cemetery includes four teeth from two infants (Colombi, Villa, and Guggisberg 2018), with a range of 0.70875–0.70885 and six bones from adult individuals, resulting in 0.70880–0.70917. A comparison to the suggested main agricultural areas of the Timpone Motta community (marine terraces, EFM29–33, cf. Table 3) shows that the $^{87}Sr/^{86}Sr$ of both, modern plant data and the archaeological skeletal remains, are in good agreement with plant ratios, the latter being slightly more variable.

Macchiabate individuals that fall within the range of local $^{87}Sr/^{86}Sr$ of 0.70889 ± 0.00025 (Table 3) probably obtained their food from the agricultural fields surrounding Timpone Motta. Individuals within this range could also come from other locations in the Sibaritide or from other regions in southern Italy with a similar isotopic composition, e.g. northern Pollino region, or the Crati basin. Modern vegetation and water from the area considered as catchment area or settlement territory of Timpone Motta showed more varied $^{87}Sr/^{86}Sr$ (0.7085–0.7101). This shows that people buried at the Macchiabate necropolis could also fall outside the estimated local Sr range when following different nutritional strategies. Humans with tooth enamel $^{87}Sr/^{86}Sr$ falling outside this range (<0.7085 and >0.7101), however, can be classified as 'non-local', at least in respect to their $^{87}Sr/^{86}Sr$, i.e. not originating from the Timpone territory as defined by Peroni (1994).

Non-locals in the Macchiabate Cemetery?

Human skeletons (18 enamel samples from 13 burials) from the Macchiabate cemetery dating to the 8th c. BC have $^{87}Sr/^{86}Sr$ ratios between 0.7084 and 0.7097 (Colombi, Villa, and Guggisberg 2018; Figure 6). Based on the comparison between the $^{87}Sr/^{86}Sr$ values in tooth enamel and sediment soil of the necropolis, the analysed Macchiabate individuals were interpreted as a homogeneous group that grew up in an area of 'similar geological features in the Francavilla Marittima district' (Colombi, Villa, and Guggisberg 2018). All analysed individuals were buried in the Oinotrian custom, three of them (Strada 5, Strada 14, and De Leo 1) were additionally given non-local objects.

Ten out of 13 individuals (i.e. twelve out of 18 tooth samples, Figure 6) lie within the local baseline and likely fed on food from the marine terraces around the Timpone Motta or an isotopically similar region during time of tooth enamel formation. Five individuals showed $^{87}Sr/^{86}Sr$ ratios that are not consistent with the local baseline in at least one enamel sample. Based on the isoscape (Figure 4b) these ratios are common in the presumed settlement territory of the Timpone. It is therefore conceivable that these individuals lived within the Timpone territory but ate food derived from different agricultural fields, e.g. on the Contrada Damale, or Contrada Portieri. The four individuals Strada 4–7 can also originate from regions farther away, e.g. from the southern part of the Sibaritide. All of them were accompanied by typical Oinotrian objects attesting to their embedment in a local context. On the other hand, grave goods such as the bronze spearhead in grave Strada 5 testify of specific connections with other regions, such as southern Campania (Colombi et al. 2021). Isotopic outlier De Leo 1 seems to have a special status within the Macchiabate community due to its funerary equipment attesting intensive relationships with the Greek world. The $^{87}Sr/^{86}Sr$ values of De Leo 1 isotopically match the surroundings of Castrovillari, the western Pollino mountains, and the eastern highlands (Figure 4b), but similar $^{87}Sr/^{86}Sr$ values have been reported from the entire Mediterranean region, e.g. Apulia (Tafuri et al. 2016; Emery et al. 2018), Campania (Stark 2016; Stark et al. 2020), Lazio (Killgrove and Montgomery 2016) and northern Italy (Cavazzuti et al. 2019; Milella et al. 2019). Furthermore, the De Leo 1 $^{87}Sr/^{86}Sr$ values match the baselines of various Greek regions established by Frank et al. (2021a), e.g. West Greece (incl. Achaea, after Voerkelius et al. 2010; Petropoulos 2015; Hoogewerff et al. 2019; Frank et al. 2021b) and Attica (incl. Euboea, after Nafplioti 2011; Petropoulos 2015; Hoogewerff et al. 2019).

The isotopic locals Strada 9, 11–12, 14–15, and 17 have predominantly Oinotrian grave inventories except for Strada 14. This woman, 'local' to the Timpone community in respect to her $^{87}Sr/^{86}Sr$, had 'exotic'

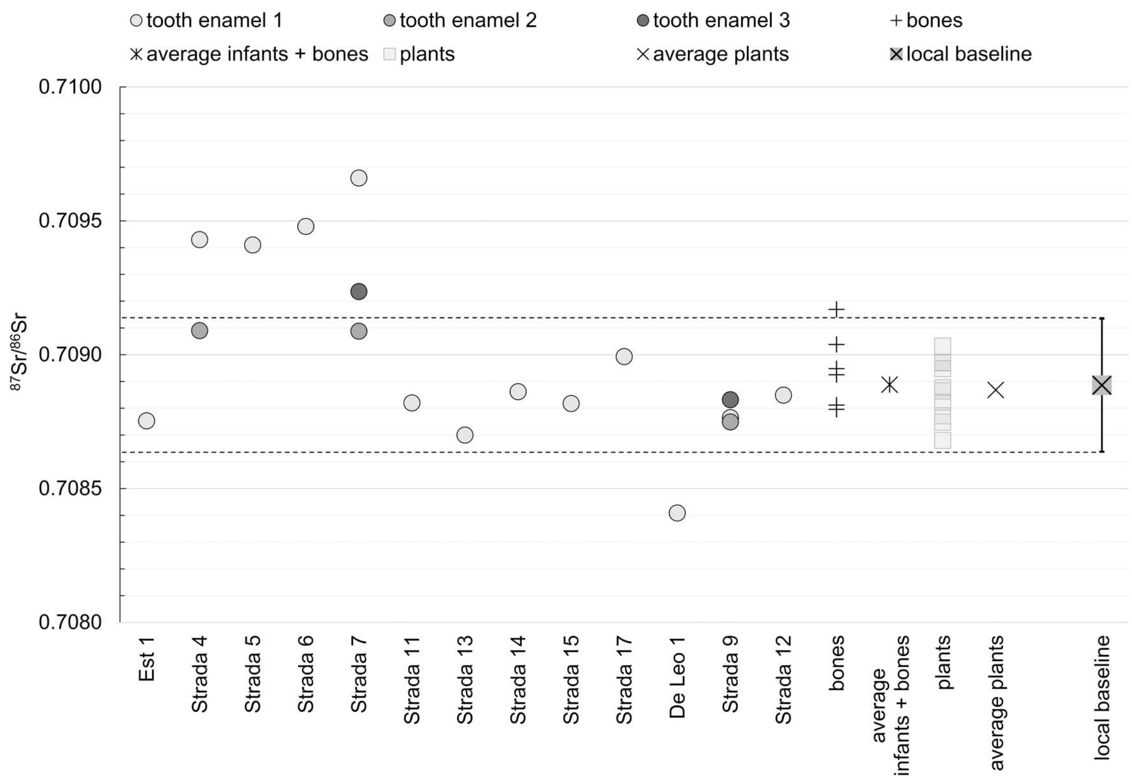

Figure 6. $^{87}Sr/^{86}Sr$ measured in human teeth and bones of the Macchiabate individuals (after Colombi, Villa, and Guggisberg 2018), compared to measurements in modern plants from the Francavilla Marittima region.

objects presumably from the eastern Mediterranean (Colombi et al. 2021). She also agrees isotopically with the eastern Mediterranean, i.e. Knossos (Nafplioti 2011; Isaakidou et al. 2019), Kea and Euboea (Nafplioti 2011), as well as Thessaly (Panagiotopoulou et al. 2018) and the South Aegean (0.70889 ± 0.00083; Frank et al. 2021a after Nafplioti 2011; Petropoulos 2015; Hoogewerff et al. 2019). The discussion of 'isotopic outliers' is solely based on the results obtained from $^{87}Sr/^{86}Sr$ analysis and will be combined with additionally obtained $\delta^{18}O$ and $\delta^{13}C$ data from the tooth enamel, currently under investigation.

Conclusions

This paper presents the first high spatial resolution $^{87}Sr/^{86}Sr$ isoscape of North Calabria. 66 modern vegetation and five river water samples were analysed to characterise the bioavailable strontium in the catchment area and the wider surrounding of the Iron Age settlement and cemetery at Francavilla Marittima. From the four Sr baseline maps that were produced and evaluated, the isotope group map with 21 groups obtained the most representative results. It has the advantage of taking the influencing geolithological formations into account, while averaging the isotopic variability within one geological unit. The generated surface model provides a robust basis for archaeological mobility studies at Francavilla Marittima and the Sibaritide. The geological diversity of the region is reflected in the broad range of $^{87}Sr/^{86}Sr$ ratios, the heterogeneity of the 21 isotopic groups and finally in the isoscape modelling. The estimated $^{87}Sr/^{86}Sr$ baseline of 0.70889 ± 0.00025 for Francavilla Macchiabate was compared to the primary food catchment area of the Timpone Motta. The generated isoscape enables a more detailed differentiation between local, regional, and non-locals, e.g. individuals with $^{87}Sr/^{86}Sr$ ratios outside the local baseline may have belonged to the local community, although feeding on food from fields located off the marine terraces. Additionally, the presented data set serves as a robust baseline for further machine-learning modelling approaches. In a future perspective, a combined analysis of strontium, oxygen, and carbon isotope data obtained from the tooth enamel of the buried skeletons at Francavilla Marittima, local land use strategies, and settlement dynamics in the Sibaritide as well as the archaeological grave findings and additional bioarchaeological studies, which is currently under preparation, will support a finer differentiation between local and non-local individuals in the Macchiabate.

Acknowledgments

This work was financially supported by the Swiss National Science Foundation (grant number 175613). The authors thank Norbert Spichtig (Technical Director, Francavilla Marittima research project), Marta Billo-Imbach (Project Assistant, Francavilla Marittima research project), Michael Kempf (Department of Geography, University of Kiel), Urs Rosemann (Augusta Raurica), Lukas Richner (Archäologie BL), and the peer reviewers for valuable information at various stages of the research project.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Swiss National Science Foundation: [grant no 175613].

Notes on Contributors

Céline Zaugg has a M.A. in Classical Archaeology and Archaeological Sciences from the University of Basel. Her research focuses on the application of an interdisciplinary set of (bio-)archaeological methods to study past human interactions.

Martin A. Guggisberg is professor of Classical Archaeology at the University of Basel and director of the SNSF-funded Francavilla Marittima archaeological research project. His scientific interests focus on the cultural interaction of Greek and non-Greek populations in the Mediterranean in the 1st millennium BC.

Werner Vach, PhD in Statistics, is an external lecturer in Archaeostatistics at the Department of Environmental Sciences, University of Basel. His research focuses on research methodology and the application of statistical methods in archaeology and anthropology.

Matthew J. Cooper has a PhD in Earth Sciences from the University of Cambridge and is a senior research fellow at the University of Southampton. His research focuses on the application of analytical methods to problems in the environment and archaeology.

Claudia Gerling, PhD in Prehistory and Archaeological Sciences, is a senior researcher at the University of Basel, Department of Environmental Sciences and Department of Ancient Civilizations. Her research focus is on understanding human and faunal mobility and subsistence in past societies.

References

Aldrich, S. 2015. Video «Week 15, Monday – Kriging and Empirical Bayesian Kriging in ArcMap», Indiana State University. https://www.youtube.com/watch?v = oArvlYzCYq4 (accessed 22 November 2020).

Attema, P. A. J., G. J. Burger, and P. M. van Leusen. 2010. "Regional Pathways to Complexity. Settlement and Land-Use Dynamics in Early Italy from the Bronze Age to the Republican Period", Amsterdam 15, Amsterdam.

Attema, P. A. J., J. J. Delvigne, E. Drost, and M. Kleibrink. 1998. "Habitation on Plateau I of the Hill Timpone Della Motta (Francavilla Marittima, Italy): A Preliminary Report Based on Surveys, Test Pits and Test Trenches." *Palaeohistoria* 39/40: 375–410.

Avanzinelli, R., E. Boari, S. Conticelli, L. Francalanci, L. Guarnieri, G. Perini, C. M. Petrone, S. Tommasini, and M. Ulivi. 2005. "High Precision Sr, Nd, and Pb Isotopic Analyses Using the new Generation Thermal Ionisation Mass Spectrometer ThermoFinnigan Triton-Ti®." *Period Miner* 74 (3): 147–166.

Bataille, C. P., I. C. C. von Holstein, J. E. Laffoon, M. Willmes, X.-M. Liu, and G. R. Davies. 2018. "A Bioavailable Strontium Isoscape for Western Europe: A Machine Learning Approach." *PLoS ONE* 13 (5): e0197386. doi:10.1371/journal.pone.0197386.

Beard, B. L., and C. M. Johnson. 2000. "Strontium Isotope Composition of Skeletal Material Can Determine the Birth Place and Geographic Mobility of Humans and Animals." *Journal of Forensic Sciences* 45 (5): 1049–1061. https://doi.org/10.1520/JFS14829J

Bentley, R. A. 2006. "Strontium Isotopes from the Earth to the Archaeological Skeleton: A Review." *Journal of Archaeological Method and Theory* 13 (3): 135–187. https://doi.org/10.1007/s10816-006-9009-x

Bentley, R. A., and C. Knipper. 2005. "Geographic Patterns in Biologically-Available Strontium, Carbon and Oxygen Isotopes Signatures in Prehistoric SW Germany." *Archaeometry* 47 (3): 629–644. https://doi.org/10.1111/j.1475-4754.2005.00223.x

Billo-Imbach, M., C. Gerling, C. Zaugg, and M. A. Guggisberg. 2020. "Mobilität und Migration im Fokus der Untersuchungen zur eisenzeitlichen Nekropole von Francavilla Marittima (CS)." In *Sciences naturelles en archéologie classique / Naturwissenschaften in der Klassischen Archäologie*, 55–58. Schweizer Arbeitsgemeinschaft für Klassische Archäologie. https://edoc.unibas.ch/81293/ (last access 25.09.2023).

Blank, M., K.-G. Sjögren, C. Knipper, K. M. Frei, and J. Stora. 2018. "Isotope Values of the Bioavailable Strontium in Inland Southwestern Sweden—A Baseline for Mobility Studies." *PLoS ONE* 13 (10): e0204649. doi:10.1371/journal.pone.0204649.

Bowen, G. J., and J. B. West. 2019. "3. Isoscapes for Terrestrial Migration Research." In *Tracking Animal Migration with Stable Isotopes*, second ed, edited by K. A. Hobson, and L. I. Wassenaar, 53–84. London: Elsevier Inc.

Britton, K., M. Le Corre, M. Willmes, I. Moffat, R. Grün, M. A. Mannino, S. Woodward, and K. Jaouen. 2020. "Sampling Plants and Malacofauna in 87Sr/86Sr Bioavailability Studies: Implications for Isoscape Mapping and Reconstructing of Past Mobility Patterns." *Frontiers in Ecology and Evolution* 8: 579473. doi:10.3389/fevo.2020.579473.

Brönnimann, D., C. Knipper, S. L. Pichler, B. Röder, H. Rissanen, B. Stopp, M. Rosner, et al. 2018. "The lay of Land: Strontium Isotope Variability in the Dietary Catchment of the Late Iron Age Proto-Urban Settlement of Basel-Gasfabrik, Switzerland." *Journal of Archaeological Science: Reports* 17: 279–292. https://doi.org/10.1016/j.jasrep.2017.11.009

Burgers, G. J., and J. P. Crielaard. 2016. "The Migrant's Identity. 'Greeks' and 'Natives' at L'Amastuola, Southern Italy." In *Conceptualising Early Colonisation, Vol. II*, edited by L. Donnellan, V. Nizzo, and G. J. Burgers, 225–238. Turnhout: Brepols Publishing.

Carloni, D., and M. Pacciarelli. 2021. "Grotta del Tesauro (Sant'Agata di Esaro, Cosenza): un contesto archeologico con evidenze di attività minerarie preistoriche e storiche. Scavi 2011-2013", in: Mittica, G., Colelli, C., Larocca, A., Larocca, F. (Eds.), Dal Pollino all'Orsomarso. Ricerche archeologiche fra Ionio e Tirreno. Atti del convegno internazionale San Lorenzo Bellizzi, 4-6 ottobre 2019. Quasar di Severino Tognon srl, Roma, 69–85.

Cavazzuti, C., R. Skeates, A. R. Millard, G. Nowell, J. Peterkin, M. Bernabò Brea, A. Cardarelli, and L. Salzani. 2019. "Flows of People in Villages and Large Centres in Bronze Age Italy Through Strontium and Oxygen Isotopes." *PLoS ONE* 14 (1): e0209693. doi:10.1371/journal.pone.0209693.

Collella, A., P. L. De Boer, and S. D. Nio. 1987. “Sedimentology of a Marine Intermontane Pleistocene Gilbert-Type fan-Delta Complex in the Crati Basin, Calabria, Southern Italy.” *Sedimentology* 34 (4): 721–736. https://doi.org/10.1111/j.1365-3091.1987.tb00798.x

Colombi, C., C. Juon, S. Billo, and M. A. Guggisberg. 2021. “Basler Ausgrabungen 2009–2016: Die Gräber der Areale Strada und De Leo,” in: Guggisberg, M. A., Colombi, C. (Eds.), Ausgrabungen in der Nekropole von Francavilla Marittima, Kalabrien, 2009–2016: Die Areale Strada und De Leo. Reichert Verlag, Wiesbaden, 46–98.

Colombi, C., I. M. Villa, and M. A. Guggisberg. 2018. “Identità e isotopi: il contributo delle analisi scientifiche all’interpretazione della necropoli enotria di Francavilla Marittima,” in: Herring, E., O’Donoghue, E. (Eds.), Papers in Italian Archaeology VII: The Archaeology of Death. Proceedings of the Seventh Conference of Italian Archaeology, National University of Ireland, Galway, April 16–18 2016. Archaeopress, Oxford, 217–226.

Cotecchia, V. 1993. “Incidenze geologiche e geotecniche su Sibari e la Sibaritide,” in: Atti del 32mo convegno di studi sulla Magna Grecia “Sibari e la Sibaritide”, 7–12 Ottobre 1992, Istituto per la Storia e l’Archeologia della Magna Grecia, Taranto-Sibari, 21–49.

Coubray, S. 2001. “Étude anthracologique,” in: Trucco, F., Vagnetti, L. (Eds.), Torre Mordillo 1987–1990. Le relazioni egee di una comunità protostorica della Sibaritide. CNR – Istituto per gli Studi Micenei ed Egeo-Anatolici, Rome, 419–431.

Cucci, L. 2005. “Geology Versus Myth: The Holocene Evolution of the Sybaris Plain.” *Ann. Geophys* 48 (6): 1017–1033.

Cucci, L., and F. R. Cinti. 1998. “Regional Uplift and Local Tectonic Deformation Recorded by the Quaternary Marine Terraces on the Ionian Coast of Northern Calabria (Southern Italy).” *Tectonophysics* 292 (1-2): 67–83. https://doi.org/10.1016/S0040-1951(98)00061-4

D’Alessio, A., and A. Taliano Grasso. 2014. “Enotri, Greci e Brettii nella valle del Crati: La scoperta del sito in località Area delle Fate a Rose (CS).” *Riv. dell’Ist. Naz. d’Archeol. e Storia dell’Arte* 69: 81–105.

Declerck, S., T. De Bie, D. Ercken, H. Hampel, S. Schrijvers, J. Van Wichelen, V. Gillard, et al. 2006. “Ecological Characteristics of Small Farmland Ponds: Associations with Land use Practices at Multiple Spatial Scales.” *Biological Conservation* 131 (4): 523–532. doi:10.1016/j.biocon.2006.02.024.

De Neef, W. 2016. Surface Subsurface: A methodological study of Metal Age settlement and land use in Calabria (Italy). PHD Thesis Rijksuniversiteit Groningen. https://doi.org/10.13140/RG.2.2.17394.50881.

Donnellan, L. 2016. “‘Greek Colonisation’ and Mediterranean Networks: Patterns of Mobility and Interaction at Pithekoussai.” *Journal of Greek Archaeology* 1: 109–149. https://doi.org/10.32028/jga.v1i.646

Elevelt, S. C. 2012. Subsistence and Social Stratification in Northern Ionic Calabria from the Middle Bronze Age until the Early Iron Age. PHD Thesis Rijksuniversiteit Groningen. Online access link https://research.rug.nl/en/publications/subsistence-and-social-stratification-in-northern-ionic-calabria- (last access 01.09.2022).

Emery, M. V., R. J. Stark, T. J. Murchie, S. Elford, H. P. Schwarcz, and T. L. Prowse. 2018. “Mapping the Origins of Imperial Roman Workers (1st-4th Century CE) at Vagnari, Southern Italy, Using $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ Variability.” *American Journal of Physical Anthropology* 166 (4): 837–850. https://doi.org/10.1002/ajpa.23473

Ericson, J. E. 1981. “Residence patterns by isotopic characterization.” Paper presented at the Society for American Archaeology. San Diego.

Ericson, J. E. 1985. “Strontium Isotope Characterization in the Study of Prehistoric Human Ecology.” *Journal of Human Evolution* 14 (5): 503–514. https://doi.org/10.1016/S0047-2484(85)80029-4

Esri Inc. 380 New York St, Redlands, CA 92373, USA; retrieved from https://desktop.arcgis.com/de/ on 07.11.2020.

Evans, J. A., J. Montgomery, and G. Wildman. 2009. “Isotope Domain Mapping of $^{87}Sr/^{86}Sr$ Biosphere Variation on the Isle of Skye.” *Journal of the Geological Society* 166 (4): 617–631. https://doi.org/10.1144/0016-76492008-043

Evans, J. A., J. Montgomery, G. Wildman, and N. Boulton. 2010. “Spatial Variations in Biosphere $^{87}Sr/^{86}Sr$ in Britain.” *J. Geol. Soc* 167 (1): 1–4. https://doi.org/10.1144/0016-76492009-090

Frank, A. B., R. Frei, I. Moutafi, S. Voutsaki, R. Orgeolet, K. Kristiansen, and K. M. Frei. 2021a. “The Geographic Distribution of Bioavailable Strontium Isotopes in Greece – A Base for Provenance Studies in Archaeology.” *Science of The Total Environment* 791: 148156. doi:10.1016/j.scitotenv.2021.148156.

Frank, A. B., R. Frei, M. Triantaphyllou, E. Vassilakis, K. Kristiansen, and K. M. Frei. 2021b. “Isotopic Range of Bioavailable Strontium on the Peloponnese Peninsula, Greece: A Multi-Proxy Approach.” *Science of The Total Environment* 774: 145181. doi:10.1016/j.scitotenv.2021.145181.

Gerling, C., T. Doppler, V. Heyd, C. Knipper, T. Kuhn, M. F. Lehmann, A. W. G. Pike, and J. Schibler. 2017. “High-resolution Isotopic Evidence of Specialised Cattle Herding in the European Neolithic.” *PLoS ONE* 12 (7): e0180164. doi:10.1371/journal.pone.0180164.

Gerling, C., C. Zaugg, M. Billo-Imbach, and M. Guggisberg. 2021. “Between «Local» and «Non-local». Basic Considerations and First Results of an Isotopic Mapping of the Sibaritide,” in: Colelli, C., Mittica, G., Larocca, A., Larocca, F. (Eds.), Dal Pollino all’Orsomarso. Ricerche archeologiche tra Ionio e Tirreno, Giornate Internazionali di Archeologia 2, 4–6 Ottobre 2019 San Lorenzo Bellizzi, 157–164. Edizioni Quasar di Severino Tognon srl, Roma.

Giangiulio, M. 2001. “Constructing the Past: Colonial Traditions and the Writing of History. The Case of Cyrene.” In *The Historian’s Craft in the Age of Herodotus*, edited by N. Luraghi, 116–137. Oxford.: Oxford University Press.

Gigante, M., V. Warter, W. Müller, A. Sperduti, and L. Bondioli. 2017. “Anthropological evidence of multi-ethnicity in the first Greek settlement in Italy.” Strontium isotopic analysis of the skeletal sample from the necropolis of Pithekoussai (Ischia VIII cent. BCE – III cent. CE). Poster presented at The American Association of Physical Anthropologists (AAPA) 86th annual meeting, April 19–22. New Orleans. Online access link https://www.academia.edu/38557235/Anthropological_evidence_of_multi_ethnicity_in_the_first_Greek_settlement_in_Italy_Strontium_isotopic_analysis_of_the_skeletal_sample_from_the_necropolis_of_Pithekoussai_Ischia_VIII_cent_BCE_III_cent_CE_ (last access 01.09.2022).

Guggisberg, M. A., and C. Colombi. 2021. unter Mitarbeit von Billo-Imbach, M., 2021. Macchiabate I. Ausgrabungen in der Nekropole von Francavilla

Marittima, Kalabrien (2009-2016): Die Areale Strada und De Leo. Reichert Verlag, Wiesbaden.

Hartman, G., and M. Richards. 2014. "Mapping and Defining Sources of Variability in Bioavailable Strontium Isotope Ratios in the Eastern Mediterranean." *Geochimica et Cosmochimica Acta* 126: 250–264. https://doi.org/10.1016/j.gca.2013.11.015

Henneberg, M., and R. J. Henneberg. 2001. "Analysis of Human Skeletal and Dental Remains from Metaponto (7th–2nd c BC)." *AttiTaranto* 40: 461–474.

Henneberg, R. J., and M. Henneberg. 2003. "The Diet of the Metapontine Population as Reconstructed from the Physical Remains, in: Living off the Chora." Diet and Nutrition at Metaponto, 29–36. Institute of Classical Archaeology, University of Texas, Austin.

Hess, J., M. L. Bender, and J.-G. Schilling. 1986. "Evolution of the Ratio of Strontium-87 to Strontium-86 in Seawater from Cretaceous to Present." *Science* 231 (4741): 979–984. doi:10.1126/science.231.4741.979.

Hodos, T. 2006. *Local Responses to Colonization in the Iron Age Mediterranean*. London.: Routledge.

Hölscher, T. 2002. *Klassische Archäologie. Grundwissen*. Darmstadt.: Konrad Theiss Verlag.

Hoogewerff, J., W. Papesch, M. Kralik, M. Berner, P. Vroon, H. Miesbauer, O. Gaber, K. H. Kunzel, and J. Kleinjans. 2001. "The Last Domicile of the Iceman from Hauslabjoch: A Geochemical Approach Using Sr, C and O Isotopes and Trace Element Signatures." *Journal of Archaeological Science* 28 (9): 983–989. https://doi.org/10.1006/jasc.2001.0659

Isaakidou, V., A. Styring, P. Halstead, E. Nitsch, E. Stroud, P. le Roux, J. Lee-Thorp, and A. Bogaard. 2019. "From Texts to Teeth: A Multi-Isotope Study of Sheep and Goat Herding Practices in the Late Bronze Age (Mycenaean) Polity of Knossos, Crete." *Journal of Archaeological Science: Reports* 23: 36–56. https://doi.org/10.1016/j.jasrep.2018.09.019

Jarvis, A., H. I. Reuter, A. Nelson, E. Guevara. 2008. Hole-Filled Seamless SRTM Data V4, International Centre for Tropical Agriculture (CIAT), retrieved from https://srtm.csi.cgiar.org on 09.11.2020.

Keenleyside, A., H. Schwarcz, and K. Panayotova. 2006. "Stable Isotopic Evidence of Diet in a Greek Colonial Population from the Black Sea." *Journal of Archaeological Science* 33 (9): 1205–1215. doi:10.1016/j.jas.2005.12.008.

Keenleyside, A., H. P. Schwarcz, and K. Panayotova. 2011. "Oxygen Isotopic Evidence of Residence and Migration in a Greek Colonial Population on the Black Sea." *Journal of Archaeological Science* 38: 2658–2666. doi:10.1016/j.jas.2011.06.001.

Killgrove, K. 2013. "Biohistory of the Roman Republic: The Potential of Isotope Analysis of Human Skeletal Remains, Post-Class." *Archaeol* 3: 41–62.

Killgrove, K., and J. Montgomery. 2016. "All Roads Lead to Rome: Exploring Human Migration to the Eternal City Through Biochemistry of Skeletons from two Imperial-era Cemeteries (1st-3rd c AD)." *PLoS ONE* 11 (2): e0147585–30. doi:10.1371/journal.pone.0147585.

Kleibrink, M. 2004. "Towards an Archaeology of Oinotria, Observations on Indigenous Patterns of Religion and Settlement in the Coastal Plain of Sybaris (Calabria)," in: Attema, P. (Ed.), Centralization, Early Urbanization, and Colonization in First Millenium B. C. Italy and Greece, Bull. antieke beschav. Suppl. 9. Peeters, Leuven, 29–96.

Kleibrink, M. 2006. "Oenotrians at Lagaria near Sybaris. A Native Proto-urban Centralised Settlement." A Preliminary Report on the Excavation of Two Timber Dwellings on the Timpone della Motta near Francavilla Marittima, southern Italy. Accordia Research Institute, University of London, London.

Kleibrink, M. 2011. "Archaeological Park «Lagaria». Francavilla Marittima (near Sybaris)." Grafosud, Rossano.

Knipper, C. 2004. "Die Strontiumisotopenanalyse: eine naturwissenschaftliche Methode zur Erfassung von Mobilität in der Ur- und Frühgeschichte, Jahrb." *Röm.-Germ. Zentralmus* 51: 589–685.

Knipper, C. 2011. Die räumliche Organisation der linearbandkeramischen Rinderhaltung: naturwissenschaftliche und archäologische Untersuchungen. PHD Thesis Eberhard-Karls-Universität Tübingen. Online access link https://www.researchgate.net/publication/235889699_Die_raumliche_Organisation_der_linearbandkeramischen_Rinderhaltung_naturwissenschaftliche_und_archaologische_Untersuchungen (last access 01.09.2022).

Krige, D. G. 1951. "A Statistical Approach to Some Basic Mine Valuation Problems on the Witwatersrand." *J. South. Afr. Inst. Min. Metall* 52: 119–139.

Kwok, C. S., and A. Keenleyside. 2015. "Stable Isotope Evidence for Infant Feeding Practices in the Greek Colony of Apollonia Pontica." *Hesperia Suppl* 49: 147–170. http://www.jstor.org/stable/24637316.

Lugli, F., A. Cipriani, L. Bruno, F. Ronchetti, C. Cavazzuti, and S. Benazzi. 2022. "A Strontium Isoscape of Italy for Provenance Studies." *Chemical Geology* 587: 120624. doi:10.1016/j.chemgeo.2021.120624.

Marino, D. A. M., and C. Colelli. 2021. "San Sosti. Materiali e contesti fra la protostoria e l'età greca," in: Mittica, G., Colelli, C., Larocca, A., Larocca, F. (Eds.), Dal Pollino all'Orsomarso. Ricerche archeologiche fra Ionio e Tirreno. Atti del convegno internazionale San Lorenzo Bellizzi, 4-6 ottobre 2019. Quasar di Severino Tognon srl, Roma, 171–187.

Maurer, A.-F., S. J. G. Galer, C. Knipper, L. Beierlein, E. V. Nunn, D. Peters, T. Tütken, K. W. Alt, and B. R. Schöne. 2012. "Bioavailable 87Sr/86Sr in Different Environmental Samples — Effects of Anthropogenic Contamination and Implications for Isoscapes in Past Migration Studies." *Science of The Total Environment* 433: 216–229. https://doi.org/10.1016/j.scitotenv.2012.06.046

McArthur, J. M., R. J. Howarth, and T. Bailey. 2001. "Strontium Isotope Stratigraphy: LOWESS Version 3: Best Fit to the Marine Sr-Isotope Curve for 0–509 Ma and Accompanying Look-up Table for Deriving Numerical Age." *The Journal of Geology*, 155–170. doi:10.1086/319243.

Milella, M., C. Gerling, T. Doppler, T. Kuhn, M. Cooper, V. Mariotti, M. G. Belcastro, M. S. Pone de Léon, and C. P. E. Zollikofer. 2019. "Different in Death: Different in Life? Diet and Mobility Correlates of Irregular Burials in a Roman Necropolis from Bologna (Northern Italy, 1st-4th Century CE)." *Journal of Archaeological Science: Reports* 27: 101926. doi:10.1016/j.jasrep.2019.101926.

Murray, C. A., and J. Lucas. 2019. "1 Introduction." In *Greek Colonization in Local Contexts: Case Studies in Colonial Interactions*, Vol. 4, edited by J. Lucas, C. A. Murray, and S. Owen, 1–6. Oxford: Oxbow Books. doi:10.2307/j.ctvh9w120.4.

Nafplioti, A. 2008. ""Mycenaean" Political Domination of Knossos Following the Late Minoan IB Destructions on Crete: Negative Evidence from Strontium Isotope Ratio Analysis (87Sr/86Sr)." *Journal of Archaeological Science* 35 (8): 2307–2317. doi:10.1016/j.jas.2008.03.006.

Nafplioti, A. 2009a. "Early Bronze Age Manika on Euboea (Greece): A `Colony' or not? Evidence from Strontium Isotope Ratio ($^{87}Sr/^{86}Sr$) Analysis." *Geochim. et Cosmochim. Acta* 73 (13 Suppl. 1): A925.

Nafplioti, A. 2009b. "Mycenae Revisited Part 2. Exploring the Local Versus Non-Local Geographical Origin of the Individuals from Grave Circle A: Evidence from Strontium Isotope Ratio ($^{87}Sr/^{86}Sr$) Analysis." *The Annual of the British School at Athens* 104: 279–291. doi:10.1017/S0068245400000253.

Nafplioti, A. 2011. "Tracing Population Mobility in the Aegean Using Isotope Geochemistry: A First map of Local Biologically Available $^{87}Sr/^{86}Sr$ Signatures." *Journal of Archaeological Science* 38 (7): 1560–1570. doi:10.1016/j.jas.2011.02.021.

Nafplioti, A. 2016. "Eating in Prosperity: First Stable Isotope Evidence of Diet from Palatial Knossos." *Journal of Archaeological Science: Reports* 6: 42–52. doi:10.1016/j.jasrep.2016.01.017.

Nisbet, R. 1984. "Dati Archeobotanici dal Broglio: I Carboni." In *Nuove Ricerche Sulla Protostoria Della Sibaritide*, edited by R. Peroni. Rome: Paleani. 266–271.

Nisbet, R., and G. Ventura. 1994. "I dati archeobotanici," in: Peroni, R., Trucco, F. (Eds.), Enotri e Micenei nella Sibaritide, 1. Broglio di Trebisacce. Istituto per la Storia e l'Archeologia della Magna Grecia, Taranto, 577–585.

OpenStreetMap, ODbL 1.0: Map data OpenStreetMap, ODbL 1.0; retrieved from download.geofabrik.de on 09.11.2020.

Pacciarelli, M. 2005. "Osservazioni sulla cronologia assoluta del bronzo finale e della prima età del ferro," in: Bartoloni, G., Delpino, F. (Eds.), Oriente e Occidente. Metodi e discipline a confronto. Riflessioni sulla cronologia dell'età del ferro in Italia. Atti dell'incontro di studi, Roma, 30–31 ottobre 2003, Pisa, 81–90.

Panagiotopoulou, E., J. Montgomery, G. Nowell, J. Peterkin, A. Doulgeri-Intzesiloglou, P. Arachoviti, S. Katakouta, and F. Tsiouka. 2018. "Detecting Mobility in Early Iron Age Thessaly by Strontium Isotope Analysis." *European Journal of Archaeology* 21 (4): 590–611. doi:10.1017/eaa.2017.88.

Peroni, R. 1994. "Le comunità enotrie della Sibaritide ed i loro rapporti con i navigatori egei." In *Enotri e Micenei nella Sibaritide vol. II*, edited by R. Peroni, and F. Trucco, 831–879. Taranto.

Peroni, R., and A. Vanzetti. 2008. "Parco archeologico di Broglio di Trebisacce (Cosenza, Italia)." Soprintendenza per i Beni Archeologici della Calabria / Comune di Trebisacce / Comunità Montana dell'Alto Jonio, Trebisacce.

Petropoulos, M. 2015. "Excavating an Ancient Greek Colony: the Case of Sybaris in South Italy," in: Adam-Veleni, P., Tsangari, D. (Eds.), Greek Colonisation. New Data, Current Approaches. Proceedings of the Scientific Meeting held in Thessaloniki, 6 February 2015. Archaeological Museum of Thessaloniki, Athens, 113–133.

Post, M. 2014. "The potential of stable isotope analysis: Transhumance at Francavilla Marittima, Calabria, Italy." Master's Thesis Rijksuniversiteit Groningen. Online access link https://www.academia.edu/24990361/The_potential_of_stable_isotope_analysis_Transhumance_at_Francavilla_Marittima_Calabria_Italy (last access 01.09.2022).

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 (1): 117–135. https://doi.org/10.1111/1475-4754.00047

Price, T. D., C. M. Johnson, J. A. Ezzo, J. H. Burton, and J. A. Ericson. 1994. "Residential Mobility in the Prehistoric Southwest United States: A Preliminary Study Using Strontium Isotope Analysis." *Journal of Archaeological Science* 21 (3): 315–330. https://doi.org/10.1006/jasc.1994.1031

Price, T. D., M. J. Schoeninger, and G. J. Armelagos. 1985. "Bone Chemistry and Past Behavior: An Overview." *Journal of Human Evolution* 14 (5): 419–447. https://doi.org/10.1016/S0047-2484(85)80022-1

Prowse, T. L., H. P. Schwarcz, P. Garnsey, M. Knyf, R. Macchiarelli, and L. Bondioli. 2007. "Isotopic Evidence for age-Related Immigration to Imperial Rome." *American Journal of Physical Anthropology* 132 (4): 510–519. doi:10.1002/ajpa.20541.

Prowse, T. L., H. P. Schwarcz, S. Saunders, R. Macchiarelli, and L. Bondioli. 2004. "Isotopic Paleodiet Studies of Skeletons from the Imperial Roman-age Cemetery of Isola Sacra, Rome, Italy." *Journal of Archaeological Science* 31 (3): 259–272. doi:10.1016/j.jas.2003.08.008.

Rainey, F. G., and C. M. Lerici, eds. 1967. *The Search for Sybaris 1960–1965*. Rome.: Univ Museum Pubns.

Salesse, K., R. Fernandes, X. de Rochefort, J. Brůžek, D. Castex, and É Dufour. 2018. "IsoArcH.eu: An Open-Access and Collaborative Isotope Database for Bioarchaeological Samples from the Graeco-Roman World and its Margins." *Journal of Archaeological Science: Reports* 19: 1050–1055. doi:10.1016/j.jasrep.2017.07.030.

Sillen, A., G. Hall, S. Richardson, and R. Armstrong. 1998. "87Sr/86Sr Ratios in Modern and Fossil Foodwebs of the Sterkfontein Valley: Implications for Early Hominid Habitat Preference." *Geochimica et Cosmochimica Acta* 62 (14): 2463–2473. https://doi.org/10.1016/S0016-7037(98)00182-3

Stallo, J. R., L. A. Schepartz, V. Grimes, and M. P. Richards. 2010. "Strontium Isotope Ratios and Mobility Reconstruction," in: Amore, M. G. (Eds.), The Complex of Tumuli 9, 10 and 11 in the Necropolis of Apollonia (Albania). Int. Cent. for Albanian Archaeol. Monogr. Ser. 2. Hadrian Books, Oxford, 78–84.

Stark, R. J. 2016. "Ancient Lives in Motion: A Bioarchaeological Examination of Stable Isotopes, Nonmetric Traits, and Human Mobility in an Imperial Roman Context (1st-3rd c. CE)." PHD Thesis McMaster University, Hamilton. Online access link http://hdl.handle.net/11375/20937 (last access 01.09.2022).

Stark, R. J., M. V. Emery, H. Schwarcz, A. Sperduti, L. Bondioli, O. E. Craig, and T. Prowse. 2020. "Imperial Roman Mobility and Migration at Velia (1st to 2nd c. CE) in Southern Italy." *Journal of Archaeological Science: Reports* 30: 102217. doi:10.1016/j.jasrep.2020.102217.

Tafuri, M. A., P. D. Fullagar, T. C. O'Connell, M. G. Belcastro, P. Iacumin, C. Conati Barbaro, R. Sanseverino, and J. Robb. 2016. "Life and Death in Neolithic Southeastern Italy: The Strontium Isotopic Evidence." *International Journal of Osteoarchaeology* 26 (6): 1045–1057. doi:10.1002/oa.2516.

Tanasi, D., R. H. Tykot, A. Vianello, and S. Hassam. 2017. "Stable Isotope Analysis of the Dietary Habits of a Greek Community in Archaic Syracuse (Sicily): A Pilot Study." *Sci. & Technol. Archaeol. Res* 3 (2), International Symposium on Archaeometry 2016

(Kalamata, Greece): Proceedings, 466–477. https://doi.org/10.1080/20548923.2018.1441695.
Thirlwall, M. F. 1991. "Long-term Reproducibility of Multicollector Sr and Nd Isotope Ratio Analysis." *Chemical Geology* 94 (2): 85–104. https://doi.org/10.1016/S0009-2541(10)80021-X
Thomsen, E., and R. Andreasen. 2019. "Agricultural Lime Disturbs Natural Strontium Isotope Variations: Implications for Provenance and Migration Studies." *Science Advances* 5 (3): eaav8083. https://doi.org/10.1126/sciadv.aav8083
Ubelaker, D. H. 1978. *Human Skeletal Remains: Excavation, Analysis, Interpretation*. Chicago.: Aldine Publishing.
Vallino, F. O., and G. Ventura. 1984. "Dati archeobotanici dal Broglio: semi ed altri reperti." In *Nuove ricerche sulla protostoria della Sibaritide*, edited by R. Peroni, 272–284. Rome: Paleani Editrice.
Van Joolen, E. 2003. "Archaeological land evaluation: A reconstruction of the suitability of ancient landscapes for various land uses in Italy focused on the first millennium BC." PHD Thesis University of Groningen, Groningen. Online access link https://research.rug.nl/en/publications/archaeological-land-evaluation-a-reconstruction-of-the-suitabilit (last access 01.09.2022).
Vanzetti, A. 2013. "Sibari protostorica." In *Sibari. Archeologia, storia, metafora. Il Coscile*, edited by G. Delia, and T. Masneri, 11–33. Castrovillari: Il Coscile.
Vespasiano, G., C. Apollaro, R. De Rosa, F. Muto, S. Larosa, J. Fiebig, A. Mulch, and L. Marini. 2015. "The Small Spring Method (SSM) for the Definition of Stable Isotope-Elevation Relationships in Northern Calabria (Southern Italy)." *Applied Geochemistry* 63: 333–346. https://doi.org/10.1016/j.apgeochem.2015.10.001.
Vespasiano, G., G. Cianflone, A. Romanazzi, C. Apollaro, R. Dominici, M. Polemio, and R. De Rosa. 2019. "A Multidisciplinary Approach for Sustainable Management of a Complex Coastal Plain: The Case of Sibari Plain (Southern Italy)." *Marine and Petroleum Geology* 109: 740–759. doi:10.1016/j.marpetgeo.2019.06.031.
Villa, I. M. 2021. "Isotope analyses of Strontium (Sr) and Lead (Pb)," in: Guggisberg, M. A., Colombi, C. (Eds.) unter Mitarbeit von Billo-Imbach, M., 2021. Macchiabate I. Ausgrabungen in der Nekropole von Francavilla Marittima, Kalabrien (2009-2016): Die Areale Strada und De Leo. Reichert Verlag, Wiesbaden, 232–235.
Voerkelius, S., G. D. Lorenz, S. Rummel, C. R. Quétel, G. Heiss, M. Baxter, C. Brach-Papa, et al. 2010. "Strontium Isotopic Signatures of Natural Mineral Waters, the Reference to a Simple Geological map and its Potential for Authentication of Food." *Food Chemistry* 118 (4): 933–940. doi:10.1016/j.foodchem.2009.04.125.
Willmes, M., C. P. Bataille, H. F. James, I. Moffat, L. McMorrow, L. Kinsley, R. A. Armstrong, S. Eggins, and R. Grün. 2018. "Mapping of Bioavailable Strontium Isotope Ratios in France for Archaeological Provenance Studies." *Applied Geochemistry* 90: 75–86. doi:10.1016/j.apgeochem.2017.12.025.