The Annual of the British School at Athens, **110**(1), 2015, pp. 3–25 © The Council, British School at Athens, 2015
doi:10.1017/S0068245415000064

EXPLORING MOBILITY PATTERNS AND BIOLOGICAL AFFINITIES IN THE SOUTHERN AEGEAN: FIRST INSIGHTS FROM EARLY BRONZE AGE EASTERN CRETE

by Sevi Triantaphyllou*, Efthymia Nikita† and Thomas Kador‡

*Department of History and Archaeology, Aristotle University of Thessaloniki
†Fitch Laboratory, British School at Athens
‡Department of Archaeology and Anthropology, University of Bristol

This paper presents the results of a pilot project which combines, for the first time, biodistance and strontium isotope analyses in the study of human skeletal remains from Early Bronze Age Crete (third millennium bc). Information from these analyses offers, in a direct way, insights into the biological distance, and consequently the gene flow and mobility patterns, among human populations in eastern Crete. The results are synthesised with the evidence of funerary practices in order to explore the nature of interaction among communities in eastern Crete. The biodistance analysis supports a strong genetic affinity between the populations represented at the two Kephala Petras skeletal assemblages, while the results of the available strontium isotope analysis favour their local origin; thus the combined results suggest the lack of significant population influx. The biological distance of the two chronologically contemporary populations at Livari-Skiadi, also manifesting completely different patterns of mortuary disposal, is of particular interest since it contrasts with the Petras situation and raises issues of intra-community distinctions, cultural and biological.

INTRODUCTION

The mobility of materials, ideas and technological knowledge has recently attracted the attention of historical and archaeological research. Contrary to the cultural–historical approach to archaeology, where 'cultural' entities are assumed to correspond to particular groups of people (Trigger 1989), recent studies of identity trace the movement of material and humans in order to offer interpretations of the scale and nature of such interactions (Zakrzewski 2011). Powerful tools, such as biodistance studies, combined with biomolecular and chemical analyses, can provide new insights into the behaviour of past populations (*e.g.* Gilbert *et al.* 2005; Brown and Brown 2011; Pinhasi and Stock 2011; Shapiro and Hofreiter 2012). Skeletal morphology is, in part, genetically determined and it is well established that analyses of metric and non-metric traits can be used to explore the biological/genetic relationship between populations (*e.g.* Betti *et al.* 2010; Irish 2006; Coppa *et al.* 2007; Nikita, Mattingly and Lahr 2012; Ricaut *et al.* 2010). Strontium isotopes detected from dental and skeletal tissues can provide valuable information regarding the movement of people during the course of a person's lifetime (*e.g.* Bentley 2006; Montgomery and Evans 2003; Bentley *et al.* 2012; Giblin *et al.* 2013). This paper presents the results of a pilot project where such methods were applied, for the first time, to human skeletal remains of the third and early second millennia BC from Crete; the aim is to distinguish the scale and the character of gene flow in the study area. It should be noted that the term 'gene flow' refers to the movement of people across the landscape and the resulting interbreeding between members of different groups (Stojanowski 2005; Relethford 2010; Weiss and Buchanan 2010). In this paper, gene flow is deduced by assessing the biological distance among the population samples under study, and mobility patterns are revealed through analysis of strontium isotopes within Crete.

EARLY BRONZE AGE CRETE: REGIONAL DIVERSITY AND *CYCLADICA*

It is widely recognised that, during the third millennium BC, Crete was characterised by distinct cultural diversity. This has cast serious doubts upon the traditional assumption 'that the island was inhabited by a single population with a more or less homogeneous culture' (see discussion and relevant bibliography in Legarra Herrero 2009, 29, 49). In contrast, significant variations in ceramic production (*e.g.* Wilson and Day 1994; Day, Wilson and Kiriatzi 1997; Whitelaw *et al.* 1997), stylistic traits, values of consumption, circulation of materials and finished artefacts (*e.g.* Carter 1998; Bevan 2004; Doonan, Day and Dimopoulou-Rethemiotaki 2007; Sbonias 2012), and the funerary record (especially tomb architecture, quantity and quality of the associated grave goods and the manipulation of the deceased within the island: *e.g.* Soles 1992; Vavouranakis 2007; Papadatos and Sofianou 2012; Legarra Herrero 2009; 2014; Papadatos and Sofianou in press) reinforce the idea that communities in Prepalatial Crete, located sometimes in close proximity, developed different socio-economic and ideological trajectories.

Special emphasis has been placed, to date, upon relationships with other parts of the southern Aegean and in particular with the Cyclades. During the early and mid third millennium BC, places in a large area of the southern Aegean, including Crete (*e.g.* Hagia Photia Siteias: Davaras and Betancourt 2004; 2012; Gournes Pediados: Galanaki 2006); Attica (*e.g.* Agios Kosmas: Mylonas 1959; Tsepi: Pantelidou-Gofa 2005), Euboea (*e.g.* Manika: Sampson 1988) and to a lesser degree the Anatolian coast (*e.g.* Iasos cemetery: Levi 1961–2; 1965–6; Pecorella 1984), exhibit close cultural affinity: this is demonstrated in terms both of material culture (*e.g.* portable artefacts and grave forms) and of ideas and technological knowledge (Renfrew 1972; Broodbank 2000; Papadatos 2005; Brodie *et al.* 2008; Wilson, Day and Dimopoulou-Rethemiotaki 2008; Cherry 2009; Papadatos and Tomkins 2013). The impact of the Early Bronze Age Cycladic tradition in this area is materially expressed through marble figurines with folded arms (Branigan 1971; Getz-Preziosi 1987; Papadatos 1999), metal objects (especially daggers with raised mid-rib made of Cycladic raw materials: Branigan 1974; Stos-Gale 1993; Doonan and Day 2007), a specific type of pottery known as the 'Kampos Group' style (Day, Wilson and Kiriatzi 1998; Wilson, Day and Dimopoulou 2004; Day *et al.* 2012; Davaras and Betancourt 2012; Nodarou 2012; Tsipopoulou 2012b), the so-called 'frying pans' with symbolic cosmological and marine representations (Betancourt 2012), long blades of Melian obsidian (Carter 1998) and other artefacts.

The manner in which Cycladic-related items (hereafter *Cycladica*), ideas and practices were transferred from the core islands of the Archipelago has provoked considerable debate. The main topics of interest include the mode of transmission of objects, people and ideas around the southern Aegean during the third millennium BC, and the character and quantity of *Cycladica*, particularly since these objects frequently accompany funerary assemblages. There are two opposing interpretations of this phenomenon: Cycladic colonists settled outside their core area and transferred pottery, technical equipment, ideas, practices and technological knowledge from their original home area to their new settlements (Sakellarakis 1977a; 1977b; Doumas 1979; Sapouna-Sakellaraki 1987); alternatively, individuals and local populations adopted Cycladic imports or artefacts of Cycladic character in order to shape and probably project different identities for themselves and their local communities (see recent discussion in Papadatos 2007). Current approaches support the idea that a combination of the two processes took place: locals adopted Cycladic objects and traditions while Cycladic groups moved to Crete, in the context of trading networks and intermarriage, particularly during the mid-third millennium BC (Broodbank 2000).

In order for the above issues to be addressed effectively, there is a need for research into cultural interchange between Prepalatial Crete and the Cyclades in the light of human mobility patterns and interbreeding practices. It is possible that analysis of the nature and scale of such patterns and practices may offer new perspectives on the role that the local populations played in cultural, material and technological interaction among the different regions of Prepalatial Crete.

THE CASE STUDY FUNERARY ASSEMBLAGES

The evidence of funerary assemblages demonstrates the integration of Crete with the wider southern Aegean. In contrast to the majority of studies to date, which have focused upon *items of material culture*, the current paper will focus on the *people* who lived in eastern Crete during the third and early second millennia BC. The wider region of eastern Crete was selected as a case study area on the basis of recently excavated and partly, or completely, studied mortuary assemblages with human skeletal remains. This material demonstrates: (a) temporal proximity, (b) cultural similarities that may suggest participation in common networks of interaction, and (c) cultural differences that may imply biological differences between the corresponding population groups.

Crete, particularly the north coast, exhibits a relatively large series of mortuary contexts manifesting Cycladic-related materials: among the most recently excavated assemblages (Fig. 1) are the rockshelter at Kephala Petras, near Siteia (Tsipopoulou 2010; 2012b; 2012c) and the tholos tomb and rockshelter at Livari-Skiadi in south-east Crete (Papadatos and Sofianou 2012; in press). The Kephala Petras cemetery lies on the flat plateau area of a high hill, less than 1 km east of the modern town of Siteia, overlooking Siteia bay. On the west slope of the cemetery there is a burial rockshelter which faces the Protopalatial palace and the surrounding Minoan town; its use extends from Early Minoan IB to Middle Minoan IB, *c.*2900–1875/1850 BC (Tsipopoulou 2010; 2012c; for absolute chronology see Manning 2010, table 2.2). Moreover, systematic excavation since 2004 has recovered 11 house tombs with multiple rooms, special open areas and platforms for ritual activities in memory of the deceased. The use of the house tombs extends from the mid-third millennium BC to the early second millennium BC, *c.*2400–1850 BC (Early Minoan IIB – Middle Minoan IIA) (Manning 1995, fig. 2; 2010, table 2.2), with peak use in the early Protopalatial period (Middle Minoan IB–IIA) (Tsipopoulou 2012a; 2012c).

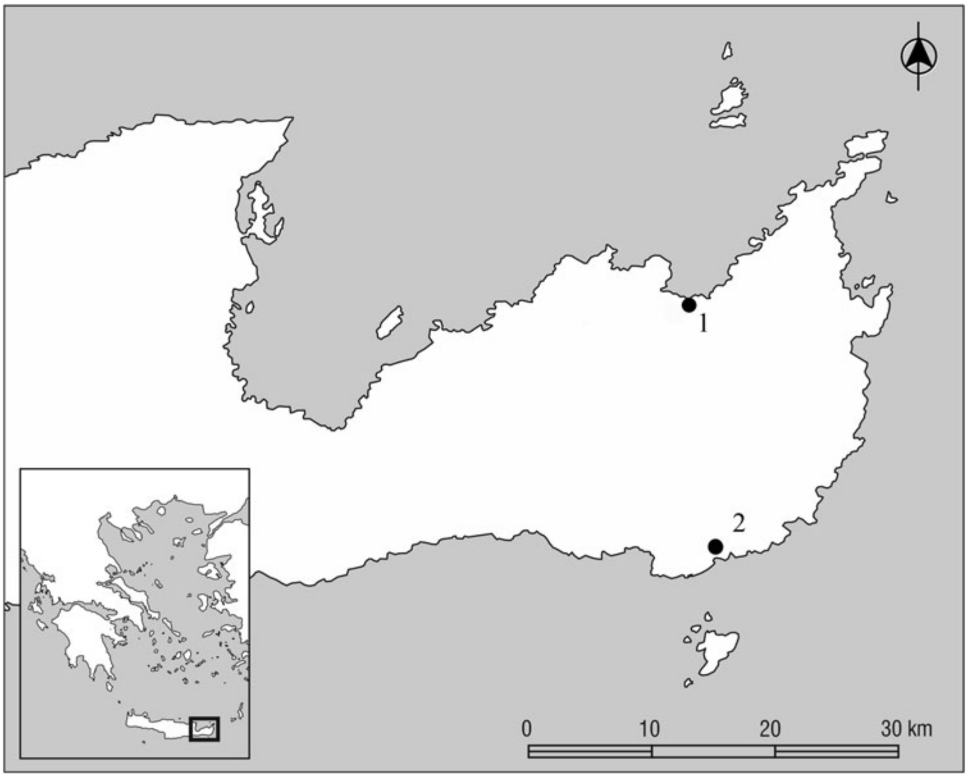

Fig. 1. Map indicating the location of the study areas (drawn by N. Valasiadis). *Key*: 1 = Kephala Petras, 2 = Livari-Skiadi.

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

The current analysis focuses on House Tomb 2, the only fully excavated mortuary complex of the cemetery, which spans the period from Early Minoan III to Middle Minoan IB/IIA, *c.*2200–1875/1850. There is, therefore, an overlapping period of approximately 350 years when the burial rockshelter and House Tomb 2 were in contemporary use. The Livari-Skiadi tholos tomb and rockshelter are situated on a small coastal plain opposite the islet of Kouphonisi, about 50 m from the seashore. The plain is cut by deep gorges which run from the inland Ziros plateau, while a rocky promontory protrudes into the sea, forming a small bay in front of the cemetery (Papadatos and Sofianou 2012; in press). The tholos tomb was in contemporary use with the rockshelter from Early Minoan IB to Early Minoan IIB (Papadatos and Sofianou in press), *c.*2900–2200 BC (Manning 1995, fig. 2; 2010, table 2.2), while the rockshelter seems to have been in continual use until Early Minoan III, *c.*2200–2100/2050 BC, that is, almost one or two centuries after the last use of the tholos tomb.

Funerary assemblages from both the Kephala Petras rockshelter and the Livari-Skiadi tholos tomb and rockshelter include various types of artefacts which follow well-known local and non-local traditions from other regions across the island: the pottery may be paralleled with material from the Mesara-Asterousia area (Papadatos and Sofianou in press), and there are obsidian blades (Carter in press) and metal objects which 'seem to be Cretan in origin' (Ferrence, Muhly and Betancourt. 2012, 140); significantly, however, they include also a number of *Cycladica*. The latter consist of various pottery artefacts which are classified as part of the so-called 'Kampos Group' (Nodarou 2012; in press, 85; Papadatos and Sofianou 2012, 51; Tsipopoulou 2012a; 2012b), mid-rib copper daggers (Papadatos and Sofianou in press) and four fragments of marble figurines with folded arms (Tsipopoulou 2012a; 2012b). It is interesting to note that the recent petrographic analysis of 45 samples belonging to the 'Kampos Group' pottery from the Kephala Petras rockshelter identified a highly calcite-tempered fabric (Nodarou 2012, 85), which is a common Cycladic manufacturing tradition found also at sites on the north coast of Crete which offer similarly strong evidence for off-island contacts with the Aegean; these sites include Hagia Photia, Gournes and Poros-Katsambas (Hagia Photia: Day, Wilson and Kiriatzi 1998; Day *et al.* 2000; Gournes: Galanaki 2006; Poros-Katsambas: Dimopoulou-Rethemiotaki, Wilson and Day 2007).

To sum up, in three (Kephala Petras rockshelter, Livari-Skiadi tholos tomb and rockshelter) out of the four (Kephala Petras rockshelter and House Tomb 2, Livari-Skiadi tholos tomb and rockshelter) mortuary assemblages investigated in this study, there is significant evidence for off-island relations with the Cyclades. These coincide with the critical time span of Early Minoan IB–IIA (*c.*2900–2450/2400 based on Manning 2010, table 2.2), that is, the peak time of interregional cultural contacts in the southern Aegean, described in the literature by Renfrew (1972) as the 'international spirit' phenomenon. Meanwhile, all case study sites seem to have been engaged in diverse cultural networks within Crete. Moreover, regarding temporal proximity, in the Kephala Petras and Livari rockshelters as well as in the Livari tholos tomb, there is an overlapping period of approximately 700 years of use which extends from Early Minoan IB to Early Minoan IIB, *c.*2900–2200 BC. In contrast, Kephala Petras House Tomb 2 is of a slightly later date, *c.*2200–1850 BC, partially overlapping with the later period of use of the Kephala Petras rockshelter, and has provided no evidence of *Cycladica*. It will be of interest therefore to explore the biological connections among these assemblages and to assess the degree to which the observed cultural similarities or diversities can be explained by means of population relocations and exogamy.

THE PEOPLE REPRESENTED: RESULTS OF THE MACROSCOPIC STUDY

The macroscopic analysis of the skeletal populations disposed of in the Kephala Petras rockshelter and House Tomb 2 (HT 2), as well as in the Livari-Skiadi tholos tomb and rockshelter (Table 1), has offered valuable evidence with regard to the manipulation of the deceased and the demographic composition of each assemblage. Disarticulated skeletal remains and major anatomical units are consistent with the deposition of secondary burials of either skeletonised or fresh bone in both

Table 1. Sample size of the populations under study.

Cemetery	No. of identified bone fragments	Minimum number of individuals (MNI)
Kephala Petras rockshelter	*c.*21000	165
Kephala Petras House Tomb 2	*c.*1000	37
Livari tholos tomb	*c.*6000	82
Livari rockshelter	*c.*12000	115

rockshelters, which appear to represent one-off episodes of systematic redeposition of burials placed initially in a different disposal area (*e.g.* Triantaphyllou 2009; 2012; in press; Triantaphyllou, Tsipopoulou and Betancourt in press). The manipulation of the deceased in the Kephala Petras House Tomb 2 differs slightly since, along with the secondary skeletal remains, there are a number of burials which appear to lie in their initial disposal area but manifest clear evidence of the removal of body parts shortly after death (for a synthetic discussion on secondary removal of body parts during the Pre- and Protopalatial periods, see Triantaphyllou in press; Triantaphyllou, Tsipopoulou and Betancourt in press). Finally, in the Livari-Skiadi tholos tomb bone alterations due to burning (*e.g.* severe cracking and warping) suggest a lengthy and systematic exposure of the body parts to high temperature as part of the secondary treatment of the deceased (Triantaphyllou in press).

Assessment of the population groups deposited inside the communal tombs has occupied archaeologists working on Early Bronze Age Crete since the earliest stage of research (*e.g.* Branigan 1987b; 1993, 84–95; Papadatos 1999, 59–63; Vasilakis and Branigan 2010, 262 and more recently Triantaphyllou in press). Analysis has been based upon (a) survey work and the association of the tombs with nearby settlements (Bintliff 1977; Blackman and Branigan 1977; Branigan 1993; Vasilakis and Branigan 2010; Whitelaw 2012), (b) the internal social organisation of the fully excavated Early Minoan settlement at Myrtos Fournou Korifi based on the spatial distribution of artefacts across the site and the functional interpretation of rooms, built facilities and finds (Whitelaw 1983 *vs* Warren 1972 and more recently Whitelaw 2007), (c) the number of the skulls recognised during excavation (particularly with regard to the house tombs: Soles 1992, 252), and (d) the study of artefacts and their distribution within the tombs (Whitelaw 1983, fig.71). Recent analysis of skeletal remains has shed some new light on issues concerning the group size and composition of the people deposited in Prepalatial and early Protopalatial funerary assemblages (Table 2). Table 2 demonstrates that the low estimates of skeletal remains deposited per 100 years do not approach the hundreds of individuals commonly assumed (*cf. e.g.* Branigan 1987b). In contrast, assuming that a household of about five to seven individuals contributes approximately 20 corpses per century – a figure based on ethnographic observations of agricultural communities but also on historical studies of census data from rural communities

Table 2. Estimation of skeletons deposited per 100 years from recently examined skeletal assemblages on Crete (*key*: HT = House Tomb, MNI = minimum number of individuals).

Skeletal assemblage	MNI	Length of use (yrs)	Skeletons/100 yrs
Kephala Petras HT 2	37	350	10.57
Kephala Petras rockshelter	165	1050	15.71
Livari tholos tomb	81	700	11.57
Livari rockshelter	115	850	13.52
Kamilari A tholos tomb	134	500	26.8
Moni Odigitria A tholos tomb	133	900	14.77
Moni Odigitria B tholos tomb	64	900	7.11
Apesokari A tholos tomb	14	200	7
Hagios Haralambos cave	*c.*400	1800	22.22

(for specific references see Chamberlain 2006, 52; for an application of population estimates in prehistoric Aegean contexts, see Bintliff 1977, 83) – Table 2 suggests that the nuclear family was perhaps the basic population unit in Early Bronze Age communities on Crete, as has been convincingly demonstrated by Whitelaw (1983; 2007). Analysis of household models from small rural communities in Early Bronze Age Crete would sustain the idea of independent households represented by nuclear families which appear to have been bound together with close ties (Whitelaw 2007, 73). In a recent study Whitelaw considered new data derived from archaeological surveys in the Mirabello area; combining this with his early work at Myrtos Fournou Korifi, he proposed a notional model of Early Minoan II site distributions and local demographic networks (Whitelaw 2015, fig. 4). The results of this study suggested that small hamlets located particularly in a very dry landscape of thin soils would 'have to have maintained a wide network of connections with comparable communities to be demographically viable' (Whitelaw 2015, 2).

Both sexes and all age groups were equally represented in the skeletal assemblages (Table 3). The Livari-Skiadi tholos tomb, however, deviates from this pattern; the demographic composition of this skeletal assemblage suggests a significant under-representation of the sub-adult age categories since only six sub-adult, as against seventy-five adult individuals, were identified (Triantaphyllou in press; forthcoming). It is evident, therefore, that the manipulation of the deceased in the third and early second millennia BC in eastern Crete is dominated by the communal character of deposition, but with significant deviations with regard to the disposal area, the treatment of the deceased and perhaps segregation according to age groups. It is equally important to point out here that, given population estimates from recently studied skeletal assemblages (Table 2) and systematic work conducted by Whitelaw (2007; 2015), further investigation of kinship connections and of the scale of exogamous networks between the small and fragmented Prepalatial communities of eastern Crete will be of great value to the recognition of social and developing political entities in the third millennium BC.

MATERIALS AND METHODS

In order to explore the character of gene flow in the study area and mobility patterns within Crete and the southern Aegean, this pilot project combined strontium isotope analysis of limited scale and biological distance calculation by means of dental non-metric traits. It is essential to clarify that these two methods provide evidence for different and independent phenomena. Dental non-metric traits can offer information on the biological affinity of the study populations, while strontium isotope analysis has the potential to distinguish whether individuals have moved between different geographic regions in terms of their geological and environmental settings; these methods can therefore complement each other in the context of the current research project. It should also be noted that analysis of ancient DNA was applied on a limited number of teeth from the Kephala Petras and the Livari-Skiadi rockshelters by the Palaeogenetics Group at the Institute of Anthropology at Mainz, Germany, but the samples were too collagen-depleted to extract sufficient usable DNA.

Table 3. Distribution of age groups in the case study skeletal assemblages (*key*: HT = House Tomb).

Skeletal assemblage	<0	0–1	1–6	6–12	12–18	+18
Kephala Petras HT 2	1	2	3	3	1	27
Kephala Petras rockshelter		6	12	11	7	129
Livari tholos tomb			2	2	2	75
Livari rockshelter	4	5	9	14	9	74

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

Owing to the limited budget for analytical work, only 18 teeth (Table 4) were selected from the Kephala Petras rockshelter, the Kephala Petras House Tomb 2 and the Livari-Skiadi rockshelter for strontium isotope analysis, while 31 dental non-metric traits were recorded for 475 teeth from the Kephala Petras rockshelter, 73 teeth from the Kephala Petras House Tomb 2, 127 teeth from the Livari-Skiadi tholos tomb, and 355 teeth from the Livari-Skiadi rockshelter, using the Arizona State University Dental Anthropology System (ASUDAS: Turner, Nichol and Scott 1991) (Table 5). The Livari-Skiadi tholos tomb was not sampled for strontium isotope analysis since all skeletal elements were severely affected by firing conditions due to their lengthy exposure to high temperatures.

Before proceeding to the presentation of the results, it is important to clarify the limitations of the sampling carried out for the strontium isotope analysis: the small sample of data produced means that our conclusions are tentative. Moreover, the commingled nature of the skeletal assemblages makes it impossible to know for certain whether or not first-generation immigrants were among those sampled from sites which demonstrated direct or indirect relations with the Cyclades (that is, the Kephala Petras and Livari rockshelters and the Livari tholos tomb). This problem is accentuated particularly due to the broad temporal span of use of the mortuary assemblages, which ranges from 400 to 1000 years. Moreover, given the very limited budget of the current project, it was impossible to perform large-scale sampling and/or direct dating of all samples analysed for strontium isotopes. Assuming that immigration was not a one-off event but rather a continuing process of new individuals drifting from the Cyclades and regularly establishing themselves in Crete through exogamy or other processes, the sampling approach adopted for the strontium isotope analysis, which incorporated bone and tooth samples from different layers of the skeletal depositions, aimed to capture such relocation events. However, a large-scale sampling programme would be more appropriate in future work.

Given the fact that evolutionary change in humans is very slow and happens across many generations (Fuentes 2011, 96), temporal distance within and between assemblages is not large enough to have had a substantial impact upon the expression of non-metric traits and the calculated biological/genetic relationships based on them. Among the primary factors that generate changes in the frequency of specific alleles and subsequent changes in the morphological characters under study – in our case the dental non-metric traits – is gene flow (Fuentes 2011, 97). Biological diversity within populations increases with gene flow because of the introduction of new alleles from an external source. The strength of this diversity depends on the migration rate and amount of gene flow over time, but also on the population size of the living community (Stojanowski 2005, 78). Therefore, in the small Early Bronze Age populations of Crete, even minimal gene flow should result in substantial biological diversity within and between populations, even though the rate and time span of biological isolation or interbreeding of the study communities is also important.

STRONTIUM ISOTOPE ANALYSIS: GEOLOGICAL SETTING AND METHODS

Isotope work in the Aegean, with a particular focus on human mobility, was introduced recently by Nafplioti (Nafplioti 2007; 2008; 2009a; 2009b; 2010; 2011) and Vika (Vika 2009) and was combined in one case with the study of cranial non-metric traits (Nafplioti 2007). Moreover, Nafplioti has created a preliminary map of the $^{87}Sr/^{86}Sr$ values in different geological and geographic settings in the Aegean as measured not only from archaeological human and animal dental enamel and bone material, but also from modern snail shells (Nafplioti 2011); however, the sample sizes upon which this map was created were very limited, so further work is required in this direction.

Geologically a major part of the island of Crete belongs to the Gavrovo isopic zone, while certain areas in the central and central-western part of the island fall within the Ionian zone (Higgins and Higgins 1996, fig. 2.2). The Gavrovo zone, which includes a narrow strip of Albania and central Greece, widens out in the Peloponnese. This isopic zone was a continental fragment for the

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

Table 4. Strontium isotope ratio ($^{87}Sr/^{86}Sr$) values for the case study populations (*key*: C = canine, HT = House Tomb, L = left, mand = mandibular, max = maxillary, M1 = first molar, M2 = second molar, R = right).

Site	Sample	Burial area	Tooth	Sample	$^{87}Sr/^{86}Sr$	±2 S.E.	Sex	Age
Kephala Petras	1	HT 2	maxLC	Enamel	0.709173	0.000003	Male	Adult
	1			Dentine	0.709061	0.000003		
	2	HT 2	maxRM2	Enamel	0.709073	0.000004	Male	Adult
	2			Dentine	0.709042	0.000003		
	3	HT 2	maxRC	Enamel	0.709056	0.000003	Male	Adult
	4	HT 2	maxRM2	Enamel	0.708994	0.000004	Female	Adult
	4			Dentine	0.709060	0.000003		
	5	HT 2	mandLM1	Enamel	0.709087	0.000003	Female	Adult
	6	HT 2	maxLC	Enamel	0.709038	0.000003	Male	Adult
Kephala Petras	7	Rockshelter	mandLM1	Enamel	0.709044	0.000003	Male	Adult
	7			Dentine	0.709027	0.000003		
	8	Rockshelter	mandLM1	Enamel	0.709069	0.000003	Male	Adult
	9	Rockshelter	maxLC	Enamel	0.709014	0.000003	Male	Adult
	10	Rockshelter	mandLM1	Enamel	0.709062	0.000003	?	Adult
	11	Rockshelter	maxRM2	Enamel	0.709056	0.000003	Female	Adult
	12	Rockshelter	maxRM2	Enamel	0.709048	0.000003	Female	Adult
	12			Dentine	0.709037	0.000003		
	12			Jaw bone	0.709066	0.000003		
Livari-Skiadi	13	Rockshelter	mandLM1	Enamel	0.708579	0.000003	Male	Adult
	13			Dentine	0.708779	0.000003		
	14	Rockshelter	mandLM1	Enamel	0.708643	0.000003	Male	Adult
	15	Rockshelter	mandRM1	Enamel	0.708596	0.000003	?	Child
	16	Rockshelter	mandLM1	Enamel	0.708653	0.000003	?	Child
	17	Rockshelter	mandLM1	Enamel	0.708835	0.000003	Female	Adult
	17			Dentine	0.708878	0.000003		
	18	Rockshelter	mandLM1	Enamel	0.708599	0.000003	?	Adult

Table 5. Non-metric dental traits under study (*key*: C = canine, I = incisor, M = molar, P = premolar).

All traits	Traits after editing
Maxilla	**Maxilla**
Labial curvature (I1)	Bushman canine (C)
Shovelling (I1)	Root number (P1)
Double shovelling (I1)	Enamel extension (M1)
Interruption groove (I2)	
Tuberculum dentale (I2)	**Mandible**
Peg/reduced (I2)	Protostylid (M1)
Bushman canine (C)	Cusp 7 (M1)
Distal accessory ridge (C)	Root number (M1)
Root number (P1)	
Cusp 5 (M1)	
Carabelli's trait (M1)	
Enamel extension (M1)	
Hypocone (M2)	
Root number (M2)	
Peg-shaped (M3)	
Parastyle (M3)	
Mandible	
Root number (C)	
Tome's root (P1)	
Lingual cusp (P2)	
Protostylid (M1)	
Cusp 6 (M1)	
Cusp 7 (M1)	
Anterior fovea (M1)	
Cusp number (M1)	
Root number (M1)	
Deflecting wrinkle (M1)	
Distal trigonid crest (M1)	
Hypoconulid (M2)	
Groove pattern (M2)	
Root number (M2)	
Maxilla and mandible	
Odontome (P)	

early part of its history (Higgins and Higgins 1996, 19). The two study areas, Petras and Livari, are situated on the north and south coast, respectively, of the eastern part of Crete which belongs to the Gavrovo zone (Higgins and Higgins 1996, fig. 2.2). However, these two areas are located in different geological formations. Petras is situated on a combination of Miocene marine sediments and exposures of older (Permian–Triassic) phyllites (Papastamatiou *et al.* 1959b). Livari-Skiadi is at the junction of two geological units which consist, to the north-north-east, of Jurassic to Eocene thick-bedded to massive grey limestones and dolomites (Gavrovo-Tripolitza series) and the sandstone conglomerate of the Tripolis flysch, whereas the area to the south-south-west consists of Miocene continental sediments (Papastamatiou *et al.* 1959a; Creutzburg, Drooger and Meulenkamp 1977).

Owing both to the disarticulated state of the remains from the two rockshelters and to budgetary limitation, sampling for strontium isotope analysis could not include postcranial bone and teeth from the same individuals; this would have allowed more accurate assessment of diagenetic contamination and of the local range of isotopic values. The sampling strategy for strontium isotope analysis is based on the assumption that migrant individuals who moved between different geologic regions will demonstrate different $^{87}Sr/^{86}Sr$ signatures between the teeth and bones; this is a reasonable assumption given that adult tooth enamel will capture the $^{87}Sr/^{86}Sr$

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

values of their youth, whereas bones, which remodel throughout life, will represent the $^{87}Sr/^{86}Sr$ values of the environment where the person spent his or her last years (Sealy, Armstrong and Schrire 1995; Bentley 2006; see, however, the comments on diagenetic alteration below). In addition to the 18 tooth enamel samples extracted from the study skeletal assemblages, seven samples of dentine and one of maxillary bone were also analysed (Table 4). Analysis on the same individual was avoided by selecting teeth of the same type and side. Analysis of the strontium isotope ratios was conducted at the Bristol Isotope Group (BIG) Laboratory, School of Earth Sciences, University of Bristol.[1] The strontium isotope ratio ($^{87}Sr/^{86}Sr$) in human tooth enamel, after the development of permanent dentition, reflects dietary strontium derived from soils and ground water via the food chain and undergoes relatively little change after it has mineralised in childhood and early adolescence (Hillson 1996; Bentley 2006, 169–74; Haak *et al.* 2008, 18229). Moreover, it is considered highly resistant to post-mortem diagenesis (Hillson 1996; Budd *et al.* 2000, 688). In contrast, the strontium ratios in other skeletal tissues, such as bone and dentine, are known to be subject to diagenetic change after burial. Consequently, it is likely that the $^{87}Sr/^{86}Sr$ ratio in these tissues will be heavily but variably modified by post-depositional strontium uptake and therefore give a closer indication of the local burial environment rather than the place of origin of the individual (Budd *et al.* 2000, 688; Haak *et al.* 2008, 18229). However, this is only an indication, depending on the extent to which the strontium originally in these tissues has been equilibriated with the local environment. Therefore, the measurements of strontium in dentine and bone cannot be taken as direct evidence for the values of the burial environment and may be different from the bioavailable strontium in the wider area (Budd *et al.* 2000). Nonetheless, in the absence of other biological samples (see below) it was felt that the measurement of some dentine and jaw bone samples would at least provide an indication/approximation of the $^{87}Sr/^{86}Sr$ ratio of the burial environment. However, ideally, analysis of human bone and teeth should be applied in parallel to analysis of biosphere samples (waters, soils, modern plants), animal teeth, bones and archaeobotanical material in order to map more accurately the local range of isotopic values in a particular area (Bentley 2006, 136; Evans *et al.* 2010; Frei and Price 2012).

DENTAL NON-METRIC TRAITS

The biological affinity among the study population samples was assessed by means of dental non-metric traits. Non-metric traits are minor variants of skeletal and dental anatomy which are not metrically measurable and are not a sign of disease (Tyrrell 2000). Many twin and family studies (*e.g.* Scott 1973; Berry 1978; Nichol 1990; Townsend *et al.* 1992; Scott and Turner 1997; Schnutenhaus and Rösing 1998) suggest that non-metric dental variants are inherited polygenically, while the natural environment in which growth takes place also affects trait expression. It should, however, be noted that while environmental factors influence trait expression to some extent, they have not been shown to significantly affect population trait frequencies (Scott and Turner 1997). Accordingly, non-metric traits have been used extensively in reconstructing patterns of intra- and inter-population affiliations spanning wide geographical

[1] Samples of dental enamel and dentine were taken and manually cleaned with a mechanical drill, using a flexible diamond-impregnated disk and a dental burr, respectively. The samples were then further cleaned in an ultrasonic bath before being dissolved in nitric acid (7 N HNO_3). The solution was centrifuged to remove any detritus before being dried down and redissolved in 3 N HNO_3. An aliquot of the solution representing 3 mg of enamel was then removed and loaded onto ion exchange columns. Strontium was separated from the dissolved samples by ion exchange chromatography using Eichrom Sr-Spec resin (Horwitz, Dietz and Chiarizia 1992). The samples were collected in teflon beakers and dried down before being dissolved in 1 μl of 10% HNO_3 and loaded onto rhenium filaments preconditioned with $TaCl_5$ and H_3PO_4. The isotope ratios were measured on a Triton thermal ionisation mass spectrometer (TIMS). Ratios are corrected to a $^{87}Sr/^{86}Sr$ value of 0.710248 for carbonate standard SRM 987 (Slovak and Paytan 2011, 754). Internal precision for $^{87}Sr/^{86}Sr$ isotope ratios is typically ±0.00001.

areas and long periods of time (*e.g.* Corruccini and Shimada 2002; Tomczak and Powell 2003; Irish 2006; Coppa *et al.* 2007; Hanihara 2010; Nikita, Mattingly and Lahr 2012).

Each non-metric trait was scored on one tooth within a class (Nichol 1990). The general practice is to score both the right and left side and use the highest degree of expression of a variant for population comparisons (Turner, Nichol and Scott 1991). Given that the sample under study consisted of loose and commingled teeth, in order to avoid biases we recorded non-metric traits on the maxillary and mandibular teeth that belonged only to the right side, even though this may not have been the side with the greatest degree of trait expression.

The fact that most of the material was preserved as loose teeth, disassociated from any cranial or postcranial elements, should not have any impact on the obtained results given that the mean measure of divergence (MMD), the distance measure employed in the present study (see below for details), is calculated on the overall frequency of each trait in the sample. In respect to levels of sexual dimorphism in trait expression and the potential bias of pooling sexes in the current analyses, sex differences in dental non-metric traits have been found to be low, and pooling data on males and females constitutes standard procedure (Turner, Nichol and Scott 1991; Scott and Turner 1997).

The ordinal scores for each trait were transformed into dichotomised presence/absence values based on each trait's morphological threshold as determined by Turner (1987) and Irish (2006). Traits that exhibited very low frequency (at least one sample of <2 cases) were removed from the dataset, as were traits that did not exhibit at least one statistically significant difference between sample pairs (Harris and Sjøvold 2004). Moreover, significantly intercorrelated traits were also dropped from the dataset (Sjøvold 1977). The non-discriminatory and intercorrelated traits were identified by means of Chi-square and Fisher's exact tests. Table 5 shows the original dataset and the traits that remained after editing.

Smith's MMD was calculated using the remaining traits and the Freeman–Tukey angular transformation was employed in order to correct for small sample sizes (Freeman and Tukey 1950; Sjøvold 1973; 1977). Although the MMD has occasionally been criticised, it has been found to perform very well and to offer results that are in accordance with the generalised Mahalanobis D^2 distance for non-metric traits (Irish 2010). The p-values for each MMD were estimated using a method that is based on the fact that the MMD values follow the normal distribution (Sjøvold 1973; Green, Suchey and Gokhale 1979).

RESULTS

Strontium isotope analysis

The results of the strontium isotope analysis applied to tooth enamel and selectively to one bone and seven dentine samples are given in Table 4 and Fig. 2. Utilising the dentine and bone samples as a very rough indicator of the isotopic range within the local burial environment, the range for the two Petras sites could be defined as between 0.7089 and 0.7091 and all the samples from these sites fall within this range, though the particularly small sample sizes make this observation tentative. The expected local range for Livari-Skiadi is, however, more difficult to define as there is no easy correlation between the majority of the enamel and the dentine samples (see below).

The mean $^{87}Sr/^{86}Sr$ ratios from tooth enamel are 0.70907 for the Kephala Petras House Tomb 2, 0.70905 for the Kephala Petras rockshelter and 0.70865 for the Livari-Skiadi rockshelter. Intra-group variation is highest in the Livari-Skiadi rockshelter (SD = 0.00009), followed by the Kephala Petras House Tomb 2 values (SD = 0.00006), while the Kephala Petras rockshelter (SD = 0.00002) shows the lowest intra-group variation, suggesting a tightly clustered population. Equally, the ratios from enamel, compared with those measured on dentine and jaw bone, correlate well with those from the Kephala Petras House Tomb 2 and the rockshelter, both individually and across the two populations (Fig. 2). The correlation between dentine and enamel values is especially strong

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

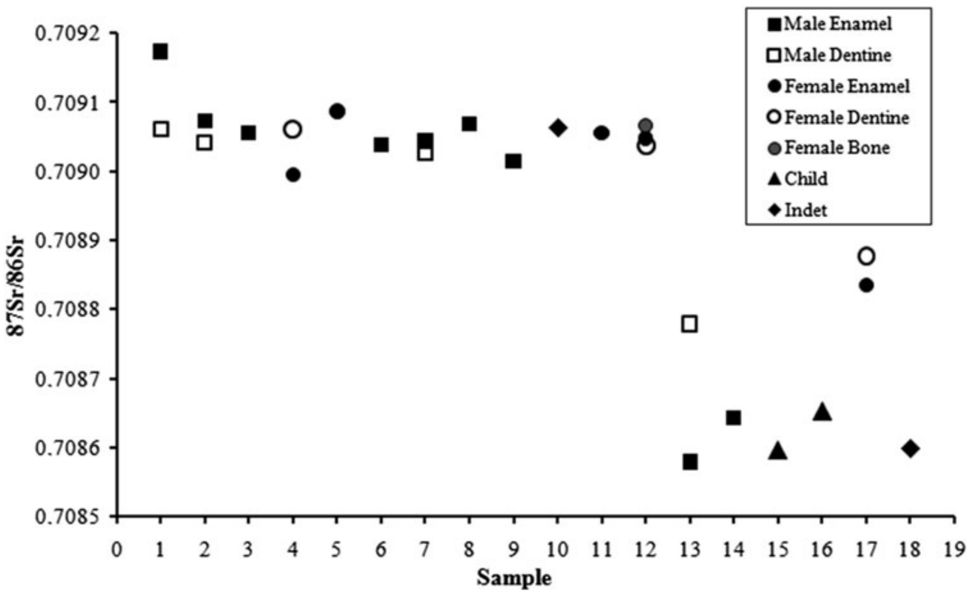

Fig. 2. Scatterplot of enamel and dentine isotope values per population, age and sex. Samples 1–6: Petras House Tomb 2, 7–12: Petras rockshelter, 13–18: Livari rockshelter.

at the rockshelter, where the average ratios for dentine (0.70904) and enamel (0.709048) are almost identical. It should be noted that the ratio of sample 1 at the Kephala Petras House Tomb 2 (0.70917) is slightly higher than all the others from the site but still within the expected local range. The broader range in strontium ratios from Livari-Skiadi compared with those from Kephala Petras is largely due to one sample (sample 17 = 0.70884), representing the only female sampled at the Livari rockshelter. When this sample is excluded, the results cluster quite tightly around the average of 0.70861. Sample 13 highlights the divergence in strontium ratios between enamel and dentine, while there appears to be good agreement between the enamel from this sample and the enamel values from all other individuals at the Livari rockshelter, except sample 17.

Interestingly, with the exception of the female (sample 17), all the dentine strontium ratios from the Livari rockshelter samples are more radiogenic than those on enamel. Perhaps the most likely explanation is that the dentine has become enriched in more radiogenic strontium through post-depositional diagenetic changes from sea spray, as the Livari rockshelter is located only a very short distance from the shore; the $^{87}Sr/^{86}Sr$ ratio for sea water ≈ 0.7092 (Elderfield 1986). The difference in strontium ratios on the enamel of sample 17 compared with the other Livari samples could reflect a difference in diet, from a very early age onwards. For example the $^{87}Sr/^{86}Sr$ ratio in the female could have been elevated through a diet higher in marine resources or sourced from a slightly more radiogenic area of the island than that of the other five individuals. Alternatively, as Livari-Skiadi is located at the junction of two geological units (see above) it is also possible that the differences in ratios between these samples stem from the different underlying geological units. Consequently, all the individuals buried at the Livari-Skiadi rockshelter could be interpreted as local to south-eastern Crete but their Sr isotope ratios reflect two distinct geological areas. This could only be tested conclusively through more extensive sampling of biological material from throughout the island in order to arrive at a better understanding of the relationship between the bioavailable strontium ratios and the local geology.

The difference in the $^{87}Sr/^{86}Sr$ ratios from tooth enamel between the three assemblages was tested statistically. Given that the values for the sample from Livari-Skiadi deviated from normality ($p = 0.024 < 0.05$), both ANOVA as well as Kruskal-Wallis tests were employed. Both the parametric and the non-parametric statistical tests gave the same results. Specifically, there is an overall statistically significant difference among the three samples ($p = 0.000 < 0.001$ and $p = 0.003 < 0.01$ for the ANOVA and Kruskal-Wallis tests, respectively). When the pairwise comparisons were examined by means of post hoc tests and pairwise Mann-Whitney tests (in which the obtained p-values were corrected for multiple comparisons using the Holm-Bonferroni method), the difference between the two Kephala Petras assemblages did not appear to be significant ($p = 0.841$ and $p = 0.485 > 0.05$, respectively), whereas the Livari-Skiadi rockshelter was significantly differentiated from both Kephala Petras assemblages (Kephala Petras House Tomb 2 – Livari-Skiadi rockshelter: $p = 0.000$ and $p = 0.006 < 0.05$, Kephala Petras rockshelter – Livari-Skiadi rockshelter: $p = 0.000$ and $p = 0.006 < 0.05$).

The lack of other data on the local biologically available $^{87}Sr/^{86}Sr$ in eastern Crete limits considerably the interpretation of our results, particularly in terms of assessing geographical sources for the identified strontium ratios. Some comparative analysis is made possible on the basis of Nafplioti's (2011) preliminary strontium isotope determinations in other parts of Crete, though the following comparisons are based on very small sample sizes and so should be treated as tentative, given that no statistical analysis can be performed on them. The strontium ratios from both the Kephala Petras skeletal assemblages (House Tomb 2 average = 0.70907, rockshelter average = 0.70905) correspond reasonably well to the average signatures from central Crete (Knossos and Ano Asites: 0.7089) and even better to those from Kastelos (0.709054) and Chania (0.709075) in the west as well as Margarites (0.709080) in the north-central part of the island. More broadly the ratios are also comparable to those from south-eastern Attica (0.7089) and the western Cyclades (0.7090) in the Attic–Cycladic metamorphic belt (Nafplioti 2011, 1567). In contrast to this, the ratios from the Livari-Skiadi rockshelter (average = 0.70865) are below the average for any of the other sampled sites on Crete. The ratio from sample 17 at Livari-Skiadi would broadly fit alongside the average strontium ratio from Myrtos Pyrgos (0.7088), located *c.*60 km to the west of Livari along the south coast (Nafplioti 2011, 1565). However, the other ratios from Livari-Skiadi match more closely to those measured outside Crete, such as those from the Parnassos and Pindos zones of mainland Greece (*e.g.* Corinthia average: 0.70866; Nafplioti 2011, 1567). Importantly, they appear to be distinct from the strontium ratios from the Central (average = 0.70948) and Western (average = 0.70901) Cyclades (Nafplioti 2011, 1568).

In summary, considering these results (which admittedly are based on a limited dataset), the most probable interpretation is that the sampled individuals from both sites at Petras are indeed local to Crete. While on the balance of probability the Livari-Skiadi samples may be local too, this cannot be stated with the same degree of certainty. Five of the six enamel samples from this site have strontium ratios of 0.7086 and below, making them some of the lowest $^{87}Sr/^{86}Sr$ values measured from Crete to date (Nafplioti 2008, 2313). This highlights the need for generating additional strontium isotope data, in particular from eastern Crete. In the absence of more samples indicating bioavailable strontium ratios from this part of Crete we can only say that the contrast between sample 17 and the other five samples, and the difference between enamel and dentine ratios, are extremely interesting and warrant further investigation.

Dental non-metric traits

Table 5 shows the traits that remained in the dataset after the editing process. We observe that the final dataset on which population biodistances were calculated included six variables. Table 6 presents the MMD values for all pairwise inter-population comparisons using the edited dataset. It can be seen that a statistically significant biological distance is traced between the assemblages from the Kephala Petras rockshelter and the Livari-Skiadi rockshelter, as well as between the Kephala Petras rockshelter and the Livari-Skiadi tholos tomb. Moreover, it is interesting that the distance between the Kephala Petras House Tomb 2 and the Kephala Petras rockshelter is minimal (note that negative MMD values are interpreted as 0 divergence among samples). Given that the material from the House Tomb 2 temporally coincides with the later phases of use of the rockshelter, this result implies either that both Petras groups are local, despite the evidence of *Cycladica* at the rockshelter, or that any Cycladic immigrants were few and interbred so extensively with the locals that their genome – or at least the part of it responsible for the

Table 6. Mean measure of divergence values for inter-population comparisons (*key*: HT = House Tomb, MMD = mean measure of divergence).

Pair of populations	MMD values using Turner (1987) thresholds	MMD values using Irish (2006) thresholds
Petras rockshelter – Petras HT 2	−0.103	0.009
Petras rockshelter – Livari tholos tomb	**0.245****	**0.340****
Petras rockshelter – Livari rockshelter	**0.355****	**0.319****
Petras HT 2 – Livari tholos tomb	−0.128	0.281*
Petras HT 2 – Livari rockshelter	0.079	0.055
Livari tholos tomb – Livari rockshelter	0.121	0.283**

*MMD values are statistically significant at $p < 0.05$.
**MMD values are statistically significant at $p < 0.001$.

expression of non-metric traits – was homogenised. The latter scenario is also made feasible by the fact that the 'Kampos Group' pottery would suggest that the most likely time for any actual immigration was early (in the Early Minoan IB), which allows plenty of time for assimilation between the potential immigrants and the local populations.

The biological distance between the Livari-Skiadi tholos tomb and the Kephala Petras House Tomb 2 also appears to be particularly small; however, when we change the thresholds slightly and follow the ones used by Irish (2006), whereas most MMD values and their significance only alter slightly, the values for the Livari tholos tomb and the Kephala Petras House Tomb 2 increase and become statistically significant. This may be attributed to the small sample size for the Kephala Petras House Tomb 2. In addition, it is striking that the biodistance between the Livari-Skiadi tholos tomb and the Livari-Skiadi rockshelter also becomes statistically significant when the Irish (2006) thresholds are used.

Given the impact that shifting thresholds has on our results, it is important to clarify that there is currently no consensus on the most valid threshold for each trait. Many authors follow Turner (1987) but, as Irish (2005, 525) has noted: 'Although functional, the downside to this practice is that the full range of data is not presented, which precludes others from dichotomizing them differently.' Accordingly, other researchers establish their own thresholds for presence/absence. Among the six traits used in the calculation of the MMD here, the only ones that exhibited a difference between Turner (1987) and Irish (2006) were the enamel extensions and the seventh cusp, and this difference was of one single grade (Turner places the threshold for presence at grade 2 for the enamel extensions whereas Irish places the same threshold at grade 1, while the opposite is true for cusp 7). Despite this small difference in the thresholds per se, the biodistance results, particularly between the two Livari assemblages, are markedly different. It is not possible to determine which threshold gives more valid results, but the statistically significant difference between the two Livari groups has been confirmed in a recent study where more Cretan assemblages were incorporated in the analyses, even when the Turner (1987) threshold was employed (Nikita, Triantaphyllou and Papadatos 2014); thus it appears to be factual and not an artefact of the diverse methods.

Before closing the presentation of the results based on non-metric traits, it should be made clear that since non-metric traits constitute part of the phenotype through which we indirectly access the genes that define them, there is no method available for quantifying the scale of interbreeding between each pair of groups under examination. Such questions could potentially be addressed using ancient DNA data and bioinformatics, though in the case of the assemblages under study, no DNA could be extracted, as mentioned above. Nevertheless, in an attempt to explore the overall degree of interbreeding among the small communities of Prepalatial eastern Crete, the fixation index (Fst) was calculated based on the MMD values (Irish 2010). The fixation index is a measure of genetic differentiation between populations and its values may range from 0 to 1, where 0 suggests extensive interbreeding among samples, and 1 is indicative of no interbreeding at all (Nei and Chesser 1983). The calculated Fst values for the four assemblages under study were 0.003 and 0.007 using the Turner (1987) and Irish (2006) thresholds, respectively. It therefore appears that, despite the above-mentioned statistically significant pairwise biological distances, the overall degree of interbreeding in Prepalatial eastern Crete was high. This finding can at least in part be attributed to the small biodistance and subsequent extensive gene flow between the two Kephala Petras assemblages, but it is also accentuated by the small size of the communities under study.

DISCUSSION

The combined application of biodistance analysis and strontium isotope analysis is a valuable tool in the examination of gene flow and mobility patterns. The present project is the first attempt to apply this methodology in eastern Crete in order to approach not only outstanding questions concerning the processes underlying the extensive networks of cultural contact that characterise the southern Aegean during the Early Bronze Age, but also the exploration of regional diversities in relation to biological affinities and mobility patterns. The results presented above provide some interesting points for discussion and demonstrate the need for further studies of this kind in order to develop a comparative framework at a regional and interregional level. Issues of biological relatedness in Prepalatial Crete were investigated previously by Nafplioti, who applied metric and non-metric analyses of the cranial morphology from a very small sample of Early Bronze Age populations from the Moni Odigitria tholos tombs in the Asterousia mountains and two ossuaries from Roussolakos and the Patema enclosure in the wider area of Palaikastro in eastern Crete (Nafplioti 2007). That study found minimal biological distance between the two populations from central and eastern Crete based on cranial non-metric traits, which was interpreted by the author as suggestive of a common ancestor (parent population) (Nafplioti 2007, 201–2). This result was corroborated by the statistical analysis of cranial dimensions from the same groups, which showed a similarity in cranial shape between them (Nafplioti 2007, 226). It should be pointed out that the results based on cranial metric data in Nafplioti 2007 are rather tentative given that they actually encompass both the *shape* and the *size* of the crania under study and it has been shown that *size* is not a good indicator of biological distance between groups (see Betti *et al.* 2010 for a review). However, in combination with the non-metric data, they do suggest small genetic divergence between the sample populations from the Asterousia and Palaikastro. Moreover, a recent genetic analysis on Y-chromosome haplogroups of skeletal populations from Crete would support an influx of off-island genetic material from western and north-western Anatolia and Syro-Palestine around *c.*3100 BC (King *et al.* 2008).

The results of the current paper support an overall statistically significant differentiation of the skeletal assemblages from Kephala Petras and Livari-Skiadi based on strontium isotope analysis. This may be due to the different geological settings of the two sites. Biodistance analyses confirmed the statistically significant differentiation of the Kephala Petras rockshelter material and the Livari-Skiadi rockshelter and tholos tomb remains, though the Kephala Petras House Tomb 2 sample size is too small to allow for any positive comparisons. The Kephala Petras rockshelter and House Tomb 2 samples exhibit close biological affinities. In combination with the overall similar $^{87}Sr/^{86}Sr$ values and the suggested origin of the sampled populations from within Crete, this undermines the likelihood of any dramatic effect from outside population influx. It is important to point out that, as stated earlier, the strontium isotope results may be misleading if migrants of the first generation have not been included in the samples analysed, particularly if population movement was a one-off episode and involved small groups of individuals. However, the combined use of the two methods clearly points to the Kephala Petras rockshelter population not being genetically differentiated from the Kephala Petras House Tomb 2, despite the evidence of Cycladic-type pottery, namely the so-called 'Kampos Group', deposited together with pottery of local tradition inside the rockshelter burial area. These combined results suggest that the two Kephala Petras groups were of Cretan origin and they also point to the fact that no large-scale immigration took place throughout the third and early second millennia BC in this area. This scenario lends further support to recent theoretical approaches according to which the association of 'foreign' elements, traditions and perhaps technologies with the deceased during the third millennium BC does not necessarily reflect different ethnic groups but most probably an intentional manipulation by local groups or individuals to shape new identities and project special roles (see review in Papadatos 2007, 434–5).

In contrast, the population sampled from the Livari-Skiadi tholos tomb does not appear to be close to that from the Livari-Skiadi rockshelter in terms of biological relatedness as determined using dental non-metric traits, although the two assemblages are broadly chronologically contemporary from Early Minoan IB to IIB, *c.*2900–2200 BC. This result may imply the occurrence of gene flow during the last couple of centuries of the use of the rockshelter, after the tholos tomb had been abandoned, but given the commingled nature of the assemblage it is not possible to distinguish the later from the earlier material and analyse them separately. Nevertheless, the mortuary practices that characterise these assemblages point to another interesting explanation. In particular, the Livari-Skiadi tholos tomb diverges significantly from the typical rules for disposal of the deceased in eastern Crete with regard to its architectural type, the manipulation of the deceased and the demographic composition of the interred population. Tholos tombs are typical architectural forms which dominate in south-central Crete (Branigan 1993; Goodison and Guarita 2005; Legarra Herrero 2009; 2012; 2014). There are a few examples of tholos tombs outside the core area, *e.g.* Krasi, Pediados (Marinatos 1929; Galli 2014), tholos Epsilon and Gamma at Archanes (Panagiotopoulos 2002; Papadatos 2005), *etc.*, and the more recently discovered Mesorachi, Skopis and Livari-Skiadi, which have raised questions with regard to the identity of the people who were disposed of in these tomb types (Papadatos and Sofianou 2012). A major question concerns the origin of these people and their possible movement away from the core area of the Mesara plain and the Asterousia mountains in south-central Crete. A recent study (Nikita, Triantaphyllou and Papadatos 2014) on the biodistance of Prepalatial populations from central and eastern Crete has demonstrated a striking biological proximity between the Livari tholos material and the individuals buried in Moni Odigitria tholos B, suggesting a potential origin for part of the Livari-Skiadi population in the Mesara or Asterousia, although alternative explanations cannot be overlooked. Unfortunately, there is currently no available strontium isotope data from these areas that would allow us to explore this issue further.

Similarly, the manipulation of the deceased in the Livari-Skiadi tholos tomb, which included the systematic and lengthy exposure of human remains to high temperature, differs significantly from the common burial practices that took place in eastern Crete during the Prepalatial period (Triantaphyllou in press), though such a practice has not been traced to date anywhere in prehistoric Crete, so its point of origin cannot be identified. Evidence of burning on very few human skeletal remains in the Mesara tholoi would suggest their only short-term exposure to firing conditions and not their systematic cremation in the controlled conditions of a pyre, as is probably the case in the Livari-Skiadi tholos (Branigan 1987a; Triantaphyllou in press). Besides, the demographic profile of the Livari-Skiadi tholos assemblage does not provide typical mortality patterns; subadults are significantly under-represented. In contrast, while only very few communal skeletal assemblages in Prepalatial Crete have been thoroughly analysed, they are usually represented by all age groups and both sexes with very few exceptions (Triantaphyllou in press; forthcoming).

On the other hand, the Livari-Skiadi rockshelter constitutes a typical Prepalatial disposal context for this part of the island, where human remains were transferred at a secondary stage after their complete or partial decomposition at another location – which in the case of Livari-Skiadi remains unknown (Triantaphyllou in press). Considering all the above, it is possible that the Livari-Skiadi tholos tomb assemblage may represent a different subgroup which may have originated from somewhere else. Due to the effect of fire on tooth enamel and bone material from the Livari-Skiadi tholos, as already pointed out in the methodology section, sampling for strontium isotope analysis could not be conducted on this skeletal assemblage. Despite the various non-standard elements observed with regard to the manipulation of the deceased, it is interesting to note that material culture does not provide evidence of affinities with the Mesara plain alone, but also with sites on the north coast and the Cyclades. This phenomenon suggests that an extensive network of maritime and terrestrial interconnections was present in this rather remote part of the southern coastline (Papadatos and Sofianou 2012; in press).

Therefore, our results do not appear to support substantial gene flow in Prepalatial eastern Crete from outside the island. Instead, interbreeding within Cretan communities may have varied in scale and character, as interesting biodistance patterns emerge when pairwise comparisons are performed. One aspect of special interest is the apparent population homogeneity of the Kephala Petras cemeteries, which comes in contrast to the heterogeneity of the Livari-Skiadi population assemblages based primarily on the results of the biodistance analysis. At this point, it is important to take into account that the Kephala Petras settlement was acting as a gateway community already in the Late Final Neolithic and early Early Minoan I (see recent discussion by Papadatos and Tomkins 2013) while, in close proximity to the early site, a Protopalatial palace was established in Middle Minoan IIA (*e.g.* Tsipopoulou 2002; 2007; 2011; 2012c; Tsipopoulou and Hallager 2010; Tsipopoulou and South 2012), suggesting a continuous persistence of interest in the area operating as a nodal site at a regional level on the north-east coast of Crete. It may be plausible, therefore, to assume that the agricultural setting of the wider area of Kephala Petras favoured some self-sufficiency in demographic terms which can be translated into minimal outside population influx and exogamy with distant communities: Whitelaw (2015) suggests 'a minimum breeding group of 500 individuals for a stable local population based on anthropological studies (Wobst 1975)'. In contrast, the remote Livari-Skiadi community, located in a marginal and perhaps fragile environmental setting, would have required extensive interactions with a large range of outside communities, some of which appear to have been derived from considerably distant regions such as the Mesara plain and the Asterousia mountains in central Crete. It should be noted that cultural connections along the south coast of Crete have been documented by ceramics from the Mesara and Asterousia regions imported, on a limited scale, to EMIIA Myrtos Fournou Korifi (Whitelaw 2015).

CONCLUSIONS

The study of dental non-metric traits and strontium isotope analysis alongside the evidence of material culture and the manipulation of the deceased in eastern Crete has the potential to shed new light on the scale and character of mobility patterns and biological affinities developed among the human populations who lived in this area of the southern Aegean, and indicates the potential for more extensive studies of this kind. Given the biological distance between the two chronologically contemporary Livari populations, small-scale mobility of human groups could possibly be suggested, particularly for the remote site of Livari-Skiadi in south-eastern Crete. The results from the Kephala Petras assemblages show at a preliminary level the local origin of these individuals and highlight the fact that the manifestation of *Cycladica* in this area is not directly associated with islanders from the Cyclades. However, large-scale sampling, in order to identify outliers within populations with associated assemblages bearing strong evidence of Cycladic influence (such as at Hagia Photeia Siteias), should be considered in the future to more conclusively address this question. The manipulation of cultural elements locally invented or transferred from elsewhere and of ideas related to the treatment of the deceased, along with the study of the biological relations between populations, can offer a great deal of information regarding the formation of regional identities by communities in eastern Crete during the third millennium BC.

ACKNOWLEDGEMENTS

This pilot project was financed by the Research Committee of the Aristotle University of Thessaloniki (Code No. 88097). We would like to express our gratitude to the Greek Authorities for granting a permit to Sevi Triantaphyllou (ST) to sample the human skeletal populations. ST would like to thank especially Dr Metaxia Tsipopoulou, Dr Yiannis Papadatos and Ms Chryssa Sofianou for facilitating the study of the material. Special thanks also go to Professors Alex Bentley and Tim Elliott and the personnel of the Bristol Isotope Group for their collaboration, Drs Evangelia Kiriatzi and Eleni Nodarou for providing invaluable information and bibliographical references on the geological setting of the study areas, Professor Phil Betancourt for his comments on a preliminary draft, and Dr Tom Brogan, Director of the Institute for Aegean Prehistory in Eastern Crete, for the general support in practical matters. Finally, special thanks should go to Professor Todd Whitelaw, who critically reviewed this paper and kindly provided unpublished material motivating the authors to improve significantly their interpretation of the results.

strianta@hist.auth.gr

REFERENCES

Bentley, R.A. 2006. 'Strontium isotopes from the earth to the archaeological skeleton: A review', *Journal of Archaeological Method and Theory* 13, 35–87.

Bentley, R.A., Bickle, P., Fibiger, L., Nowell, G.M., Dale, C.W., Hedgers, R.E.M., Hamilton, J., Wahl, J., Francken, M., Grupe, G., Lenneis, E., Teschler-Nicola, M., Arbogast, R., Hofman, D. and Whittle, A. 2012. 'Community differentiation and kinship among Europe's first farmers', *Proceedings of the National Academy of Science* 109, 9326–30.

Berry, A.C. 1978. 'Anthropological and family studies on minor variants of the dental crown', in Butler, P.M. and Joysey, K.A. (eds.), *Development, Function and Evolution of Teeth* (London), 81–98.

Betancourt, P.P. 2012. 'The frying pans from Hagia Photia', in Mantzourani, E. and Betancourt, P.P. (eds.), *PHILISTOR. Studies in Honor of Costis Davaras* (Philadelphia), 1–6.

Betti, L., Balloux, F., Hanihara, T. and Manica, A. 2010. 'The relative role of drift and selection in shaping the human skull', *American Journal of Physical Anthropology* 141, 76–82.

Bevan, A. 2004. 'Emerging civilized values? The consumption and imitation of Egyptian stone vessels in EM II–MM I Crete and its wider eastern Mediterranean context', in Barrett, J.C. and Halstead, P. (eds.), *The Emergence of Civilisation Revisited* (Sheffield Studies in Aegean Archaeology 6; Oxford), 107–26.

Bintliff, J. 1977. 'Appendix 2. The number of burials in the Mesara tholoi', in Blackman and Branigan 1977, 83–4.

Blackman, D.J. and Branigan, K. 1977. 'An archaeological survey of the catchment area of the Ayiopharango', *Annual of the British School at Athens* 72, 13–84.

Branigan, K. 1971. 'Cycladic figurines and their derivatives', *Annual of the British School at Athens* 66, 57–78.

Branigan, K. 1974. *Aegean Metalwork of the Early and Middle Bronze Age* (Oxford).

Branigan, K. 1987a. 'Ritual interference with human bones in the Mesara tholoi', in Laffineur, R. (ed.), *Thanatos. Les Coutumes Funeraires en Egée à l' Age du Bronze*, (Aegaeum 1; Liège), 43–51.

Branigan, K. 1987b. 'Body counts in the Mesara tholoi', in Kastrinaki, L., Orfanou, G. and Giannadakis, N. (eds.), *Ειλαπινή. Τιμητικός Τόμος για τον καθηγητή Νικόλαο Πλάτωνα* (Herakleion), 299–309.

Branigan, K. 1993. *Dancing with Death. Life and Death in Southern Crete c.* 3000–2000 BC (Amsterdam).

Brodie, N., Doole, J., Gavalas, G. and Renfrew, C. (eds.). 2008. *HORIZON. A Colloquium on the Prehistory of the Cyclades* (Cambridge).

Broodbank, C. 2000. *An Island Archaeology of the Early Cyclades* (Cambridge).

Brown, T. and Brown, K. 2011. *Biomolecular Archaeology* (Oxford).

Budd, P., Montgomery, J., Barreiro, B. and Thomas, R. G. 2000. 'Differential diagenesis of strontium in archaeological human dental tissue', *Applied Geochemistry* 15, 687–94.

Carter, T. 1998. 'Reverberations of the International Spirit: Thoughts upon 'Cycladica' in the Mesara', in Branigan, K. (ed.), *Cemetery and Society in the Bronze Age* (Sheffield), 59–77.

Carter, T. in press. 'Chipped stone', in Papadatos, Y. and Sofianou, C. (eds.), *Livari Skiadi. A Minoan Cemetery in Lefki, Southeast Crete. Volume I: Excavation and Finds* (Philadelphia).

Chamberlain, A. 2006. *Demography in Archaeology* (Cambridge).

Cherry, J.F. 2009. 'Sorting out Crete's Prepalatial off-island interactions', in Parkinson, W.A. and Galaty, M.L. (eds.), *Archaic Interaction. The Eastern Mediterranean in the Bronze Age* (Santa Fe), 107–40.

Coppa, A., Cucina, A., Lucci, M., Mancinelli, D. and Vargiu, R. 2007. 'Origins and spread of agriculture in Italy: A nonmetric dental analysis', *American Journal of Physical Anthropology* 133, 918–30.

Corruccini, R.S. and Shimada, I. 2002. 'Dental relatedness corresponding to mortuary patterning at Huaca Loro, Peru', *American Journal of Physical Anthropology* 117, 113–21.

Creutzburg, N., Drooger, C.W. and Meulenkamp, J.E. 1977. *General Geological Map of Greece, Crete Island* (*scale* 1:200.000) (Athens Institute of Geological and Mining Research).

Davaras, C. and Betancourt, P.P. 2004. *The Hagia Photia Cemetery I. The Tomb Groups and Architecture* (New York).

Davaras, C. and Betancourt, P.P. 2012. *The Hagia Photia Cemetery II. The Pottery* (New York).

Day, P., Hein, A., Joyner, L., Kilikoglou, V., Kiriatzi, E., Tsolakidou, A. and Wilson, D.E. 2012. 'Appendix A. Petrographic and chemical analysis of the pottery', in Davaras, C. and Betancourt, P. (eds.), *The Hagia Photia Cemetery II. The Pottery* (Philadelphia), 115–38.

Day, P., Wilson, D. and Kiriatzi, E. 1997. 'Reassessing specialisation in Prepalatial Cretan ceramic production', in Laffineur, R. and Betancourt, P.P. (eds.), *TEXNH: Craftsmen, Crafstwomen and Craftsmanship in the Aegean Bronze Age* (Aegaeum 16; Liege/Austin), 275–89.

Day, P.M., Wilson, D.E. and Kiriatzi, E. 1998. 'Pot, labels and people: Burying ethnicity in the cemetery of Aghia Photia, Siteias', in Branigan, K. (ed.), *Cemetery and Society in the Bronze Age* (Sheffield), 133–49.

Day, P.M., Wilson, D.E., Kyriatzi, E. and Joyner, L. 2000. "Η κεραμική από το ΠΜ Ι νεκροταφείο στην Αγία Φωτιά Σητείας: Τοπική ή εισηγμένη;", *Πεπραγμένα 8ου Διεθνούς Κρητολογικού Συνεδρίου, Ηράκλειο*, A1, 341–53.

Dimopoulou-Rethemiotaki, N., Wilson, D.E. and Day, P.M. 2007. 'The earlier prepalatial settlement of Poros-Katsambas: Craft production and exchange at the harbor town of Knossos', in Day, P.M. and Doonan, R.C.P. (eds.), *Metallurgy in the Early Bronze Age Aegean* (Oxford), 84–97.

Doonan, R. and Day, P. 2007. 'Mixed origins and the origins of mixing: Alloys and provenance in the Early Bronze Age Aegean', in Day, P. and Doonan, R. (eds.), *Metallurgy in the Early Bronze Age Aegean* (Oxford), 1–19.

Doonan, R., Day, P. and Dimopoulou-Rethemiotaki, N. 2007. 'Lame excuses for emerging complexity in Early Bronze Age Crete: The metallurgical finds from Poros-Katsambas and their context', in Day, P.M. and Doonan, R.C.P. (eds.), *Metallurgy in the Early Bronze Age Aegean* (Oxford), 98–122.

Doumas, C. 1979. "Προϊστορικοί Κυκλαδίτες στην Κρήτη", *Αρχαιολογικά Ανάλεκτα εξ Αθηνών* 12, 104–6.

Elderfield, H. 1986. 'Strontium isotope stratigraphy', *Palaeogeography, Palaeoclimatology, Palaeoecology* 57, 71–90.

Evans, J.A., Montgomery, J., Wildman, G. and Boulton, N. 2010. 'Spatial variations in biosphere 87Sr/86Sr in Britain', *Journal of the Geological Society* 167, 1–4.

Ferrence, S.C., Muhly, J.D. and Betancourt, P.P. 2012. 'Affluence in eastern Crete: Metal objects from the cemetery of Petras', in Tsipopoulou, M. (ed.), *Petras-Siteia, 25 years of Excavations and Studies: Conference organized by the Danish Institute, Athens, 9–10 October 2010* (Monographs of the Danish Institute at Athens, vol. 16; Athens), 133–43.

Freeman, M.F. and Tukey, J.W. 1950. 'Transformations related to the angular and the square root', *Annals of Mathematical Statistics* 21, 607–11.

Frei, K.M. and Price, T.D. 2012. 'Strontium isotopes and human mobility in prehistoric Denmark', *Archaeological and Anthropological Sciences* 4, 103–14.

Fuentes, A. 2011. *Biological Anthropology: Concepts and Connections*, 2nd edn (New York).

Galanaki, K. 2006. "Πρωτομινωικό ταφικό σύνολο στην πρώην Αμερικανική Βάση Γουρνών Πεδιάδος", *Πεπραγμένα του 9ου Διεθνούς Κρητολογικού Συνεδρίου, Ελούντα*, A2, 227–41.

Galli, E. 2014. 'Where the past lies. The prepalatial tholos tomb at Krasi and its stratigraphic sequence'. *Κρητικά Χρονικά* 34, 231–48.

Getz-Preziosi, P. 1987. *Sculptors of the Cyclades* (Ann Arbor).

Giblin, J.I., Knudson, K.J., Bereczki, Z., Pálfi, G. and Pap, I. 2013. 'Strontium isotope analysis and human mobility during the Neolithic and Copper Age: A case study from the Great Hungarian Plain', *Journal of Archaeological Science* 40, 227–39.

Gilbert, M.T.P., Bandelt, H.-J., Hofreite, M. and Barnes, I. 2005. 'Assessing ancient DNA studies', *Trends in Ecology and Evolution* 20, 10, 541–4.

Goodison, L. and Guarita, C. 2005. 'A new catalogue of the Mesara-type tombs'. *Studies in Mediterranean Archaeology* 47, 171–212.

Green, R.F., Suchey, J.M. and Gokhale, D.V. 1979. 'The statistical treatment of correlated bilateral traits in the analysis of cranial material', *American Journal of Physical Anthropology* 50, 629–34.

Haak, W., Brandt, G., Jong, H.N. de, Meyer, C., Ganslmeier, R., Heyd, V., Hawkesworth, C., Pike, A.W.G., Meller, H. and Alt, K.W. 2008. 'Ancient DNA, Strontium isotopes, and osteological analyses shed light on social and kinship organization of the Later Stone Age', *Proceedings of the National Academy of Science* 105, 18226–31.

Hanihara, T. 2010. 'Metric and nonmetric dental variation and the population structure of the Ainu', *American Journal of Human Biology* 22, 163–71.

Harris, E.F. and Sjøvold, T. 2004. 'Calculation of Smith's mean measure of divergence for intergoup comparisons using nonmetric data', *Dental Anthropology* 17, 83–93.

Higgins, M.D. and Higgins, R. 1996. *A Geological Companion to Greece and the Aegean* (London).

Hillson, S. 1996. *Dental Anthropology* (Cambridge).

Horwitz, E.P., Dietz, M.L. and Chiarizia, R. 1992. 'The application of novel extraction chromatographic materials to the characterization of radioactive waste solutions', *Journal of Radioanalytical and Nuclear Chemistry* 161, 575–83.

Irish, J.D. 2005. 'Population continuity vs. discontinuity revisited: Dental affinities among Late Paleolithic through Christian-era Nubians', *American Journal of Physical Anthropology* 128, 520–35.

Irish, J.D. 2006. 'Who were the ancient Egyptians? Dental affinities among Neolithic through Postdynastic peoples', *American Journal of Physical Anthropology* 129, 529–43.

Irish, J.D. 2010. 'The mean measure of divergence: Its utility in model-free and model-bound analyses relative to the Mahalanobis D^2 distance for nonmetric traits', *American Journal of Human Biology* 22, 378–95.

King, R., Özcan, S., Carter, T., Kalfoğlu, E., Atasoy, S., Triantaphyllidis, C., Kouvatsi, A., Lin, A.A., Chow, C.E.T., Zhivotovsky, L.A., Michalodimitrakis, M. and Underhill, P.A. 2008. 'Differential Y chromosome: Influences on the Greek and Cretan Neolithic', *Annals of Human Genetics* 72, 205–14.

Legarra Herrero, B. 2009. 'The Minoan fallacy: Cultural diversity and mortuary behaviour on Crete at the beginning of the Bronze Age', *Oxford Journal of Archaeology* 28, 29–57.

Legarra Herrero, B. 2012. 'The construction, deconstruction and non-construction of hierarchies in the funerary record of Prepalatial Crete', in Schoep, I. Tomkins, P. and Driessen, J. (eds.), *Back to the Beginning: Reassessing Social, Economic and Political Complexity in the Early and Middle Bronze Age on Crete* (Oxford), 325–57.

Legarra Herrero, B. 2014. *Mortuary Behavior and Social Trajectories in Pre- and Protopalatial Crete* (Philadelphia).

Levi, D. 1961–2. 'La due prime champagne di scavo a Iasos (1960–1)', *Annuario della scuola archeological di Atene e della mission Italiane in oriente N. S.* 23–4, 504–71.

Levi, D. 1965–6. 'La cambagne 1962–4 a Iasos', *Annuario della scuola archeological di Atene e della mission Italiane in oriente N. S.* 27–8, 401–56.

Manning, S. 1995. *The Absolute Chronology of the Aegean Bronze Age: Archaeology, Radiocarbon and History* (Sheffield).

Manning, S. 2010. 'Chronology and terminology', in Cline, E. (ed.), *The Oxford Handbook of the Bronze Age Aegean* (New York), 11–28.

Marinatos, S. 1929. "Πρωτομινωϊκὸς θολωτὸς τάφος παρὰ τὸ χωρίον Κράσι Πεδιάδος", *Αρχαιολογικὸν Δελτίον* 12, 102–41.

Montgomery, J. and Evans, J.A. 2003. 'Immigrants on the Isle of Lewis – combining traditional funerary and modern isotope evidence to investigate social differentiation, migration and dietary change in the Outer Hebrides of Scotland', in Gowland, R. and Knüsel, C. (eds.), *Social Archaeology of Funerary Remains* (Oxford), 122–42.

Mylonas, G.E. 1959. *Aghios Kosmas: An Early Bronze Age Settlement and Cemetery in Attica* (Princeton).

Nafplioti, A. 2007. 'Population bio-cultural history in the south Aegean during the Bronze Age' (unpublished PhD dissertation, University of Southampton).

Nafplioti, A. 2008. 'Mycenaean political domination of Knossos following the LMIB destructions on Crete: Negative evidence from strontium ratio analysis (^{87}Sr/^{86}Sr)', *Journal of Archaeological Science* 35, 2307–17.

Nafplioti, A. 2009a. 'Mycenae revisited part 2. Exploring the local vs. non-local origin of the individuals from Grave Circle A at Mycenae: Evidence from strontium isotope ratio (^{87}Sr/^{86}Sr) analysis', *Annual of the British School at Athens* 104, 279–91.

Nafplioti, A. 2009b. 'Early Bronze Age Manika on Euboea (Greece). A "colony" or not? Evidence from strontium isotope ratio (^{87}Sr/^{86}Sr) analysis', *Geochemica et Cosmochimica Acta* 73 (13 Supp. 1), A925.

Nafplioti, A. 2010. 'The Mesolithic occupants of Maroulas on Kythnos: Skeletal isotope ratio signatures of their geographic origin', in Sampson, A., Kaczanowska, M. and Kozlowski, J.K. (eds.), *The Prehistory of the Island of Kythnos (Cyclades, Greece) and the Mesolithic Settlement at Maroulas* (Warsaw), 207–15.

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, 1560–70.

Nei, M., and Chesser, R.K. 1983. 'Estimation of fixation indices and gene diversities', *Annals of Human Genetics* 47, 253–59.

Nichol, C.R. 1990. 'Dental genetics and biological relationships of the Pima Indians of Arizona' (unpublished PhD dissertation, Arizona State University, Arizona).

Nikita, E., Mattingly, D. and Lahr, M. 2012. 'Sahara: Barrier or corridor? Non-metric cranial traits and biological affinities of North African Late Holocene populations', *American Journal of Physical Anthropology* 147, 280–92.

Nikita, E., Triantaphyllou, S. and Papadatos, Y. 2014. 'Gene flow and the formation of cultural identities in Prepalatial central and eastern Crete', *European Association of Archaeologists 20th Annual Meeting, September 10–14, Istanbul*, Abstracts, 100.

Nodarou, E. 2012. 'Pottery fabrics and recipes in the Final Neolithic and Early Minoan Period: The analytical evidence from the settlement and the Rock Shelter of Kephala Petras', in Tsipopoulou, M. (ed.), *Petras-Siteia, 25 years of Excavations and Studies: Conference organized by the Danish Institute, Athens, 9–10 October 2010* (Monographs of the Danish Institute at Athens, vol. 16; Athens), 81–8.

Nodarou, E. in press. 'Prepalatial pottery: Petrographic analysis', in Papadatos, Y. and Sofianou, C. (eds.), *Livari Skiadi. A Minoan Cemetery in Lefki, Southeast Crete. Volume I: Excavation and Finds* (Philadelphia).

Panagiotopoulos, D. 2002. *Das Tholosgrab E von Phourni bei Archanes. Studien zu einem Frühkretischen Grabfund und seinem Kulturellen Kontext*, British Archaeological Reports 1014 (Oxford).

Pantelidou-Gofa, M. 2005. *Τσέπι Μαραθώνος. Το Πρωτοελλαδικό Νεκροταφείο* (Athens).

Papadatos, Y. 1999. 'Mortuary practices and their importance for the reconstruction of society and life in Prepalatial Crete: The evidence from Tholos Tomb Γ, in Archanes–Phourni' (unpublished PhD dissertation, University of Sheffield).

Papadatos, Y. 2005. *Tholos Tomb Gamma: A Prepalatial Tholos Tomb at Phourni, Archanes* (Philadelphia).

Papadatos, Y. 2007. 'Beyond cultures and ethnicity: A new look at material culture distribution and inter-regional interaction in the Early Bronze Age southern Aegean', in Antoniadou, S. and Pace, A. (eds.), *Mediterranean Crossroads* (Athens), 419–51.

Papadatos, Y. and Sofianou, C. 2012. "Πολιτισμική ομοιογένεια και διαφοροποίηση στην προανακτορική Κρήτη. Νέα δεδομένα από τις ανασκαφές Πρωτομινωικών νεκροταφείων στην επαρχεία Σητείας", in Andrianakis, M., Varthalitou, P. and Tzachili, I. (eds.), *Το Αρχαιολογικό Έργο Κρήτης* 2 (2010), 48–59.

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

Papadatos, Y. and Sofianou, C. (eds.) in press. *Livari Skiadi. A Minoan Cemetery in Lefki, Southeast Crete. Volume I: Excavation and Finds* (Philadelphia).

Papadatos, Y. and Tomkins, P. 2013. 'Trading, the longboat, and cultural interaction in the Aegean during the late fourth millennium B.C.E.: The view from Kephala Petras, east Crete', *American Journal of Archaeology* 117, 353–81.

Papastamatiou, J., Vetoulis, D., Bornovas, J., Christodoulou, G. and Katsikatsos, G. 1959a. *Geological Map of Greece, Ziros* (*1:50,000 scale*) (Athens).

Papastamatiou, J., Vetoulis, D., Bornovas, J., Christodoulou, G. and Tataris, A. 1959b. *Geological Map of Greece, Sitia* (*1:50,000 scale*) (Athens).

Pecorella, P.E. 1984. *La cultura preistorica di Iasos in Caria* (Rome).

Pinhasi, R. and Stock, J.T. (eds.) 2011. *Human Bioarchaeology of the Transition to Agriculture* (Oxford).

Renfrew, C. 1972. *The Emergence of Civilisation. The Cyclades and the Aegean in the Third Millennium BC* (London).

Relethford, J.H. 2010. 'The study of human population genetics', in Larsen, C.S. (ed.), *A Companion to Biological Anthropology* (Oxford), 74–87.

Ricaut, F., Auriol, V., Von Cramon-Taubadel, N., Keyser, C., Murail, P., Ludes, B. and Crubézy, E. 2010. 'Comparison between morphological and genetic data to estimate biological relationship: The case of the Egyin Gol necropolis (Mongolia)', *American Journal of Physical Anthropology* 143, 355–64.

Sakellarakis, Y. 1977a. 'The Cyclades and Crete', in Thimme, J. (ed.), *Art and Culture of the Cyclades in the Third Millennium B.C.* (Chicago), 145–54.

Sakellarakis, Y. 1977b. "Τα κυκλαδικά στοιχεία των Αρχανών", *Αρχαιολογικά Ανάλεκτα εξ Αθηνών* 10, 93–113.

Sampson, A. 1988. *Μάνικα. Ο Πρωτοελλαδικός Οικισμός και το Νεκροταφείο II* (Athens).

Sapouna-Sakellaraki, E. 1977. 'Cycladic jewellery', in Thimme, J. (ed.), *Art and Culture of the Cyclades in the Third Millennium B.C.* (Chicago), 123–9.

Sapouna-Sakellaraki, E. 1987. 'New evidence from the Early Bronze Age cemetery at Manika, Chalkis', *Annual of the British School at Athens* 82, 233–64.

Sbonias, K. 2012. 'Regional elite-groups and the production and consumption of seals in the Prepalatial period. A case study of the Asterousia region', in Schoep, I., Tomkins, P. and Driessen, J. (eds.), *Back to the Beginning: Reassessing Social, Economic and Political Complexity in the Early and Middle Bronze Age on Crete* (Oxford), 114–76.

Schnutenhaus, S. and Rösing, F.W. 1998. 'World variation in tooth size', in Alt, K.W., Rösing, F.W. and Teschler-Nicola, M. (eds.), *Dental Anthropology: Fundamentals, Limits, and Prospects* (Vienna), 521–35.

Scott, G.R. 1973. *Dental Morphology: A Genetic Study of American White Families and Variation in Living Southwest Indians* (unpublished PhD dissertation, Arizona State University, Arizona).

Scott, G.R. and Turner, C.G. II 1997. *The Anthropology of Modern Human Teeth: Dental Morphology and its Variation in Recent Human Populations* (Cambridge).

Sealy, J.C., Armstrong, R. and Schrire, C. 1995. 'Beyond lifetime averages: Tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeleton', *Antiquity* 69, 290–300.

Shapiro, B. and Hofreiter, M. (eds.) 2012. *Ancient DNA: Methods and Protocols* (New York).

Sjøvold, T. 1973. 'Occurrence of minor non-metrical variants in the skeleton and their quantitative treatment for population comparison', *Homo* 24, 204–33.

Sjøvold, T. 1977. 'Non-metrical divergence between skeletal populations', *Ossa* 4, 1–133.

Slovak, N.M. and Paytan, A. 2011. 'Applications of Sr isotopes in archaeology', in Baskaran, M. (ed.) *Handbook of Environmental Isotope Geochemistry, Advances in Isotope Geochemistry* (Berlin), 743–68.

Soles, J.S. 1992. *The Prepalatial Cemeteries at Mochlos and Gournia and the House Tombs of Bronze Age Crete* (Princeton, Hesperia Supplement 24).

Stojanowski, C.M. 2005. *Biocultural Histories in La Florida: A Bioarchaeological Perspective* (Tuscaloosa).

Stos-Gale, Z.A. 1993. 'The origin of metal used for making weapons in EM and MM Crete', in Scarre, C. and Healey, F. (eds.), *Trade and Exchange in Prehistoric Europe* (Oxford), 115–29.

Tomczak, P.D. and Powell, J.F. 2003. 'Postmarital residence practices in the Windover population: Sex-based dental variation as an indicator of patrilocality', *American Antiquity* 68, 93–108.

Townsend, G.C., Richards, L.C., Brown, T., Burgess, V.B., Travan, G.R. and Rogers, J.R. 1992. 'Genetic studies of dental morphology in south Australian twins', in Smith, P. and Tchernov, E. (eds.), *Structure, Function, and Evolution of Teeth* (London), 501–18.

Triantaphyllou, S. 2009. 'EM/MM Human skeletal remains from East Crete: The Kephala Petras rock shelter and the Livari tholos tomb, Skiadi', *Kentro, The Newsletter of the INSTAP Study Center for East Crete* 12, 19–23.

Triantaphyllou, S. 2012. 'Kephala Petras Siteias: Human bones and burial practices in the EM rockshelter', in Tsipopoulou, M. (ed.), *Petras-Siteia, 25 years of Excavations and Studies: Conference organized by the Danish Institute, Athens, 9–10 October 2010* (Monographs of the Danish Institute at Athens, vol. 16; Athens), 161–6.

Triantaphyllou, S. forthcoming. 'Constructing identities through ageing the body in the prehistoric Aegean: The view of the human remains', in Mina, M., Triantaphyllou, S. and Papadatos, Y. (eds.), *Embodied Identities in the Prehistoric Eastern Mediterranean: Convergence of Theory and Practice, International Conference taking place at Nicosia, April 2012* (Oxford).

Triantaphyllou, S. in press. 'Managing with death in prepalatial Crete: The evidence of the human remains', in Papadatos, Y. and Relaki, M. (eds.), *From the Foundations to the Legacy of Minoan Society* (Oxford).

Triantaphyllou, S., Tsipopoulou, M. and Betancourt, P. in press. "Κεφάλα Πετράς, Σητείας: ανθρώπινα οστά και ταφικές πρακτικές στην ΠΜ βραχοσκεπή και το ΜΜ νεκροταφείο", *Πεπραγμένα του 11ου Διεθνούς Κρητολογικού Συνεδρίου, Ρέθυμνο, 21–27 Οκτώβριος 2011* (Rethymno).

Trigger, B.G. 1989. *A History of Archaeological Thought* (Cambridge).

Tsipopoulou, M. 2002. 'Petras, Siteia: The palace, the town, the hinterland and the Protopalatial

https://doi.org/10.1017/S0068245415000064 Published online by Cambridge University Press

background', in Driessen, J., Schoep, I. and Laffineur, R. (eds.), *Monuments of Minos, Rethinking the Minoan Palaces* (Aegaeum 23; Liège), 133–44.

Tsipopoulou, M. 2007. 'The central court of the palace of Petras', in Betancourt, P.P., Nelson, M.C. and Williams, H. (eds.), *Krinoi kai Limenes, Studies in Honor of Joseph and Maria Shaw* (Philadelphia), 49–59.

Tsipopoulou, M. 2010. "Ταφική βραχοσκεπή στον Πετρά Σητείας. Πρώτη ανακοίνωση", in Andrianakis, M., Varthalitou, P. and Tzachili, I. (eds.), *Το Αρχαιολογικό Έργο Κρήτης* 1, 121–33.

Tsipopoulou, M. 2011. "Πρόσφατα ευρήματα στον Πετρά Σητείας. Οι ανασκαφές του 21ου αιώνα", *Πεπραγμένα 10ου Διεθνούς Κρητολογικού Συνεδρίου, Χανιά, 1–8 Οκτωβρίου 2006*, A2, 337–64.

Tsipopoulou, M. 2012a. "Πετράς Σητείας: προανακτορικό – πρώιμο παλαιοανακτορικό ταφικό κτίριο 2", in Andrianakis, M., Varthalitou, P. and Tzachili, I. (eds.), *Το Αρχαιολογικό Έργο Κρήτης* 2 (2010), 60–9.

Tsipopoulou, M. 2012b. 'Kampos group pottery from the cemetery of Petras, Siteia', in Mantzourani, E. and Betancourt, P.P. (eds.), *PHILISTOR. Studies in Honor of Costis Davaras* (Philadelphia), 213–22.

Tsipopoulou, M. 2012c. 'The Prepalatial–early Protopalatial cemetery at Petras, Siteia: A diachronic symbol of social coherence', in Tsipopoulou, M. (ed.), *Petras-Siteia, 25 years of Excavations and Studies: Conference organized by the Danish Institute, Athens, 9–10 October 2010* (Athens, Monographs of the Danish Institute at Athens Volume 16), 117–31.

Tsipopoulou, M. and Hallager, E. 2010. *The Hieroglyphic Archive at Petras, Siteia* (Monographs of the Danish Institute at Athens, vol. 9; Athens).

Tsipopoulou, M. and South, A. 2012. 'The economics of monumental buildings: A view from Crete, a view from Cyprus', in Cadogan, G., Iacovou, M., Kopaka, K. and Whitley, J. (eds.), *Parallel Lives: Ancient Island Societies in Crete and Cyprus* (British School at Athens Supp. Vol. 20; London), 209–31.

Turner, C.G. II 1987. 'Late Pleistocene and Holocene population history of east Asia based on dental variation', *American Journal of Physical Anthropology* 73, 305–22.

Turner, C.G. II, Nichol, C.R. and Scott, G.R. 1991. 'Scoring procedures for key morphological traits of the permanent dentition: The Arizona State University Dental Anthropology System', in Kelley, M.A. and Larsen, C.S. (eds.), *Advances in Dental Anthropology* (New York), 13–31.

Tyrell, A. 2000. 'Skeletal non-metric traits and the assessment of inter- and intra-population diversity: Past problems and future potential', in Cox, M. and Mays, S. (eds.), *Human Osteology in Archaeology and Forensic Science* (London), 289–306.

Vasilakis, A. and Branigan, K. (eds.) 2010. *Moni Odigitria: A Prepalatial Cemetery and Its Environs in the Asterousia, Southern Crete* (Philadelphia).

Vavouranakis, G. 2007. *Funerary Landscapes East of Lasithi, Crete, in the Bronze Age* (British Archaeological Reports 1606; Oxford).

Vika, E. 2009. 'Strangers in the grave? Investigating local provenance in a Greek Bronze Age mass burial using $\delta^{34}S$ analysis', *Journal of Archaeological Science* 36, 2024–8.

Warren, P. 1972. *Myrtos: An Early Bronze Age in Crete* (British School at Athens Supp. Vol. 7; London).

Weiss, K.M. and Buchanan, A.V. 2010. 'Evolution: What it means and how we know', in Larsen, C. S. (ed.), *A Companion to Biological Anthropology* (Oxford), 41–55.

Whitelaw, T.M. 1983. 'The settlement at Phournou Korifi, Myrtos and aspects of Early Minoan social organisation', in Krzyszkowska, O. and Nixon, L. (eds.), *Minoan Society* (Bristol), 323–45.

Whitelaw, T.M. 2007. 'House, households and community at Early Minoan Fournou Korifi: Methods and models for interpretation', in Westgate, R., Fisher, N. and Whitley, J. (eds.), *Building Communities: House, Settlement and Society in the Aegean and Beyond* (British School at Athens Supp. Vol. 15; London), 65–76.

Whitelaw, T.M. 2012. 'The urbanisation of prehistoric Crete: Settlement perspectives on Minoan state formation', in Schoep, I., Tomkins, P. and Driessen, J. (eds.), *Back to the Beginning: Reassessing Social, Economic and Political Complexity in the Early and Middle Bronze Age on Crete* (Oxford), 114–76.

Whitelaw, T.M. 2015. 'The divergence of civilisation: Fournou Korifi and Pyrgos', in Macdonald, C., Hatzaki, E. and Andreou, S. (eds.) *The Great Islands. Studies of Crete and Cyprus presented to Gerald Cadogan* (Athens), 41–8.

Whitelaw, T.M., Day, P.M., Kiriatzi, E., Kilikoglou, V. and Wilson, D.E. 1997. 'Ceramic traditions at EM IIB Myrtos, Fournou Korifi', in Laffineur, R. and Betancourt, P.P. (eds.), *TEXNH: Craftsmen, Craftswomen and Craftsmanship in the Aegean Bronze Age. Proceedings of the 6th International Aegean Conference/6e Rencontre égéenne internationale, Philadelphia, Temple University, 18–21 April 1996* (Aegaeum 16; Liège), 265–74.

Wilson, D.E and Day, P.M. 1994. 'Ceramic regionalism in Prepalatial central Crete: The Messara imports at EM I to EM IIA Knossos', *Annual of the British School at Athens* 89, 1–87.

Wilson, D.E., Day, P.M. and Dimopoulou, N. 2004. 'The pottery from Early Minoan IIIB Knossos and its relations with the harbour site of Poros-Katsambas', in Cadogan, G., Hatzaki, E. and Vasilakis, A. (eds.), *Knossos: Palace, City, State* (British School at Athens Studies Series 12; London), 67–74.

Wilson, D.E., Day, P.M. and Dimopoulou-Rethemiotaki, N. 2008. 'The gateway port of : Trade and exchange between north-central Crete and the Cyclades in EB I–II', in Brodie, N., Doole, J., Gavalas, G. and Renfrew, C. (eds.), *HORIZON. A Colloquium on the Prehistory of the Cyclades* (Cambridge), 261–70.

Wobst, M. 1975. 'The demography of finite populations and the origins of the incest taboo', *Memoirs of the Society for American Archaeology* 30, 75–81.

Zakrzewski, S. 2011. 'Population migration, variation and identity', in Agarwal, S.C. and Glenross, B. A. (eds.), *Social Bioarchaeology* (Oxford), 183–211.

Ανθρώπινη κινητικότητα και βιολογικές συγγένειες στο νότιο Αιγαίο: μια πρώτη προσέγγιση στὴν ανατολική Κρήτη στὴν πρώιμη εποχή του Χαλκού

Το άρθρο παρουσιάζει τα αποτελέσματα ενός πιλοτικού ερευνητικού προγράμματος και συνδυάζει για πρώτη φορά τις βιολογικές αποστάσεις πληθυσμιακών ομάδων με τις αναλύσεις σταθερών ισοτόπων του στροντίου σε ανθρώπινα σκελετικά κατάλοιπα που προέρχονται από την Κρήτη στην Πρώιμη εποχή του Χαλκού (τρίτη χιλιετία π.Χ.). Οι συγκεκριμένες αναλύσεις προσφέρουν, με άμεσο τρόπο, μία πρώτη προσέγγιση στις βιολογικές αποστάσεις και επομένως στη γενετική ροή και στις ανθρώπινες μετακινήσεις στην ανατ. Κρήτη. Τα αποτελέσματα αυτά συνδυάζονται δε σε μία συζήτηση σε σχέση με τις ταφικές πρακτικές της περιόδου από την περιοχή αυτή, έτσι ώστε να διερευνηθεί ο χαρακτήρας της αλληλεπίδρασης των ανθρώπινων κοινοτήτων στην ανατ. Κρήτη. Τα αποτελέσματα των μετρήσεων των βιολογικών αποστάσεων συνιστούν την παρουσία ισχυρών συγγενικών σχέσεων στα δύο ταφικά σύνολα από τη θέση Κεφάλα Πετρά (βραχοσκεπή και ταφικό κτίριο 2) ενώ οι τιμές των σταθερών ισοτόπων του στροντίου υπογραμμίζουν την ντόπια καταγωγή των ανθρώπων από τα ίδια σύνολα, με αποτέλεσμα να διαπιστώνεται μία σχετική απουσία εισροής «ξένων» πληθυσμών. Οι βιολογικές αποστάσεις μεταξύ των δύο σύγχρονων χρονολογικά πληθυσμών από τη θέση Λιβάρι-Σκιάδι (θολωτός τάφος, και βραχοσκεπή) παρουσιάζουν ιδιαίτερο ενδιαφέρον και έρχονται σε αντίθεση με την περίπτωση στην Κεφάλα Πετρά καθώς εμφανίζονται σαφώς ενδείξεις ανομοιογένειας στη βιολογική συγγένεια των πληθυσμιακών ομάδων που συνάδουν με την επίσης διαφοροποιημένη εικόνα των ταφικών πρακτικών.