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1 **Imperial Roman Mobility and Migration at Velia (1st to 2nd c. CE) in Southern Italy**

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38 **Abstract:**
39 Mobility and human migration are seen as hallmarks of Roman society. With increasing
40 territorial expansion throughout the Mediterranean region during the Imperial Roman period,
41 wider opportunities for both self-driven and forced mobility became possible. This study
42 analyzes $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values from the dental enamel of 20 human second molars (M2) to
43 examine for potential instances of mobility at the 1st to 2nd c. CE site of Velia, located on the
44 Tyrrhenian coast of southern Italy. Velia served as a secondary port and was utilized for the
45 shipment of goods, boat maintenance, fish processing and arboriculture. Bagplot analysis
46 indicates that at least 10% (n=2/20) of the individuals sampled immigrated to Velia from non-
47 local regions. The remaining 18 individuals show mixed signs of local residency and local
48 mobility. Comparison of the Velia data with the contemporaneous southern Italian Imperial
49 Roman (1st to 4th c. CE) site of Vagnari indicates a similar level of mobility to both sites.
50 Though mobility is clearly evident among the individuals sampled from Velia, mobility to Velia
51 appears to have been less common than to larger cosmopolitan sites, such as Portus, in
52 proximity to the capital at Rome.

53
54
55 **Highlights:**

- 56 1. $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ were used to assess mobility at Imperial Roman Velia
- 57 2. Bagplot analysis of $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values identified two individuals as non-local
- 58 3. Mobility at Velia appears relatively local
- 59 4. Areas of isotopic homogeneity may obscure regional origins and cases of mobility
- 60 5. Velia provides insight to mobility in Imperial Roman southern Italian contexts

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65 **Keywords:** oxygen and strontium isotopes; Italian peninsula; Imperial Rome; Mediterranean;
66 migration and mobility

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70 **Declarations of Interest:** None

71

1. Introduction

The question of how do we conceptualize and identify migrants in ancient Roman contexts remains a core issue in modern Roman studies. Traditionally, migrants have been conceived of as outsiders coming in. More recent theorizations on mobility and human interaction have moved away from “us” and “them” conceptions to discuss mobility in terms of both variation in distance from an original homeland as well as transition in cultural continuity, placing qualifiers on what the distance an individual travelled means in terms of how they would have integrated into the social environs in which they ultimately came to reside (Albrecht 1972; Kearney 1986, 1995; Burmeister 2000; Brettel 2015; Moatti 2019). As Horden and Purcell (2000) contend, it is theoretically challenging to speak of the population of a city or region, given that on any given day there will be within the boundaries of a city, or imperial territory, hundreds of individuals who will not be there tomorrow, thousands who will not be there a year from now and tens of thousands who will have left the city over a decade. The converse can also be argued in terms of individuals who will arrive: in the Roman Imperial period it has been suggested that ~40% of adult Italian males over age 45 would have dwelt in a place different to their birthplace (Pearce 2010). A wide range of evidence, from epigraphy to burial style and chemical methods, have been utilized within Roman studies to identify mobile individuals and to qualify potential instances of and reasons for mobility.

From epigraphic and literary sources, it is clear that mobility events in the Roman circum-Mediterranean were common (Huttunen 1974; Wierschowski 1995; Noy 2000, 2010). One of the challenges of these sources, however, is that inscriptional evidence reflects only individuals who received burial commemoration and who explicitly had their experience of mobility documented, such as the rare case of Barates of Palmyrene origin and his wife Regina of Catuvellaunian origin (Noy 2010). Social and linguistic factors may have also played a role in the commemoration of homelands in epigraphic materials. It has been argued that some locations of origin may have carried greater potential stigma than others and as such were likely less frequently recorded, with Noy (2000) noting that it may be significant that the vast majority of Egyptians documented in the pagan civilian epitaphs are listed as having a connection to Alexandria and not Egypt.

Who then were the most likely to have their homelands commemorated? It has been argued that soldiers were the most likely to provide insight to their place of origin, having likely never intended to move to the military outpost where they ultimately perished (Noy 2000, 2010; Wierschowski 2001; Woolf 2013). In rare instances epigraphic materials can provide insights to multiple migrations, such as the epitaph discussed by Moatti (2006) of an artisan who made seventy-two journeys from Phrygia to Rome. Regionally specific names can also help identify potential cases of migration, though caution is needed as regionally specific names do not necessarily imply foreign origins as such names may simply be ancestral or family names (Maier 1953-1954; Cebeillac-Gervasoni 1996; Salomies 2002; Noy 2010). Documentation of foreign deities can also provide indirect evidence of nonlocal individuals in a region, such as the worship of Syrian storm gods along the Danube and Rhine frontiers (Fulford 2010; Hin 2013; Woolf 2013). The use of epigraphic evidence is, however, faced with the challenge that males are disproportionately represented over females, with Noy (2000) identifying 76.7% of Roman epitaphs as documenting males, whereas only 21.0% document females.

Similarly, literary sources, in many cases, provided a skewed representation of the nature of mobility. Typically written by social elites, literary accounts of mobility often have a distinct agenda: either embracing the merits of migration, recording prestigious and “exotic” foreigners, or vilifying various foreign groups; it is uncommon to find textual evidence regarding more mundane migrations (e.g. mobility related to work), even though it is clear from other sources, such as censuses and documents discussing trade, that employment-related migration was ubiquitous (Vallat 2001; Salomies 2002; Helttula 2007; Bruun 2010; Noy 2010; Hin 2013;

123 Woolf 2013). Ball (2000) likens this process of selective epigraphic commemoration and textual
124 discussion to believing what you see on television, in that such evidence presents one
125 perspective that must be treated with due caution as it is not always free of bias.

126 Burial style and grave goods have also long been a method for examining possible
127 instances of foreignness and migration in archaeological contexts (Saxe 1970; Morris 1992;
128 Fontana 2001; Sprague 2005; Pearce 2010; Wells 2013). However, as Pearce (2010) notes,
129 caution is needed so as not to equate a culture-historical view of burial practices with a specific
130 “people.” Noy (2000) contends that there is very little evidence that groups with a common
131 geographical origin ever established their own separate burial areas in Rome. This is further
132 supported by the fact that there are, to date, no known ancient burial grounds reserved for
133 “foreigners” at Rome, suggesting a degree of homogenization in burial that makes separating
134 regional origins of buried individuals based on burial style alone unlikely (Nuzzo 1997).

135 With the advent of isotopic methodologies came the possibility to assess mobility events
136 at an individual level based on preserved chemical values within skeletal materials. Though this
137 method cannot attest to the name or precise homeland of origin, it does provide insight to
138 mobility that can be developed in tandem with other methods to provide increasingly nuanced
139 assessments of individual and group mobility events.

140 Initial isotopic studies of Imperial Roman mobility in Italy focussed on the area around
141 Rome (e.g. Prowse et al. 2007; Killgrove 2010a, b; Killgrove and Montgomery 2016), with
142 subsequent studies presenting data from broader pre-Roman and Roman contexts, such as
143 those examining mobility and genetic diversity at Vagnari and Botromagno (Roman Silvium) in
144 southern Italy (Prowse et al. 2010; Emery et al. 2018a, b). To varying degrees, these studies all
145 documented instances of mobility. The distance of mobility and evident regions from which
146 migrants emigrated however, are variable. The studies of Prowse et al. (2007) at Isola Sacra
147 and Killgrove (2010a, b, c, 2013, 2014) and Killgrove and Montgomery (2016) at Casal Bertone
148 and Castellaccio Europarco suggest a much more geographically diverse nature of mobility to
149 the area around Rome in comparison to the more regionally-local mobility evident at Vagnari in
150 southern Italy, though mobility from evidently distant locales was evident at this site as well
151 (Prowse et al. 2010; Emery et al. 2018a, b). This diversity of mobility patterns brings into
152 question the nature of migration to larger cosmopolitan centres, such as Rome, in comparison
153 to mobility to more rural and provincial settings, such as those at Vagnari and Velia.

154 What remains clear regardless of the methodology employed, is that mobility was a
155 common occurrence within Imperial Roman contexts. Who was mobile, the pattern of mobility,
156 and the purpose of mobility remain much greater challenges to address substantively. The study
157 presented herein utilizes oxygen ($\delta^{18}\text{O}_{\text{dw}}$) and strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) values to provide an
158 assessment of mobility at the Imperial Roman site of Velia (1st to 2nd c. CE). This study seeks
159 to investigate the degree of mobility to Velia, a secondary port city where access to the Italian
160 peninsula via coastal routes is expected to have resulted in higher rates of mobility compared to
161 inland sites in southern Italy, such as Vagnari, but less frequent, and ostensibly less regionally
162 diverse, than at primary ports and major cities, such as Portus and Rome.

163 164 **1.2 The Site of Velia**

165
166 Velia is located on a promontory on the Tyrrhenian coast of Italy in the Cilento of Lucania
167 between the mouths of the rivers Alento and Fiumarella, 112 km southeast of Naples (Pellegrino
168 1957; Richardson 1976) (**Fig. 1**). Velia (Elea) originated as a Phocaeen colony known as Hyele
169 in ca. 540 BCE, during which time construction concentrated in the area of the acropolis
170 (Pellegrino 1957; Musti 1966; Cerchiai 2004; Mele 2006; Nenci and Vallet 2012).

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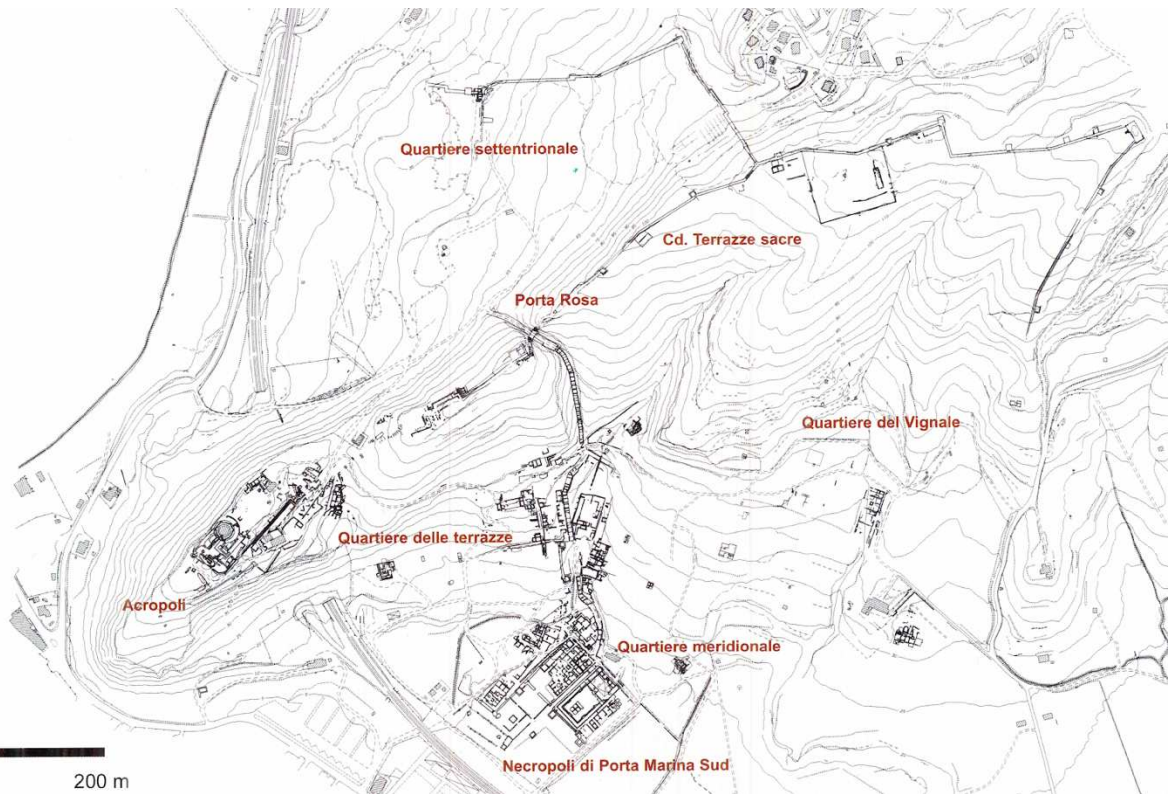
Fig. 1: Map showing the location of the sites of Velia, Botromagno (Roman Silvium), and Vagnari.

Following incorporation into Roman territory in the 3rd c. BCE, development focussed in the southern quarter, including the establishment of a necropolis (Richardson 1976; Ermolli et al. 2013).

Numerous accounts of the ruins at Velia are provided by early travelers in the region, with the first known being that of Carletti in 1794 (Vecchio 2007). Ramage (1868) describes a number of the Roman ruins and Schleuning (1889) provides an early archaeological

183 assessment of Velia, but it was not until 1927 that limited excavations began under the direction
184 of Amedeo Maiuri, Superintendent of Campania (Vecchio 2007). Extensive excavation of the
185 site was initiated in the 1960s with the research of Mario Napoli on the southern slope of the
186 Phocaean acropolis (Napoli 1972; Krinzinger and Tocco Sciarelli 1997; Vecchio 2007). From
187 1969–1978 and throughout the 1990s, a systematic survey of the ruins of the Phocaean colony
188 was undertaken by German and Austrian archaeological missions (Fiammenghi 1994;
189 Krinzinger and Tocco Sciarelli 1997).

190 Archaeological research on the Roman contexts at Velia focussed in the southern part of
191 the site, around the area of the Porta Marina Sud. Several houses, a building with a
192 cryptoporticus, and early Imperial era structures flanking the road exiting the Porta Marina Sud
193 were documented in this area (Krinzinger and Tocco Sciarelli 1997; Fiammenghi 2003;
194 Fiammenghi and La Torre 2005). The Porta Marina Sud area is also the location of the Roman
195 necropolis (ca. 1st to 2nd c. CE), identified along what Fiammenghi and La Torre (2005) refer to as
196 a “street of burials” in proximity to the coast (**Fig. 2**).
197



198
199 **Fig 2.** Velia site plan showing the Acropolis and Imperial Roman settlement, including the
200 necropoli di Porta Marina Sud (as published in Greco 2003).
201
202

203 The Roman necropolis at Velia was investigated by Fiammenghi (2003), who notes that,
204 up until the time of her research, the only known information about the necropolis had come
205 from the works of Ebner (1962, 1970, 1978) who discusses a limited number of
206 decontextualized funerary inscriptions. Excavations by Fiammenghi identified approximately 330
207 burials scattered over a 0.5 ha area with no apparent subdivisions of the cemetery (Fiammenghi
208 and La Torre 2005).

209 Burial types at Velia ranged from simple earthen graves to monumental tombs and
210 mausolea (Fiammenghi 2003; Fiammenghi and La Torre 2005). To date, only the earthen

211 graves have been excavated, of which both cremations and inhumations were documented
212 (Craig et al. 2009). Each grave contained a variable number and type of grave goods, though
213 the exact type and distribution of grave goods is currently unknown as the necropolis has not
214 been fully published. Both Fiammenghi (2003) and Craig (2009) note that evidence of variation
215 in social status was not evident from burial contexts alone. Bioarchaeological examinations of
216 the Roman skeletal remains from Velia have focused on dietary reconstruction (Craig et al.
217 2009), dental asymmetry (LaFleur 2011), palaeodemography, health status and working
218 activities (Crowe et al. 2010; Sperduti et al. 2012; Bondioli et al. 2016; Marciniak et al. 2016),
219 and age-related bone loss (Beauchesne and Agarwal 2014).

220

221 **1.3 $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ Variation in Nature**

222

223 The water cycle is the key medium through which oxygen isotope variation occurs and can be
224 tracked: $\delta^{18}\text{O}$ of precipitation generally decreases with distance from a marine coastline,
225 increase in elevation and latitude, and decrease in temperature of precipitation and increasing
226 latitude, with further potential effects due to humidity (Dansgaard 1964; Gat 1996, 2005; Gat et
227 al. 2003; Bowen 2010; Schwarcz et al. 2010). In continually hot climates ($> \sim 25^\circ\text{C}$) this trend
228 breaks down and one must rely on the amount of precipitation, where low $\delta^{18}\text{O}$ values occur in
229 rainy periods and high $\delta^{18}\text{O}$ in dry periods (Dansgaard 1964). Using these parameters, global
230 variability of $\delta^{18}\text{O}$ in meteoric precipitation can be mapped using region specific data, such as
231 those compiled as part of the Global Network of Isotopes in Precipitation (GNIP) project (GNIP
232 2015).

233 $^{87}\text{Sr}/^{86}\text{Sr}$ values in underlying geology are dependent upon time allowed for $^{87}\text{Rb} \rightarrow ^{87}\text{Sr}$
234 decay, with ^{87}Rb having a half-life of $\sim 4.88 \times 10^{10}$ years; initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio; and original
235 concentrations of ^{87}Rb and ^{87}Sr (Faure and Mensing 2005; Dickin 2005). Rocks that are very old
236 (i.e. > 100 mya) with high original $^{87}\text{Rb}/^{87}\text{Sr}$ content have $^{87}\text{Sr}/^{86}\text{Sr}$ values generally > 0.710 , with
237 the upper limit being ~ 0.750 ; rocks formed comparatively recently ($< 1\text{--}10$ mya) with low original
238 $^{87}\text{Rb}/^{87}\text{Sr}$ have low $^{87}\text{Sr}/^{86}\text{Sr}$ values, generally < 0.704 ; the $^{87}\text{Sr}/^{86}\text{Sr}$ of river water varies with
239 local geology, while marine water has had a value of ~ 0.7092 for at least the last 10,000 years
240 (Faure and Powell 1972; DePaolo and Ingram 1985; Elderfield 1986; Veizer 1989; Bentley
241 2006; Copeland et al. 2008; Malainey 2010; Bataille and Bowen 2012; Zaky et al. 2019).

242

243 **1.4 $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ in Dental Enamel and Dental Development**

244

245 Oxygen and strontium in enamel reflect values integrated during dental development from the
246 foods ($^{87}\text{Sr}/^{86}\text{Sr}$) an individual eats and the water ($\delta^{18}\text{O}$) they consume, with dietary water and
247 atmospheric oxygen playing minor secondary roles (Bentley 2006; Hedges et al. 2006; Price
248 and Burton 2002). $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ are integrated into bioapatite, $(\text{Ca}_9(\text{PO}_4)_4.5(\text{CO}_3)_{1.5}(\text{OH})_{1.5})$,
249 allowing for their use in tracing instances of mobility (Rey et al. 1991; Kolodny and Luz 1991;
250 Arppe and Karhu 2005; Price and Burton 2011; Rabadjeva et al. 2011). Strontium ($^{87}\text{Sr}/^{86}\text{Sr}$)
251 can substitute for calcium (Ca) in the body and does not undergo fractionation, providing a
252 direct reflection of the values consumed (Bentley 2006; Burton 2008; Price et al. 2015). Oxygen
253 ($\delta^{18}\text{O}$) undergoes fractionation in the body and can be derived from two locations within apatite:
254 carbonate (CO_3) and phosphate (PO_4) (Elliot et al. 1985; Kolodny and Luz 1991; Daux et al.
255 2008; Price and Burton 2011).

256 Dental development begins *in utero* at $\sim 14\text{--}20$ weeks post-fertilization and proceeds
257 until around age 17 (Scheuer and Black 2000; Hillson 1996). Crown initiation for the first
258 permanent molar (M1) is underway by birth, for the second molar (M2) by $\sim 2.5\text{--}3$ yrs., and for
259 the third molar (M3) by $\sim 7\text{--}10$ yrs.; crown development is complete for M1 by $\sim 2.5\text{--}3$ yrs., for M2
260 by $\sim 7\text{--}8$ yrs., and for M3 by $\sim 10\text{--}17.5$ yrs. (Schour and Massler 1940; Hillson 1996; Al Qahtani

261 2009). Possible late term *in utero* diet and breastfeeding, in the case of M1, and childhood diet
262 contribute to $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values reflected in the permanent dentition (Christensen and
263 Kraus 1965; Herring et al. 1998; Wright and Schwarcz 1998, 1999; Knudson 2009; Schuurs
264 2012). Accordingly, the isotopic signature in dental enamel of the permanent dentition can be
265 used as an indicator of residence for the period from around birth until completion of dental
266 development.

267

268 **1.5 Diagenesis and Preservation of Isotopic Values**

269

270 Within depositional contexts the isotopic values present in skeletal remains can progressively
271 equilibrate towards the isotopic signature of the surrounding matrix due to isotopic exchange,
272 sorption factors, crystallite growth, and re-crystallization, resulting from elemental commonalities
273 between skeletal materials and the surrounding burial environment (Likins et al. 1960; Nelson et
274 al. 1986; Ayliffe et al. 1992; Stuart-Williams et al. 1996). Bone is very porous, being composed
275 of smaller poorly crystalline structures, and has a significant organic component that is subject
276 to postmortem decay and microbial attack; enamel is more resistant to diagenesis due to the
277 larger, less porous, and denser arrangement of apatite crystals (Kohn et al. 1999; Hedges 2002;
278 Kohn and Cerling 2002; Hedges et al. 2006; Price 2008; King et al. 2011).

279

280 Isotopic exchange towards equilibrium with the surrounding burial environment remains
281 the key process for $\delta^{18}\text{O}$ diagenesis; for $^{87}\text{Sr}/^{86}\text{Sr}$, secondary Ca and Sr exchange with biogenic
282 Sr through pore filling and concentration along microcracks and on the bone surface, re-
283 crystallization, and re-mineralization of diagenetic Sr in hydroxyapatite are the key forms of
284 diagenesis (Budd et al. 2000; Bentley 2006). Given these characteristics of diagenesis, dental
285 enamel is the preferred material for palaeomobility studies.

285

286 **2. Materials and Methods**

287

288 Adult second molars (M2) from 20 individuals (10 male and 10 female) were selected for
289 assessing potential instances of mobility to the site of Velia utilizing $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values
290 from dental enamel. Samples were collected from the Museo delle Civiltà (formerly the Museo
291 Nazionale Preistorico Etnografico “L. Pigorini”) in Rome. The collection is curated by the
292 Servizio di Bioarchaeologia of the Museo delle Civiltà.

293

294 **2.1 Age and Sex Estimation**

295

296 Age and sex estimations were determined based on macromorphological skeletal traits.
297 Morphology of the greater sciatic notch, ischiopubic ramus, ventral arc, subpubic concavity, and
298 cranial morphology were used for establishing sex; pubic symphysis, sternal ends of ribs,
299 auricular surface morphology, and cranial suture closure were utilized for establishing age
300 (Acsádi and Nemeskéri 1970; Ferembach et al. 1977-79; Buikstra and Ubelaker, 1994; Nikita,
301 2017).

302

303 **2.2 Dental Enamel Preparation**

304

305 All 20 second molars were initially manually brushed to remove adhering debris before being
306 submerged in individual containers of distilled water (dH_2O) and ultrasonicated for 10 minutes.
307 Ultrasonication was repeated three times changing the water after each session. Following
308 ultrasonication, teeth were allowed to dry before using a diamond tipped hand-held electric
309 Dremel drill to remove enamel for sampling: ≥ 10 mg of powdered enamel for $\delta^{18}\text{O}$ analysis and
310 ≥ 60 mg for $^{87}\text{Sr}/^{86}\text{Sr}$. After each use the drill bit was soaked in 0.25M hydrochloric acid (HCl) to

311 avoid cross contamination. Enamel powder was collected in 1.5 ml plastic centrifuge
312 microtubes.

313

314 **2.3 $\delta^{18}\text{O}$ Methodology**

315

316 Enamel preparation for oxygen ($\delta^{18}\text{O}$) isotope analysis followed the protocols established in
317 Koch et al. (1997). Collected enamel samples were treated with 0.04 ml of 2.5% bleach solution
318 (NaClO) per mg of sample, agitated, and allowed to react for 24 hrs. Following this reaction,
319 samples were centrifuged and rinsed with de-ionized water five times, centrifuging after each
320 rinse. After rinsing, 0.04 ml of 1M acetic acid acetate buffer (CH_3COOH) per mg of sample was
321 added to remove potential diagenetic secondary carbonates. Samples were agitated and
322 allowed to react for up to 24hrs. Samples were centrifuged and rinsed five times with de-ionized
323 water, centrifuging after each rinse. After the fifth rinse samples were centrifuged and the
324 remaining water removed before allowing samples to dry.

325

326 This methodology should not detrimentally affect carbonate values, though recent
327 research has shown the potential impacts of pre-treatment chemicals, reaction temperatures,
328 and phosphoric acid concentrations in terms of variability in results (Snoeck and Pellegrini 2015;
329 Pellegrini and Snoeck 2016; Demény et al. 2019). Direct comparisons of samples prepared
330 using different protocols should accordingly be undertaken with caution. In the case of the
331 present study, potential impacts of variability in preparation methodology do not form an issue of
332 concern as both the Velia and Vagnari samples were prepared using the same protocols and
333 were analyzed at the same laboratory.

334

335 Once dry, 2 mg of powdered enamel was weighed into stainless steel cups. Enamel
336 powder was reacted with 100% phosphoric acid at 90°C in an autocarb analyzer to produce CO_2
337 gas, which was analyzed on a VG OPTIMA Isocarb isotope ratio mass spectrometer (IRMS) at
338 the McMaster Research for Stable Isotopologues (MRSI) laboratory to measure $\delta^{18}\text{O}$ values.
339 For each carousel containing 14 samples one sample was run in duplicate to monitor accuracy
340 and reproducibility. The data collected are presented using delta values (δ) such that,

341

342

$$\delta^{18}\text{O} = \left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{sample}} / \left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{standard}} - 1,$$

343

344 where $\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{sample}}$ indicates the sample analyzed and $\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{standard}}$ indicates an
345 international standard, herein measured relative to the Vienna Pee Dee Belmnite (VPDB)
346 standard. The resultant values are presented in per mil (‰) notation.

347

348 **2.4 $^{87}\text{Sr}/^{86}\text{Sr}$ Methodology**

349

350 Enamel samples were dissolved in 1.2 ml of 2.5 M hydrochloric acid (HCl) and subsequently
351 centrifuged for 10 minutes. Cation exchange was employed to complete strontium separation.
352 Cation exchange columns were calibrated employing a "spiked" sample followed by 10 ml of
353 deionized water to cleanse the cation exchange columns before use. A wash of 60 ml of 6 M
354 HCl was introduced, followed by 10 ml of deionized water, and then finally 5 ml of 2.5 M HCl.
355 Dissolved enamel solution for each individual was introduced into the exchange columns in 1 ml
356 portions and was washed into the column using 1 ml of 2.5 M HCl, after which a wash of 3 ml of
357 2.5 M HCl was introduced. Waste sample matrix was eluted using 20 ml of 2.5 M HCl. After the
358 20 ml elution, 6 ml of 2.5 M HCl was introduced for strontium collection. Each dried sample was
359 loaded onto a pre-treated single tantalum filament in dilute phosphoric acid (H_3PO_4) and
360 sequentially inserted into a vacuum system. $^{87}\text{Sr}/^{86}\text{Sr}$ values were measured by dynamic multi-
collection using a thermal ionization mass spectrometer (TIMS) in the School of Geography and
Earth Sciences at McMaster University. Results were fractionation normalized to

361 $^{88}\text{Sr}/^{86}\text{Sr} = .1194$, with an average $^{87}\text{Sr}/^{86}\text{Sr} = 0.71026 \pm 18$ (1σ) for the NIST 987 Sr standard and
362 internal precision (within-run precision) of ± 0.0012 – 0.0018% (1σ) standard error based on 150
363 dynamic cycles.

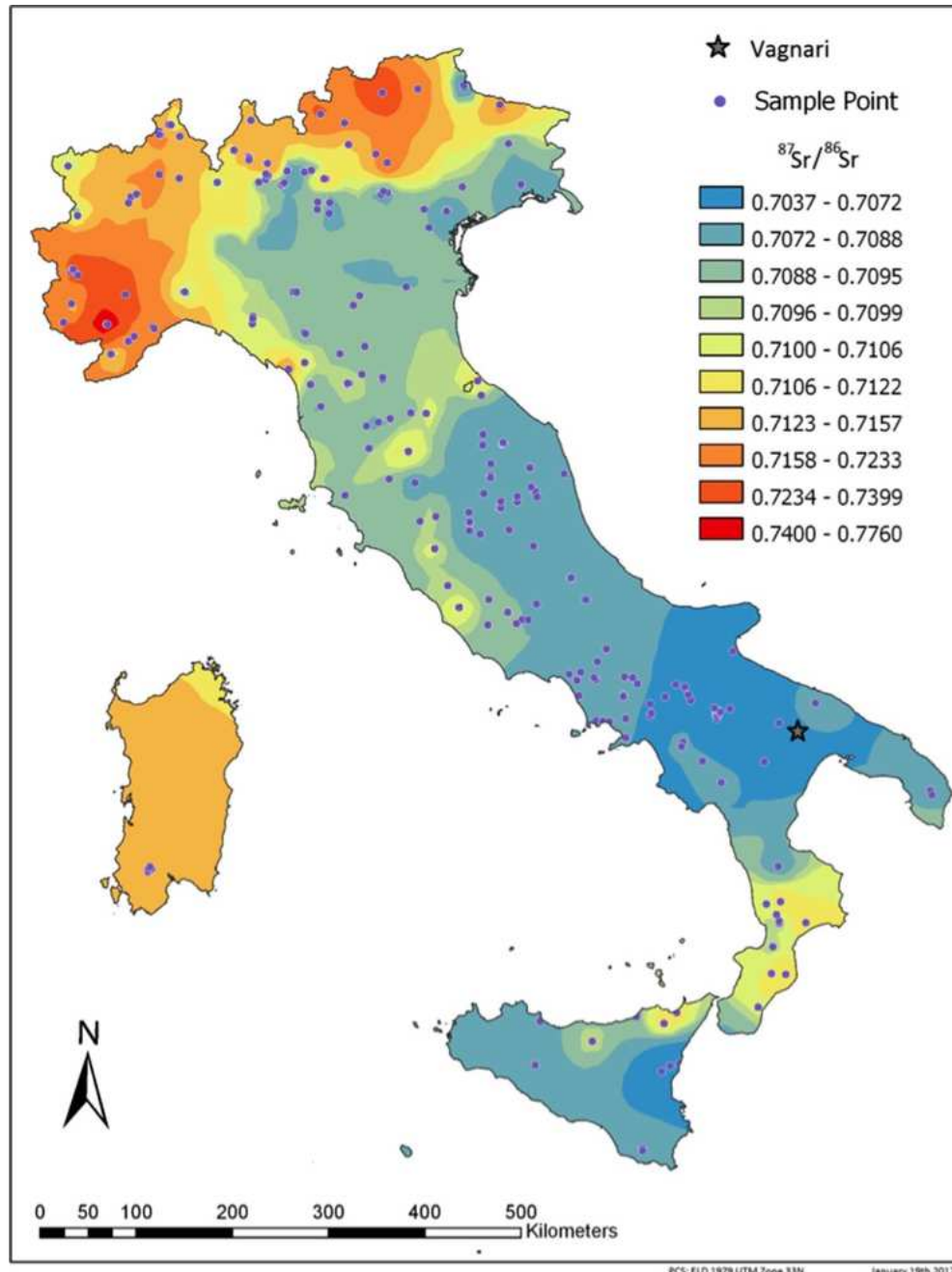
364 365 **2.5 FTIR**

366
367 Preservation of biogenic apatite at Velia was assessed utilizing Fourier transformation infrared
368 spectroscopy (FTIR) analysis of dental enamel from five individuals interred at Velia. FTIR was
369 used for calculating crystallinity index (CI) where, $\text{CI} = (A_{565} + A_{605})/A_{595}$, A_x being absorbance at
370 the wave number X in cm^{-1} ; CI values ≤ 3.8 indicate preservation of biogenic apatite (Shemesh
371 1990; Wright and Schwarcz 1996). FTIR analysis was conducted at the McMaster Combustion
372 Analysis and Optical Spectroscopy Facility. Samples were cleaned, enamel ground into a fine
373 powder, passed through a #200 mesh sieve, combined with dry potassium bromide (KBr),
374 ground, and compressed into pellets at 10,000 psi. Samples were analyzed using a Nicolet
375 6700 dry nitrogen purged FTIR, room temperature DTGS detector with extended KBr beam
376 splitter, resolution 4 cm^{-1} (wavenumber) at 32 scans.

377 378 **2.6 Predicted Strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) and Oxygen ($\delta^{18}\text{O}_{\text{dw}}$) Values for Velia**

379
380 The geology of Velia is a mixture of lower Miocene flysch, including limestone, sandstone, and
381 dolomite; lower Pleistocene conglomerates; middle Pleistocene clays with peat; and sand with
382 volcanic ashes, as well as more recent Holocene gravels and sand with beach gravels (Gelati et
383 al. 1989; Guariglia 2011). Based on the predictive modeling of bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ variation in
384 Italy presented by Emery et al. (2018a), Velia is located in a region where $^{87}\text{Sr}/^{86}\text{Sr}$ values
385 between 0.7037–0.7088 are expected (**Fig. 3**). To provide further refinement for the environs
386 around Velia, $^{87}\text{Sr}/^{86}\text{Sr}$ values from nine archaeofaunal pig teeth, originally presented in Stark
387 (2016), were utilized to establish an expected bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ range. Domesticated
388 porcine species in southern Italy are known from as early as the Bronze Age, with Lucania, the
389 region within which Velia is located, being a key region of pork supply during the Roman era
390 (MacKinnon 2001; Lega et al. 2016). Swine are commonly fed grains and foodstuffs consistent
391 with or similar to those used in human diets; resultant $^{87}\text{Sr}/^{86}\text{Sr}$ values can provide valuable
392 insight to expected local bioavailable ranges.

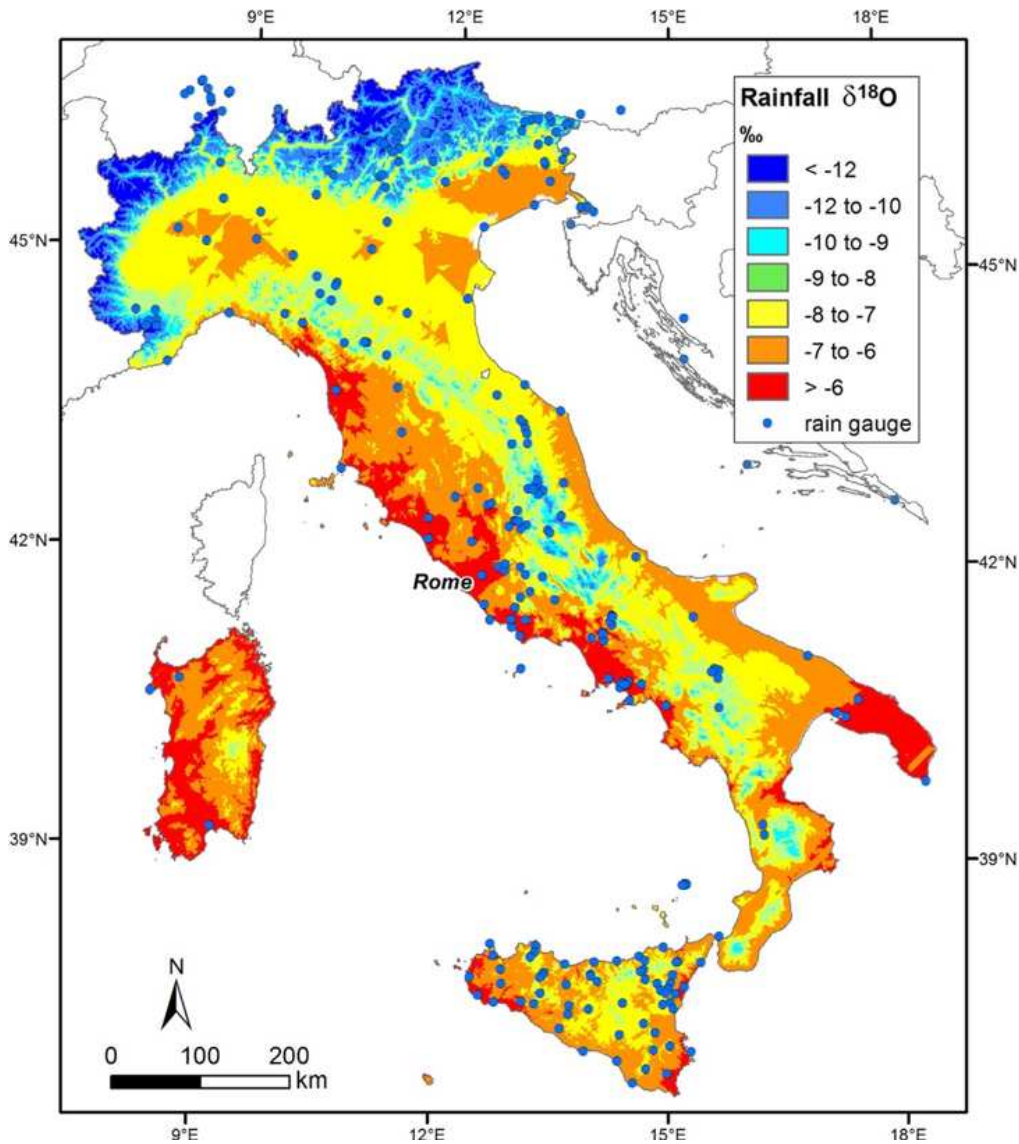
393



394
 395 **Fig. 3:** Approximated distribution of bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ values for the Italian peninsula (as
 396 published in Emery et al. 2018)
 397

398 In terms of $\delta^{18}\text{O}_{\text{dw}}$ variation, the data presented by Longinelli and Selmo (2003) place
 399 Velia within a region having expected $\delta^{18}\text{O}_{\text{dw}}$ values between -6‰ to -5‰ . This predicted range
 400 was expanded in 2016 by Giustini and colleagues, to include values from -8‰ to -6‰ (**Fig. 4**).
 401 Intra-population variation in local $\delta^{18}\text{O}$ values is generally accepted to be $\sim\pm 1\text{‰}$ (Schwarcz et al.
 402 2010). To approximate the expected local value of meteoric precipitation at Velia and to
 403 facilitate comparison with GNIP and local $\delta^{18}\text{O}_{\text{dw}}$ datasets, $\delta^{18}\text{O}_{\text{c}}$ values were converted to
 404 $\delta^{18}\text{O}_{\text{dw}}$ following Chenery et al. (2012). Such values carry an uncertainty of $\pm 1\text{‰}$ (2σ) and are
 405 used as a guide for gauging the correspondence between individuals and their residential
 406 environment (Pollard et al. 2011; Chenery et al. 2012).

407
408



409
410

Fig. 4: Approximated distribution of $\delta^{18}\text{O}$ values in precipitation for the Italian peninsula (as published in Giustini et al. 2016).

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2.7 Statistical Analyses

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SPSS was used to examine for potentially significant differences in $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values between males and females and between age categories. A Shapiro-Wilk test was employed to gauge the normality of sample distribution. To assess for significant differences between male and female individuals, a t-test was utilized for normally distributed samples and the non-parametric Mann-Whitney U test was used for non-normally distributed samples. To examine for significant differences by age group, four age categories were established: 18-29, 30-39, 40-49, and 50+. An ANOVA test was employed for normally distributed samples and a non-parametric Kruskal-Wallis test for non-normally distributed samples (Ross 2010).

Identification of local vs. non-local individuals was determined using bagplot analysis (**Fig. 5**). Bagplots provide a robust assessment of outliers utilizing three nested polygons known

425 as the “bag,” “fence”, and “loop”, which are based on a depth median, being the point with
 426 highest half space depth (visualized as a red starburst). The bag, indicated with dark blue, is
 427 established using a Tukey depth (centerpoint) and comprises $\leq 50\%$ of the data points; the
 428 fence, which is not plotted, is formed by expanding the bag by a factor of three and serves to
 429 separate inliers from outliers; the resulting intermediary area between the bag and the fence,
 430 identified using light blue, is known as the loop. This loop area represents values that fall
 431 outside of the limits of the bag (i.e. values that have greater dispersion from the depth median)
 432 but are still within the established limits of the fence (i.e. are not statistical outliers). This method
 433 creates a robust threshold beyond which values can be considered confidently as outliers within
 434 a given sample (Rousseeuw et al. 1999; Gower et al. 2011; Lightfoot and O’Connell
 435 2016). Generation of a bivariate bagplot was conducted using the R statistical package *aplpack*
 436 (Wolf 2018).

437
 438 **3. Results**

439
 440 **3.1 CI Values and Defining Local Ranges**

441
 442 FTIR analysis yielded CI values of ≤ 3.8 , indicating preservation of biogenic apatite within
 443 depositional contexts at Velia. Based on the $^{87}\text{Sr}/^{86}\text{Sr}$ values derived from nine archaeofaunal
 444 pig teeth from Velia, which were previously presented in Stark (2016), the expected bioavailable
 445 $^{87}\text{Sr}/^{86}\text{Sr}$ range for Velia was established by Stark (2016) as approximating 0.70783–0.70979
 446 (2σ), a local range consistent with $^{87}\text{Sr}/^{86}\text{Sr}$ values predicted from underlying geology in regions
 447 surrounding Velia (Emery et al. 2018a). Such consistency suggests that the pig teeth utilized
 448 from Velia were not likely imported from a distant region. Based on the expected $\delta^{18}\text{O}_{\text{dw}}$ values
 449 of precipitation established by Giustini et al. (2016) in conjunction with the expected local values
 450 established by Prowse et al. (2007) for the site of Portus, located in the same isopleth as Velia
 451 further north on the Tyrrhenian coast of Italy, an expected local $\delta^{18}\text{O}_{\text{dw}}$ range for Velia was
 452 approximated as -8.9‰ to -4.8‰ (1σ).

453
 454 **3.2 $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ Variation among Individuals from Velia**

455
 456 Among the 20 individuals sampled from Velia, all of whom were interred in inhumation style
 457 graves, $\delta^{18}\text{O}_{\text{dw}}$ values varied from -1.3‰ (Velia 57) to -9.4‰ (Velia 211), a range of 8.1‰ .
 458 $^{87}\text{Sr}/^{86}\text{Sr}$ values ranged from 0.70788 (Velia 57) to 0.70901 (Velia 211) (**Table 1**).

459
 460 **Table 1:** Osteobiographic data, $\delta^{18}\text{O}_{\text{c}}$ VPDB, $\delta^{18}\text{O}_{\text{dw}}$ VSMOW, and $^{87}\text{Sr}/^{86}\text{Sr}$ for 20 individuals
 461 sampled from Velia

Individual	Sex	Age (yrs.)	M2 $\delta^{18}\text{O}_{\text{c}}$ VPDB (‰)	M2 $\delta^{18}\text{O}_{\text{dw}}$ VSMOW (‰)	$^{87}\text{Sr}/^{86}\text{Sr}$
Velia 57	M	30-35	-1.1	-1.3	0.70788
Velia 82	F	50+	-4.1	-6.2	0.70879
Velia 117	F	20-30	-5.6	-8.7	0.70880
Velia 134	F	20-30	-5.8	-9.0	0.70890
Velia 139	M	30-40	-4.6	-7.0	0.70839
Velia 146	M	43-55	-4.3	-6.5	0.70827
Velia 160	F	30-40	-4.9	-7.5	0.70866
Velia 169	M	30-40	-5.5	-8.4	0.70874

Velia 174	M	40-50	-4.7	-7.1	0.70869
Velia 181	F	50+	-4.7	-7.1	0.70866
Velia 182	M	25-30	-4.2	-6.3	0.70873
Velia 186	M	20-24	-3.6	-5.4	0.70857
Velia 194	M	30-40	-5.8	-9.1	0.70860
Velia 205	F	30-40	-2.4	-3.5	0.70868
Velia 211	M	30-35	-6.0	-9.4	0.70901
Velia 214	F	25-35	-5.5	-8.5	0.70822
Velia 222	M	30-40	-3.5	-5.3	0.70878
Velia 223	F	40-45	-5.4	-8.4	0.70875
Velia 270	F	40-50	-3.9	-5.9	0.70900
Velia 283	F	50+	-4.2	-6.4	0.70882

462

463

3.3 Normality and Significance

464

465 Mann-Whitney U (p=0.165) and t-test analyses (p=0.573) identified no significant differences
466 between males and females at the 0.05 level. ANOVA (p=0.947) and Kruskal-Wallis (p=0.517)
467 analyses identified no significant differences between age categories at the 0.05 level. Given
468 the absence of statistically significant differences between age and sex categories, all samples
469 were pooled.

470

471

3.4 Local vs. Non-Local Individuals

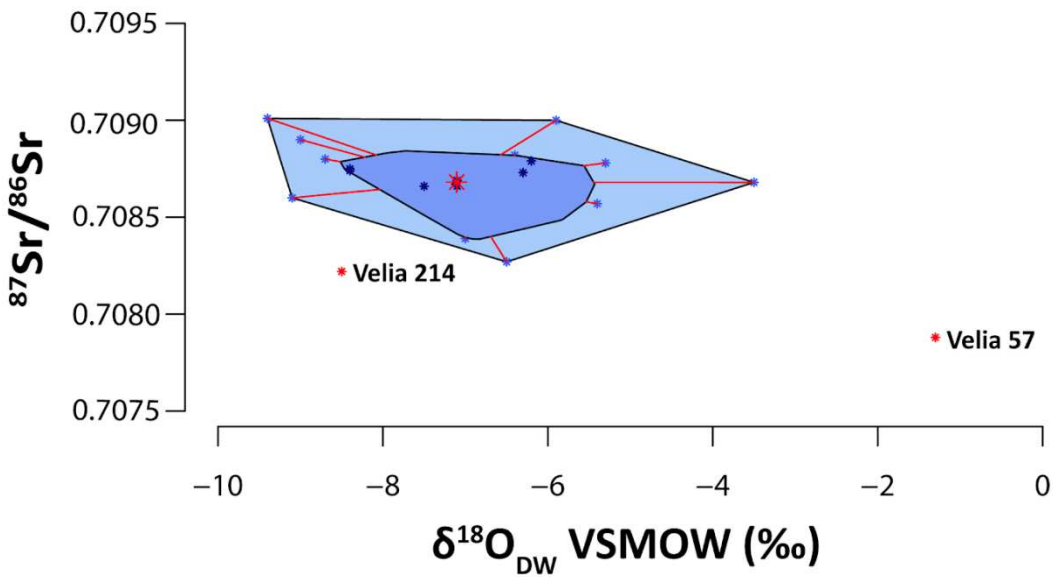
472

473 Taking the expected local $\delta^{18}\text{O}_{\text{dw}}$ range into consideration on its own, two females (Velia 134,
474 205) and three males (Velia 57, 194, 211) fall outside of the expected local range, though Velia
475 134 and 194 are only slightly outside of the predicted local range. No individuals fall outside of
476 the expected local bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ range based on the values provided by the pig teeth. A
477 graphical representation of the expected local $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ ranges is presented in
478 **Supplementary Fig. 1**.

479

480 The use of a bivariate bagplot identified two individuals as distinctly non-local: Velia 57
481 and Velia 214. Several individuals also fall between the fence and the loop which, though
482 statistically considered local, may imply mobility towards Velia from geographically similar or
483 proximate regions (**Fig. 5**).

483



484
 485 **Fig. 5:** Bagplot analysis of $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values for 20 individuals sampled from Velia.
 486 Distinct statistical outliers are shown as red dots and have been identified by their associated
 487 labels: Velia 57 and Velia 214.

488
 489 **4. Discussion**

490
 491 **4.1 Water Sources at Velia**

492
 493 From its earliest inception as a Phocaeen colony the water supply of Velia was provided by a
 494 mixture of rain water, stored in communal cisterns and pithoi, and local spring water channeled
 495 through canals from the surrounding *vallone del Frittolo* (Krinzinger 1986; Greco and De Simone
 496 2012). This method of water collection was maintained into the Roman era, at which time a
 497 small aqueduct system and public fountains were built to increase the volume and distribution of
 498 water (Smith 1854; Ashby 1935; Greco and De Simone 2012). Given the local source of the
 499 spring water, the use of enclosed distribution piping, and the large size of the main cisterns
 500 minimizing evaporation, consumption of the drinking water at Velia would have provided local
 501 $\delta^{18}\text{O}_{\text{dw}}$ values.

502
 503 **4.2 $^{87}\text{Sr}/^{86}\text{Sr}$ Variability at Velia**

504
 505 Looking at the expected $^{87}\text{Sr}/^{86}\text{Sr}$ values for Velia from the generated bioavailable mapping of
 506 Emery et al. (2018a) and the previously analyzed archaeofaunal pig teeth of Stark (2016), it is
 507 clear that discrepancies exist between the expected values and the proximate geology of the
 508 Velia region. The predicted bioavailable range of $^{87}\text{Sr}/^{86}\text{Sr}$ values for Velia presented in Emery
 509 et al. (2018a) falls between ~ 0.7037 to 0.7072 , a range into which none of the archaeofaunal or
 510 analyzed human teeth fall. Northeast of Velia is a zone in which predicted $^{87}\text{Sr}/^{86}\text{Sr}$ values range
 511 from 0.7072 to 0.7088 , a range that more readily aligns with the values observed from most of

512 the 20 individuals sampled. Such variation, particularly in light of the more variable $\delta^{18}\text{O}_{\text{dw}}$
513 observed, brings into question the nature of $^{87}\text{Sr}/^{86}\text{Sr}$ values at Velia. Three possibilities can be
514 readily questioned: predicted bioavailable values, dietary sources, and sea spray.

515 The predictive baseline model presented by Emery et al. (2018a) utilized published
516 bioavailable modern and archaeological $^{87}\text{Sr}/^{86}\text{Sr}$ datasets as well as fossil, sediment, and
517 natural spring water values (n=199 data points). Using these values, a bioavailable map of the
518 Italian peninsula was generated based on a bounded inverse distance weighting (IDW)
519 interpolation. This map provides the first approximation of bioavailable values for the Italian
520 peninsula but must also be used with caution as the values presented are derived from wide
521 regions and interpolated across the predictive ranges. Emery et al. (2018a) recommend that,
522 when available, local bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ values be utilized in tandem to supplement regional
523 values provided by the bioavailable map. In the case of Velia, the generally lower predicted
524 $^{87}\text{Sr}/^{86}\text{Sr}$ range for the area of Velia presented by Emery et al. (2018a) in comparison to the pig
525 teeth values from Velia suggests that more nuanced local $^{87}\text{Sr}/^{86}\text{Sr}$ variation in southern Italy
526 may be obscured by the larger regional trends interpolated from the values employed in the
527 mapping.

528 The possibility of consuming staple foodstuffs developed in the hinterland of Velia, or
529 potentially from regions further afield, and processed products such as garum may have played
530 a role in the $^{87}\text{Sr}/^{86}\text{Sr}$ values reflected in the 20 second molars sampled. Craig et al. (2009)
531 investigated diet at Velia and found that the primary diet appears to have been high in cereals
532 with comparatively lower intake of meat/fish. They identified two distinct dietary groups: Group I,
533 which exhibit $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values indicative of high cereal consumption with lesser
534 contributions from meat/dairy and minor fish/garum intake ($\delta^{13}\text{C}$ range= -20.0‰ to -19.0‰; $\delta^{15}\text{N}$
535 range= +6.4‰ to +9.6‰); Group II, which exhibits similar $\delta^{13}\text{C}$ values to Group I but $\delta^{15}\text{N}$ values
536 $>+9.6$ ‰, suggesting greater contributions from meat/fish products. Of the 20 individuals
537 sampled, only Velia 57 ($\delta^{15}\text{N}=14.0$ ‰) and Velia 169 ($\delta^{15}\text{N}=11.3$ ‰) fall within Group II. As
538 previously noted, Velia 57 appears distinctly non-local. Velia 169 has an $^{87}\text{Sr}/^{86}\text{Sr}$ value
539 consistent with the expected local range and similar to the remaining 18 individuals within Group
540 I of Craig et al. (2009), suggesting that the potential impacts from elevated consumption of salty
541 foods (e.g. garum) does not appear to have adversely influenced the resultant $^{87}\text{Sr}/^{86}\text{Sr}$ values
542 (cf. Wright 2005; Fenner and Wright 2014). A Pearson correlation was undertaken to assess the
543 degree of correspondence between $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values published by Craig et al. (2009) and
544 $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values presented herein. A distinct lack of correspondence is apparent
545 (**Table 2**).

546
547 **Table 2:** Pearson correlation between $\delta^{18}\text{O}_{\text{dw}}$, $^{87}\text{Sr}/^{86}\text{Sr}$, $\delta^{15}\text{N}$, and $\delta^{13}\text{C}$ values from Velia

	$\delta^{18}\text{O}_{\text{dw}}$ VSMOW	$^{87}\text{Sr}/^{86}\text{Sr}$
$\delta^{13}\text{C}$	0.22349	0.14448
$\delta^{15}\text{N}$	0.49768	-0.48048

548
549 Lastly, sea spray may have been a factor in the $^{87}\text{Sr}/^{86}\text{Sr}$ values of individuals from Velia.
550 Sea spray may unnaturally influence coastal $^{87}\text{Sr}/^{86}\text{Sr}$ values, pushing values towards that of
551 sea water (0.7092) with the addition of sea spray to consumed foodstuffs (Bentley 2006). Given
552 the proposed reliance on foodstuffs from the inland territory of Velia it is unlikely that sea spray
553 contributed significantly to the $^{87}\text{Sr}/^{86}\text{Sr}$ values documented (Veizer 1989; Chadwick et al. 1999;
554 Whipkey et al. 2000; Kusaka et al. 2009; Bentley 2006; Knudson et al. 2014). This assumption
555 is further validated by the finding that only two individuals at Velia (Velia 211, 270) exhibit values
556 approximating marine $^{87}\text{Sr}/^{86}\text{Sr}$ values, suggesting that sea spray was not a major factor at

557 Velia. Though not evident in the individuals sampled, further analysis of floral, faunal, and
558 human $^{87}\text{Sr}/^{86}\text{Sr}$ values may help to assess the potential of sea spray contributions at Velia
559 (cf. Ryan et al. 2018).

560

561 **4.3 Regions of Mobility**

562

563 Based on the bivariate bagplot, at least 2 individuals ($n=2/20$, 10%) appear distinctly non-local
564 to Velia: Velia 57 and Velia 214 (**Fig. 5**). Velia 57 has $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values consistent
565 with an origin in a warmer region such as North Africa ($\delta^{18}\text{O}_{\text{dw}}=-1.3\text{‰}$; $^{87}\text{Sr}/^{86}\text{Sr}=0.70788$), a
566 finding further supported by the comparatively high $\delta^{15}\text{N}$ at 14.0‰ and low $\delta^{13}\text{C}$ at -19.2‰
567 previously presented for this individual by Craig et al. (2009). Prowse et al. (2007) present
568 evidence of a 40–50 year old male individual from Isola Sacra (SCR 617) with a $\delta^{18}\text{O}_{\text{c}}$ signature
569 of -1.3‰ which they propose as being from North Africa, while the expected local $^{87}\text{Sr}/^{86}\text{Sr}$
570 range of 0.70732–0.70789 presented by Buzon et al. (2007) for Tombos aligns with that of
571 Velia 57, providing additional substantiating evidence for a possible North African childhood
572 residence of Velia 57. Though an origin in North Africa appears the most probable for this
573 individual, it must also be kept in mind that other circum-Mediterranean regions where similar
574 $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values are present cannot be entirely ruled out.

575 Velia 214 presents $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values suggestive of early life residency in the
576 interior of the Italian peninsula. The $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}_{\text{dw}}$ values of this individual fit within both
577 local ranges, suggesting residency in an area of proximate or similar geology and drinking water
578 to Velia; statistically however, this individual falls outside of the bagplot loop indicating a distinct
579 non-similarity to the rest of the sample. Based on the $\delta^{18}\text{O}_{\text{dw}}$ values presented in Giustini et al.
580 (2016) and $^{87}\text{Sr}/^{86}\text{Sr}$ in Emery et al. (2018a), a residency of this individual in the foothills of the
581 Apennine mountains or in the border region between Campania, Basilicata and Calabria
582 provides the most parsimonious interpretation for childhood residency.

583 Three individuals (Velia 134, 194, 211) who fall outside of the local $\delta^{18}\text{O}_{\text{dw}}$ range, but
584 who are not statistical outliers on the bagplot, have comparable $\delta^{18}\text{O}_{\text{dw}}$ (-9.4‰ to -9.0‰) and
585 $^{87}\text{Sr}/^{86}\text{Sr}$ (0.70868 to 0.70901) values that suggest a similarity in residency during M2
586 development. The area around Vallo della Lucania, northeast of Velia, and the elevated inland
587 border region between Campania, Basilicata and into Calabria exhibit a continuum of $\delta^{18}\text{O}_{\text{dw}}$
588 values that extends to -10‰ to -9.0‰ (Giustini et al. 2016). A parsimonious interpretation of the
589 data, given the similar $^{87}\text{Sr}/^{86}\text{Sr}$ values of these three individuals to other local individuals at
590 Velia, suggests it is probable that they arrived at Velia from these nearby regions, though not
591 necessarily all from the same area. Similar $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values are recorded elsewhere:
592 Schweissing and Grupe (2003a,b) report expected $^{87}\text{Sr}/^{86}\text{Sr}$ values between 0.70899 to 0.70992
593 for the area south of the Danube, while Sofeso et al. (2012) report $\delta^{18}\text{O}$ values ranging from
594 -8.1‰ to -9.9‰ for the majority of individuals from the Imperial Roman site of Erding Kletthamer
595 Feld; numerous others areas in the Apennine and Alp regions also present similar values. Such
596 a distant origin of these three individuals, though not impossible, is less probable.

597 The remainder of the individuals sampled ($n=15$) appear local. The diversity of $\delta^{18}\text{O}_{\text{dw}}$
598 and $^{87}\text{Sr}/^{86}\text{Sr}$ values represented among these 15 individuals does not suggest a singular place
599 of residency. Rather, it appears that individuals sampled likely lived in and around the region of
600 Velia and that local mobility events to Velia, where they were ultimately interred, were taking
601 place. As these individuals all fall within the expected local $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ ranges, it is not
602 possible to further delineate the potentiality of local mobility, or rather mobility within the
603 expected local $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ ranges, though such events almost certainly occurred.

604

605

606

607 **4.4 Interpreting “Foreigners” at Velia**

608
609 What can be made of the evident foreigners at Velia? From a bagplot analysis of the isotopic
610 data it is apparent that 10% (Velia 57 and 214) of the individuals examined are distinct outliers
611 and can be considered non-local to the area of Velia up to at least the age of ~7-8 when M2
612 dental enamel development is complete. Three additional individuals (Velia 134, 194, 211),
613 though statistically within the loop of the bagplot, exhibit $\delta^{18}\text{O}_{\text{dw}}$ values that suggest childhood
614 residency at a location somewhat removed from the environs of Velia. It is important to keep in
615 mind that the interpretation of $\delta^{18}\text{O}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values from bulk enamel represent the average
616 of values integrated into the enamel structure over the period of formation and as such
617 identification of mobility events from the timeframe of formation represents a broad picture of
618 mobility.

619 In the case of Velia 57, who has a signal consistent with a childhood residency in North
620 Africa, it is unclear what might have brought this male individual to Velia. Connections between
621 Roman North Africa and peninsular Italy are well known (Rickman 1980; Bagnall and Frier
622 1994; Pomey 1997; Cherry 1998; De Ligt 2012). Aside from the port environs of Velia itself,
623 access and mobility to Velia would also have been readily possible via the larger port of Puteoli
624 at Naples, a key location for shipments from Alexandria (D’Arms 1974; Brunson 2002; Arnaud
625 2005, 2012). As Velia was a port city this may provide one part of the explanation as to why
626 individual Velia 57 came to ultimately reside at Velia. Beyond this supposition, however, further
627 rationale for the eventual residency of this individual at the site of Velia cannot be clearly
628 elucidated from the evidence currently available. The case of Velia 214 appears to suggest a
629 much more local mobility event.

630 Based on textual and epigraphic data Noy (2000) estimates the percentage of free
631 migrants in 3rd CE Roman contexts at ~5%: 2% being soldiers and their families, and 3% being
632 civilian immigrants. Hin (2013) argues that Rome was overwhelmingly the main migration
633 destination for free migrants, with migration into the provinces believed to have been
634 comparatively minor. Though precise homelands cannot be determined for the two non-local
635 individuals identified at Velia, the approximated regional origins of Velia 57 and Velia 214
636 indicate that mobility to Velia was taking place from both relatively local (Velia 214) and
637 evidently more distant (Velia 57) environs. Further analysis of a larger sample of individuals and
638 faunal remains from Velia may help to refine the initial insights on mobility presented herein.

639

640 **4.5 Mobility in Southern Italian Contexts**

641
642 With Roman imperial expansion into southern Italy came the establishment of coastal ports and
643 the extension of roadways, such as the Via Appia, making mobility to these regions and
644 associated settlements increasingly possible (Garnsey and Saller 2014). The degree to which
645 mobility varied between inland and coastal sites remains an area in need of further investigation
646 (Lomas 1993, 2016; Greco 2003; Prowse et al. 2010). To date, the Imperial Roman sites of
647 Vagnari (Prowse 2010; Emery et al. 2018a,b) and that of Velia, presented herein, are the only
648 from southern Italian contexts to be investigated from an isotopic perspective.

649 Mobility to the inland site of Vagnari (1st to 4th c. CE), part of an Imperial Estate located
650 near Gravina in the Basentello valley of Puglia where tile and iron production as well as
651 development of interior lands took place, has been investigated using $\delta^{18}\text{O}$, $^{87}\text{Sr}/^{86}\text{Sr}$ and aDNA
652 (Small and Small 2005; Prowse et al. 2010; Prowse 2016; Emery 2018a,b). Initial assessments
653 of mobility using $\delta^{18}\text{O}$ identified >90% of the analyzed individuals as being from Vagnari, falling
654 within the expected local range of -8‰ to -6‰ (Prowse et al. 2010; Prowse 2016). Employing
655 $\delta^{18}\text{O}_{\text{dw}}$ in conjunction with a local bioavailable $^{87}\text{Sr}/^{86}\text{Sr}$ range of 0.70802-0.70901, as derived
656 from soil, snail shell and ungulate teeth, Emery et al. (2018a) were able to show, using bagplot

657 analysis, that 39/43 (90%) individuals were local: 25 individuals (58%) were identified as having
658 $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values that indicate their residency directly at Vagnari, while an additional
659 34% were identified as from proximate environs in southern Italy. A small proportion of
660 individuals (~7%) were indicated as having migrated to Vagnari from more distant areas. No
661 significant differences were noted between males and females. Bagplot analysis identified four
662 distinct outliers (Female: F130; Male: F67, F131, F231). The proposed origins of these outliers
663 were identified as potentially North Africa or southern Spain (F130), northern Italy, and western
664 Europe. The use of mtDNA evidence by Prowse et al. (2010) and Emery et al. (2018b) provides
665 supplementary confirmation of the generally local nature of individuals interred at Vagnari.
666 Among the mtDNA haplogroup profiles of the 30 individuals presented by Emery et al. (2018b)
667 28/30 (~93%) are consistent with a western Eurasian genetic background; the remaining 2/30
668 (~7%) individuals (F34 and F37) belong to haplogroup D4b1c, a grouping commonly found in
669 eastern Eurasian populations. Though such genetic evidence cannot provide insight to specific
670 mobility events, it nonetheless attests to haplogroup diversity at Vagnari, which has implications
671 for past mobility events into the region.

672 Taking the evidence from Vagnari and Velia into account, a similar picture of mobility is
673 evident at both sites. Both southern Italian sites exhibit similar rates of mobility at ~10% and a
674 similar distribution based on the samples analyzed. Such a finding suggests that Roman
675 Imperial era southern Italy saw a comparatively lesser degree of mobility than more urban and
676 cosmopolitan sites such as Casal Bertone, Castellaccio Europarco and Portus, where the rate
677 of non-local individuals identified approaches 33% (see Prowse et al. 2007; Killgrove 2010a, b;
678 Killgrove and Montgomery 2016). Among local and non-local individuals identified at Velia and
679 Vagnari a similar regional pattern also appears evident. At both sites the majority of individuals
680 sampled appear local from the site environs, while a smaller, though still significant number of
681 individuals, appear to have resided in environs directly proximate or within close proximity to the
682 sites in question: at Velia the inland border region between Campania, Basilicata and into
683 Calabria appears to have been a point of mobility; at Vagnari the region around the Basentello
684 valley appears to have been a primary locale of mobility. A small proportion of non-local
685 individuals at Vagnari and Velia appear to have been mobile from significantly distant regions,
686 likely including North Africa (Velia 57) and North Africa or southern Spain (F130), as well as
687 northern Italy and western Europe.

688 Such evidence indicates that while mobility in southern Italian Imperial Roman contexts
689 does appear to have been less frequent, that distant mobility events were still taking place. The
690 possible rationale behind such mobility events are so multifold—ranging from mobility for
691 employment, government or military service, to enslavement, among others—that they cannot
692 be readily delineated without further substantiating epigraphic and/or archaeological evidence
693 (Noy 2000; Scheidel 1997, 2001, 2004, 2005, 2007; Webster 2008, 2010; Woolf 2016). What is
694 evident based on the evidence from Vagnari and Velia, however, is that mobility within southern
695 Italian Imperial Roman contexts does not appear to have been significantly different for coastal
696 vs. inland access routes.

697 698 **4.6 Isotopic Assessments of Mobility for the Italian Peninsula**

699
700 The viability of using isotopes of oxygen and strontium for examining mobility within Roman
701 contexts have been confirmed on numerous occasions (e.g. Prowse et al. 2007, Killgrove 2010
702 a,b; Killgrove and Montgomery 2016; Emery et al. 2018a, b). The application of this approach,
703 however, is not without its challenges for identifying mobility within peninsular Italian contexts
704 (cf. Bruun 2010). Regions of homogeneous $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values within the environs of
705 the Italian peninsula present opportunities for the introduction of ambiguity in differentiating
706 between local and non-local mobility depending on the regions in question. In terms of $\delta^{18}\text{O}_{\text{dw}}$,

707 east to west mobility events can be comparatively easily differentiate, while large regions of
708 homogeneous $\delta^{18}\text{O}_{\text{dw}}$ values exist in a north-south direction (Longinelli and Selmo 2003;
709 Giustini et al. 2016). Conversely in the case of $^{87}\text{Sr}/^{86}\text{Sr}$, broadly speaking, north-south mobility
710 is much more readily discernible compared to east-west mobility (cf. Emery et al. 2018a). The
711 interplay of these two systems (i.e. $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$), when utilized in tandem, can mitigate
712 the challenges of regional homogeneity, as has been previously demonstrated in the work of
713 Killgrove and Montgomery (2016) and Emery et al. (2018a).

714 Though this brief synthesis of mobility events at Velia has shown a subset of individuals
715 to have been non-local, it must also be borne in mind that mobility from proximate regions as
716 well as mobility across regions with homogeneous isotopic values could also have been
717 potentially occurring at Velia, but are not readily evident from isotopic evidence due to regional
718 similarities in isotopic values. Further definition of expected local isotopic values and
719 bioavailable ranges within peninsular Italy will help to reduce the impact such areas of isotopic
720 homogeneity have on palaeomobility studies.

721

722 **5. Conclusions**

723

724 With increasing territorial expansion during the Imperial Roman era, ever greater opportunities
725 for mobility were possible: both self-directed and enforced (Noy 2000; Scheidel 1997, 2001,
726 2004, 2005, 2007; Webster 2008, 2010; Woolf 2016). Regardless of the mechanism or impetus
727 for mobility, the movement of people across the landscape is a defining feature of the Imperial
728 Roman era. The southern Italian port of Velia is no exception. Though the study presented
729 herein examines a relatively small subset of twenty individuals from the broader population of
730 Velia, the identification of two distinct non-local outliers interred at Velia makes clear that
731 individuals were mobile towards this site from both proximate and more distant regions. With
732 additional sampling and isotopic analyses and integration of further datasets from
733 archaeological and epigraphic materials it is hoped that an increasingly robust assessment of
734 mobility events to Velia can be derived in future analyses.

735

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737

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742

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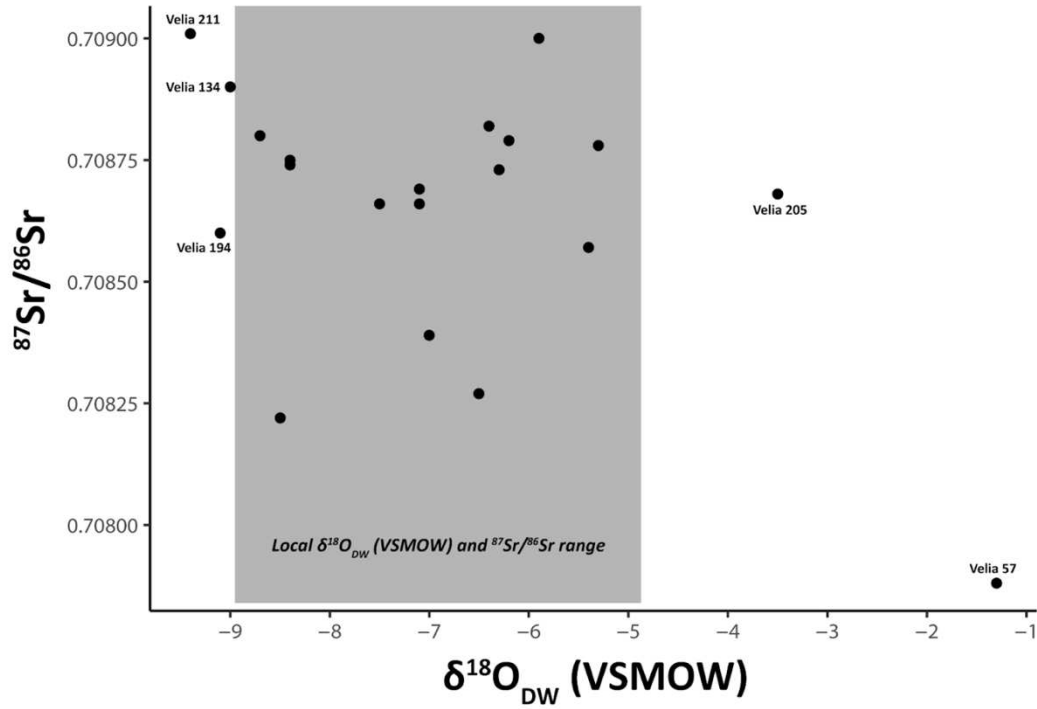
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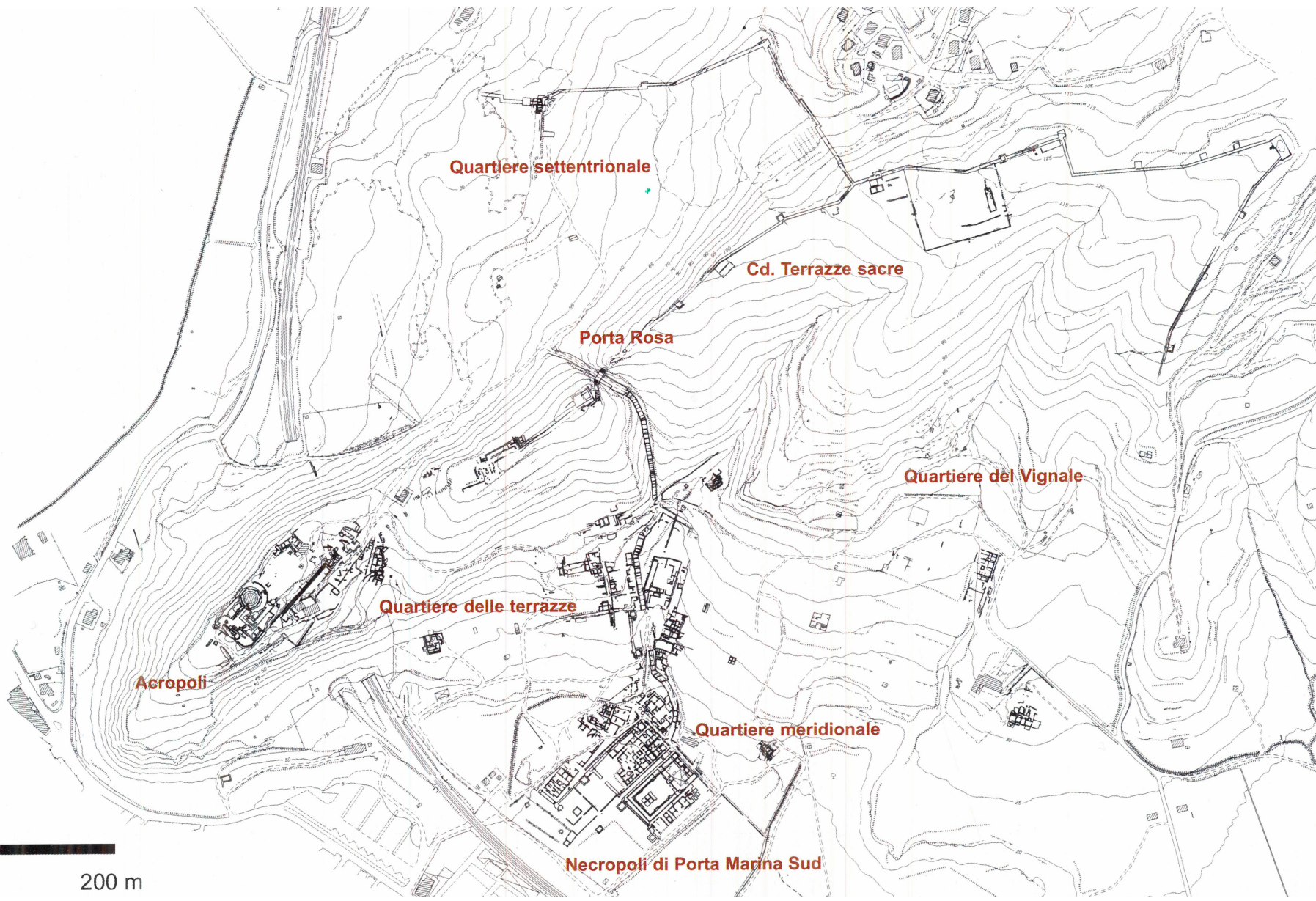
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Supplementary Fig. 1: Scatter plot showing the distribution of $\delta^{18}\text{O}_{\text{dw}}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values for the 20 individuals sampled from Velia against the expected local ranges (grey box). Individuals who fall outside of the local range have been labelled.





Quartiere settentrionale

Cd. Terrazze sacre

Porta Rosa

Quartiere del Vignale

Quartiere delle terrazze

Acropoli

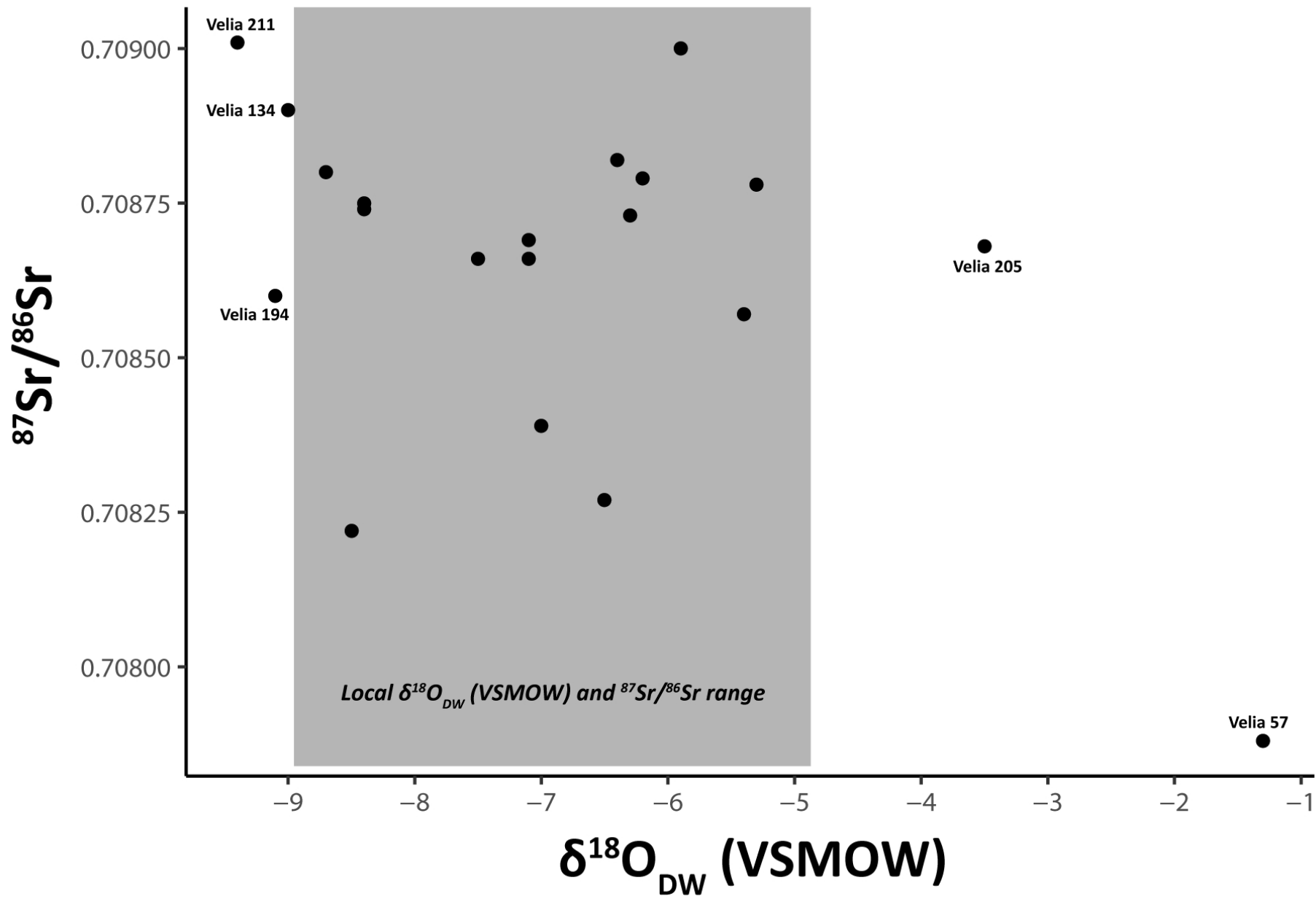
Quartiere meridionale

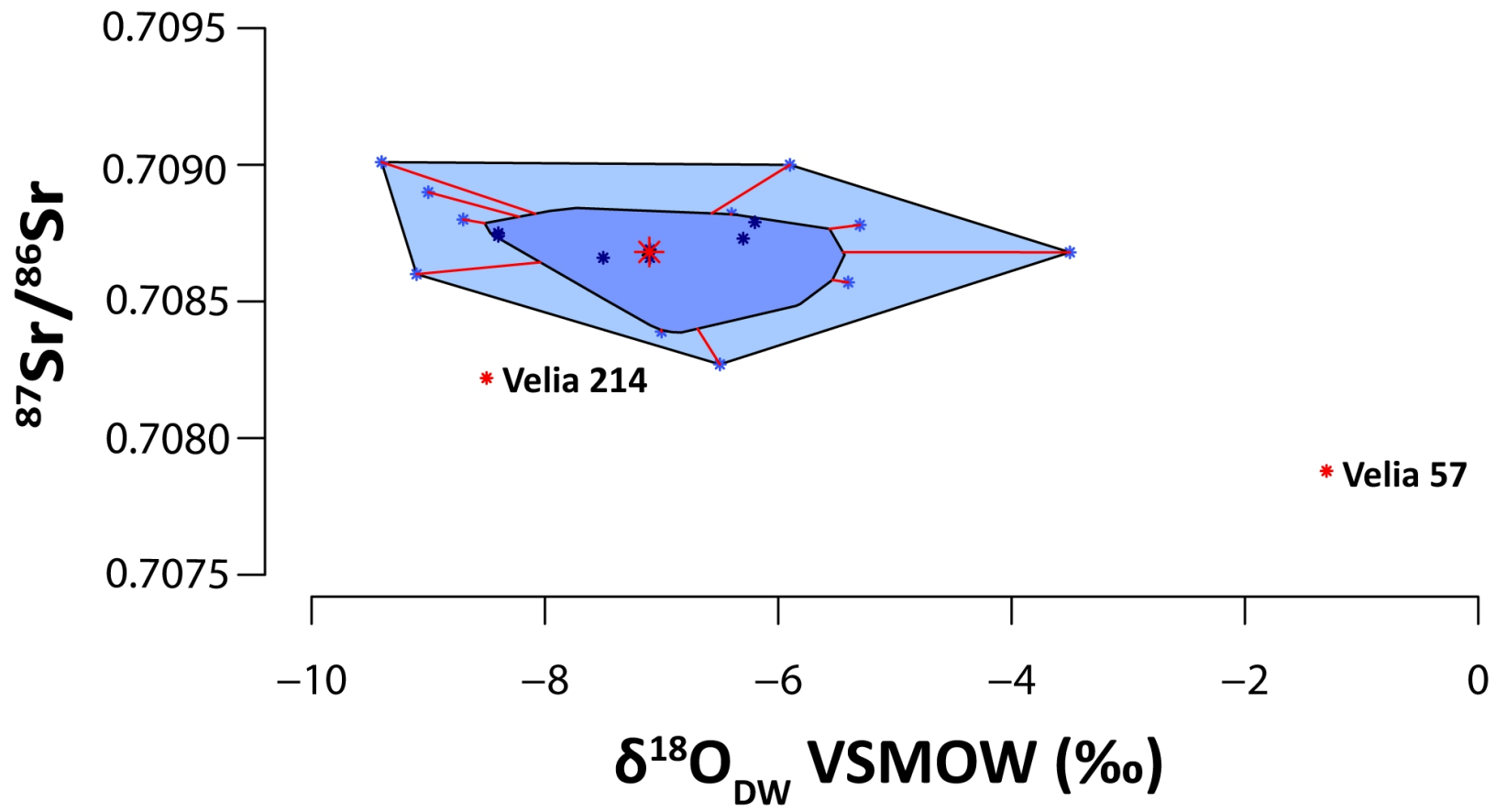
Necropoli di Porta Marina Sud



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200 m





Author Statement

Robert Stark: conceptualization; project administration; methodology; validation; formal analysis; investigation; visualization; writing – original draft and review & editing; funding acquisition

Matthew Emery: conceptualization; visualization; writing – review & editing; formal analysis

Henry Schwarcz: conceptualization; writing – review & editing

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