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OBSIDIAN CONSUMPTION IN THE LATE PLEISTOCENE – EARLY HOLOCENE AEGEAN: CONTEXTUALISING NEW DATA FROM MESOLITHIC CRETE

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This paper details the characterisation of four obsidian artefacts from the Mesolithic site of Livari Skiadi, one of only a handful of such pre-Neolithic sites on Crete. Elemental analysis using EDXRF sources the raw materials to Sta Nychia on Melos; in concert with other data, it can be suggested that this was the preferred Melian source for Late Pleistocene – Early Holocene populations. The Livari material represents the earliest Melian obsidian on Crete and by implication the first evidence of its inhabitants' connections to the Cycladic islands. When located within a broader review of Melian obsidian use in the Upper Palaeolithic – Mesolithic Aegean, it can be shown that the main consumers of these raw materials were island-based groups with immediate access to waterways that led to the Cyclades. It is suggested that distinctions between island and mainland toolkits (technical and raw material choices) may have been the product of seasonal, and environmental influences, rather than reflecting the products of different populations. Finally, certain datasets, including Livari, suggest the procurement of obsidian via intermediaries. These exchanges are viewed in avowedly social terms, with gift-giving a fundamental manner through which inter-group relations were created and maintained, whereby the circulation of obsidian can be viewed as one of those mechanisms through which Mesolithic Aegean cultural traditions came to be produced and reproduced.

INTRODUCTION

In the late 1980s three pieces of obsidian from Upper Palaeolithic strata at the Franchthi Cave were chemically characterised as coming from the source of Sta Nychia on Melos (Renfrew and Aspinall 1990). The material's importance was twofold, with these artefacts representing the earliest exploitation of Melian obsidian, and by implication the earliest maritime activity in the northern hemisphere; even allowing for lower sea-levels, a journey from the Argolid to Melos would have necessitated crossing open-water stretches of at least 20–35 km (Andel and Shackleton 1982, 453; see also Lambeck 1996, 610; Sakellariou and Galanidou 2015). While a significant discovery, the data existed in a contextual vacuum, being the only example of Late Pleistocene obsidian use in the Aegean, in contrast to the large Neolithic – Bronze Age datasets that enabled later prehistoric obsidian procurement to be discussed in terms of 'direct access', intermediary exchange, and/or itinerant traders (Perlès 1990a; Renfrew 1975; Torrence 1986). With no potential exchange intermediaries it was concluded that the Argive hunter-gatherers had themselves travelled to Melos, conceivably as part of a broader suite of fisher-forager subsistence activities in the Cyclades (Bintliff 1977, 117). This 'direct access' hypothesis was also partly based on the belief that no-one was living in the Cyclades until the Late Neolithic some 5000 years later, *i.e.* there were no local or intermediary populations through which the mainlanders could have procured their obsidian (Cherry 1981).

Subsequent archaeological work over the past two decades has served to reconfigure this image along two axes. Firstly, there are now a number of Late Pleistocene – Early Holocene sites in the Aegean whose lithic assemblages include obsidian (Kaczanowksa and Kozlowski 2013). Secondly, some of these sites are insular – including Cycladic – villages and/or campsites that date back to at least the Lower Mesolithic of the ninth millennium cal BC (Sampson 2014).[1]

[1] In the article the following abbreviations are used: BP = before present; cal = calibrated date; EDXRF = energy-dispersive X-ray fluorescence; IN = Initial Neolithic.

Fig. 1. Map showing major sites mentioned in the text (K. Freund).

This paper has two aims. Firstly it further contributes to this dataset of early obsidian use, through an 'integrated' characterisation study of four artefacts from a recently investigated site of alleged Mesolithic date at Livari Skiadi in south-eastern Crete (Fig. 1). It then provides a broader review of Aegean Late Pleistocene – Early Holocene obsidian assemblages, before offering some thoughts on the nature and significance of obsidian circulation and consumption to hunter-gatherer populations of the region.

MESOLITHIC CRETE AND LIVARI SKIADI

Until quite recently, Crete – the fifth largest island of the Mediterranean – was thought to have remained unoccupied until the foundation of an Initial Neolithic (IN) village at Knossos by migrant Anatolian farmers around 7000 cal BC (Broodbank and Strasser 1991; Cherry 1981, 43; Evans 1994). This late colonisation model was challenged in 2008 with the purported discovery of Mesolithic sites on the island's southern coast at Moni Kapsa and Plakias, an argument based on their stone tool assemblages closely resembling those from well-dated stratigraphic contexts on the Greek mainland (Galanidou 2011, 224; Strasser *et al.* 2010). One of these Plakias region sites – Damnoni – has since been excavated (Strasser 2012). The material discussed in this paper comes from Livari Skiadi (hereafter Livari) on Crete's south-eastern coast (Figs 1–2).

Today the site is located on a small and relatively flat plain enclosed by low steep hills to the north (Fig. 2). It is cut by several streams, two in quite deep gorges, while a small spring provides a perennial water supply. Aeolian and sea erosion has largely removed the Holocene soil deposits, exposing large areas of the natural bedrock: a Miocene conglomerate consisting of limestone, dolomite and chert (Brandl 2010). In 2008–10 the Greek Archaeological Service undertook a rescue excavation of a small Early–Late Bronze Age cemetery at Skiadi, 50 m from the modern seashore (Fig. 3), the site being threatened by coastal erosion and looting (Papadatos and Sofianou 2015). While the project's focus was the third to second millennia cal BC burials (in a tholos, rockshelter and 'house tomb'), it subsequently became apparent that there were also artefacts of an earlier date that we believe to be Mesolithic (see also Carter *et al.* in preparation).

The claim that Livari was a site of Early Holocene occupation is based primarily on a distinctive component of its chipped-stone assemblage (Figs 4–6). Unfortunately these finds all come from secondary contexts intermixed with Bronze Age burial material, derived from thin remnant Holocene soil deposits that were protected from erosion by the rockshelter and tombs. The entire lithic assemblage from the excavation totals 469 pieces, 251 of which are claimed to be

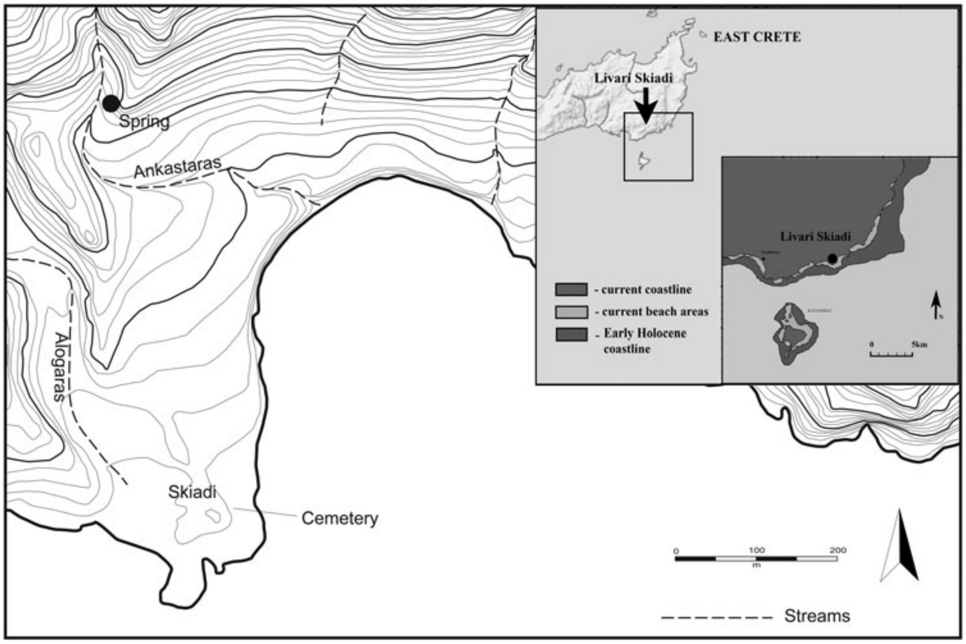

Fig. 2. Map of the Livari area and eastern Crete with reconstructed Early Holocene coastline (D. Mihailović and Y. Papadatos).

Fig. 3. View of Livari rockshelter from south-west; tholos tomb to right, 'house tomb' to left (Y. Papadatos).

Mesolithic based on their techno-typological characteristics, raw materials, nature of retouch and site-distribution. In 2014 another 20 artefacts of Mesolithic type were collected from within a 20 m radius of the excavation area.

The Bronze Age lithics are easy to distinguish, comprising fine obsidian pressure blades, typical of Cretan burial assemblages of the period (Carter 2015). The rest of the Livari assemblage is microlithic, flake-based, percussion-knapped, and dominated by chert and radiolarite (Figs 4–5). Artefacts of this form and manufacture are completely unknown from the numerous Cretan Bronze Age assemblages we have studied (Carter 2010, 2013, 2015 and references therein). Nor are they believed to be Neolithic, as Cretan assemblages of this period are almost exclusively obsidian- and blade-based (*e.g.* Christopoulou 1989); only at IN Knossos is there a significant component of flake tools, though here too obsidian prevails, at 70% of the dataset (Conolly 2008).

Fig. 4. Selection of Livari Mesolithic artefacts made of local cherts (D. Aubert).

While the chipped stone all comes from mixed contexts, we highlight the fact that the distribution of the chert percussion flake/bladelet material does *not* mirror that of the obsidian pressure blades (Table 1). This contextual distinction we strongly believe to be due to their chronological differences. For instance, the deposition of burials and grave goods (28% of the obsidian blades) deep in the rockshelter is a well-attested practice in Bronze Age Crete (Branigan 1988, 153–4), yet such a dark and cramped space makes little sense for Mesolithic activity, thus helping to explain why only 3% of the chert artefacts came from here. Indeed, most of the early material came from in front of the rockshelter; this includes the four obsidian artefacts that we believe to be of Mesolithic date (see below).

While the claim for Early Holocene activity is based mainly on the character of its chipped-stone assemblage, it is also important to note that Livari fits the Aegean Mesolithic site-location model forwarded by Runnels (2009, 60–2) at the 'intersection of woodland and aquatic habitats'. The rockshelter offered protection from the strong north winds, with a nearby spring and small caves in the gorge, while the Early Holocene coastline was only *c.*1.5 km to the south (Fig. 2). This coastal wetland plain would have provided a perennial water supply and a rich array of animals, plants, and marine resources for hunter-fisher-gatherer subsistence, a setting directly comparable to the 'foraging coastscapes' (Broodbank 2006, 211) enjoyed by the well-documented Mesolithic populations of the southern Argolid (Runnels 2009).

THE MESOLITHIC CHIPPED STONE FROM LIVARI

The Mesolithic component of the Livari chipped-stone assemblage from the excavation comprises 251 artefacts, a representative sample of which are illustrated in Figs 4–5. While most artefacts were made of chert and radiolarite that would have been collected from within a 20 km radius of the site (Brandl 2010), there were also a few made from non-local resources, including four of obsidian (Fig. 6). The latter raw material is foreign to Crete, with the nearest sources located 200–235 km to the north in the Cycladic and Dodecanesian islands (Fig. 1).

The local materials were procured in pebble and small-cobble form and worked on site, the knappers using a percussive technique to produce flakes (n = 220, 88%) from multidirectional cores, together with a smaller number of bladelets (n = 31, 12%). With only a few artefacts over 2.5 cm long, the assemblage can be characterised as microlithic, although it only included a few classic retouched geometric microliths (Fig. 5:18–20). A high proportion of this material was modified (n = 110, 44%) – yet another distinction from Cretan Bronze Age assemblages, which typically have <10% retouched pieces (Carter 2015, 116). Most of these tools have simple linear modification (Table 2), followed by 'spines', *i.e.* pointed tools used as borers/perforators or drills (Fig. 5:8–11), notches, scrapers (Fig. 5:21–22), denticulates, composite tools, those with convergent retouch (broader tips than 'spines' [Fig. 5:6–7]), backed pieces, and geometrics

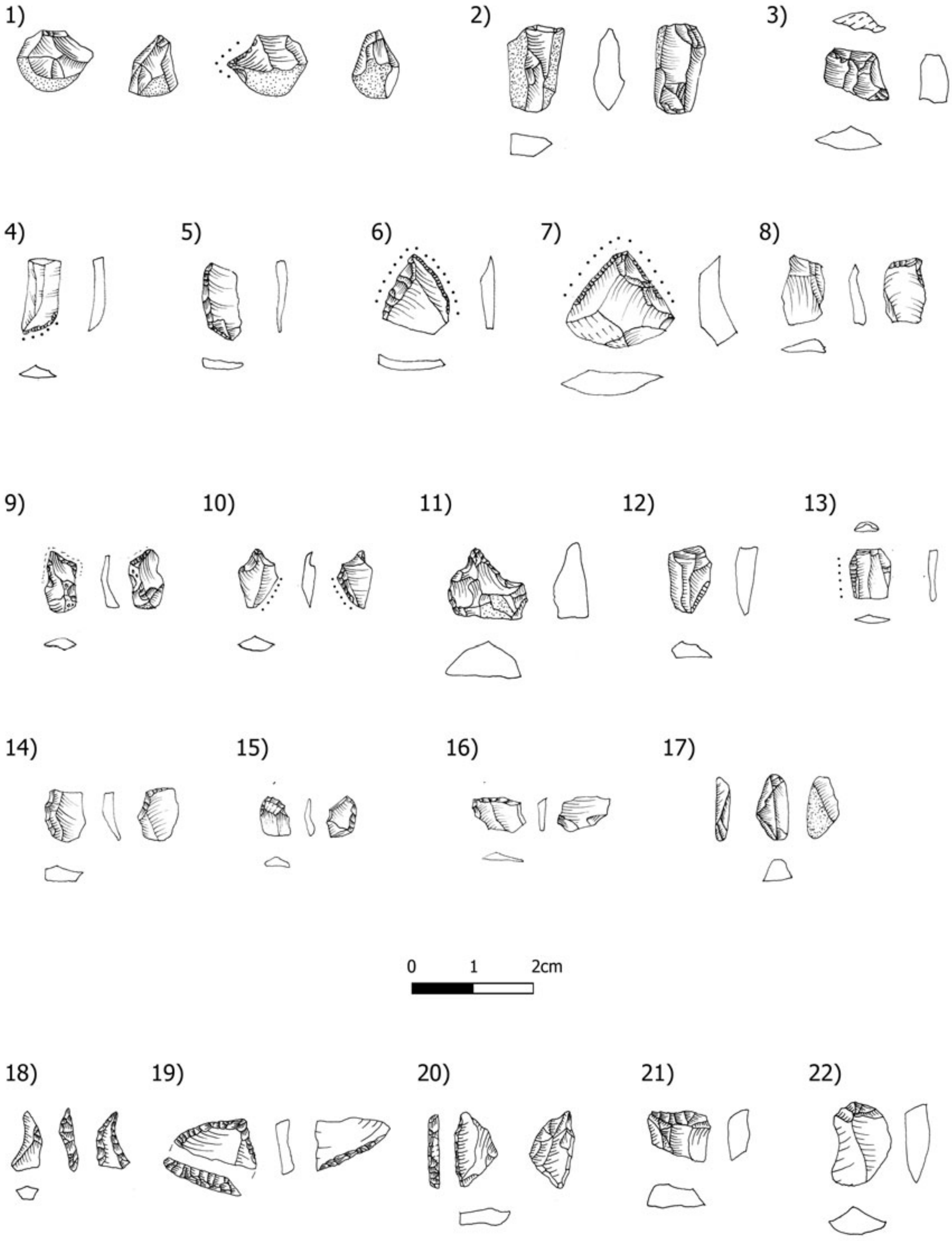

Fig. 5. Selection of Livari Mesolithic artefacts: 1: multidirectional flake core/micro chopper with spine; 2: bladelet core/pièce esquillèe; 3: core rejuvenation flake; 4–5: unidirectional retouched bladelets; 6–7: flakes with convergent retouch; 8–11: 'spines'; 12–16: retouched flakes; 17: flake; 18–20: geometrics with backed elements; 21–22: short scrapers on flakes; 14–17: obsidian; 18–22: survey material (D. Mihailović).

Table 1 Distribution of chipped stone at Livari by context and technology.

Context	Pressure Blade (n)	Pressure Blade (%)	Flake/Bladelet (n)	Flake/Bladelet (%)
Rockshelter	60	28	8	3
House tomb	51	23	40	15
Tholos tomb	29	13	143 (1 obs.)	55
Around the tholos	78	36	68 (3 obs.)	24

Fig. 6. The four Mesolithic obsidian artefacts from Livari (S. Doyle).

(Fig. 5:18–20). There were two burin spalls, but no actual burins. Inverse retouch is common, noted on a third of the modified pieces (n = 34, 33%); this is a characteristically Mesolithic mode of modification (*cf.* Perlès 1990b, doc. II.11), quite distinct from Neolithic or Bronze Age tool-making traditions. Many of the artefacts also display macroscopic use-wear, whether retouched or otherwise.

The four pieces of obsidian constitute 1.6% of the Mesolithic assemblage (Fig. 6). They include LV OBS 1 – a 'spine' made on a truncated bladelet (Fig. 5:10), LV OBS 2 – a blade-like flake (or remnant bladelet core) with possible burination from both ends, initiated from the ventral surface (Fig. 5:17), LV OBS 3 – a retouched flake (Fig. 5:15), and LV OBS 4 – a denticulated flake (Fig. 5:16). On a techno-typological basis this material is distinct from the fine Bronze Age pressure-blade products. Furthermore, in keeping with Mesolithic tool-making practices, the three modified pieces all have inverse retouch. While they form part of the same knapping tradition as the Mesolithic chert component, there is no evidence for the obsidian having been worked on site.

Given the mixed nature of the Livari deposits, the microlithic- /flake- based assemblage can be dated only by reference to *comparanda* from elsewhere. The closest parallels come from nearby Moni Kapsa (Galanidou 2011, 224), and the Plakias region sites *c.*180 km to the west (following the coast [Fig. 1]), assemblages that are similarly flake-based and microlithic, with 'spines', denticulates, notched and backed pieces well represented (Strasser *et al.* 2010, 163–71, table 2; Strasser 2012). Given that none of these sites have produced absolute dates (we await radiometric determinations for Damnoni), we need to consider parallels from overseas excavated assemblages, with those from the mainland Franchthi Cave being particularly informative (Fig. 1).

The Livari material has much to compare with Franchthi's Lower–Final Mesolithic assemblages from lithic Phases VII–IX (Fig. 7, Table 3), strata that span 8500–7000 cal BC (Perlès 2001, table 2.1). These assemblages are similarly microlithic and dominated by flakes (95%) struck from small pebble cores, with notches/denticulates the most common tools, followed by flakes with simple linear retouch, scrapers, backed pieces, and geometrics *inter alia* (Perlès 1990b, 23–93, figs. 5–8, 13–19, 21–2). The Livari material also includes proportionally more bladelets than at Franchthi VII–IX (12% *v.* 4–5%), and instances of inverse retouch (33% *v.* 17%); these are both

Table 2 Livari percussion flake and bladelet assemblage by raw material and modification type.

	Linear	'Spine'	Notch	Scraper	Denticulate	Composite	Convergent	Backed	Geometric
Chert									
Flake	18	12	12	8	8	10	6		3
Blade-like flake	4	8	1	1	2			2	
Bladelet	1	1	1		1	1		2	
Core				3	1				
Core-tablet				1					
Obsidian									
Flake	2								
Blade-like flake									
Bladelet		1							
Total (n = 110)	25 (23%)	22 (20%)	14 (13%)	13 (12%)	12 (11%)	11 (10%)	6 (5%)	4 (4%)	3 (3%)

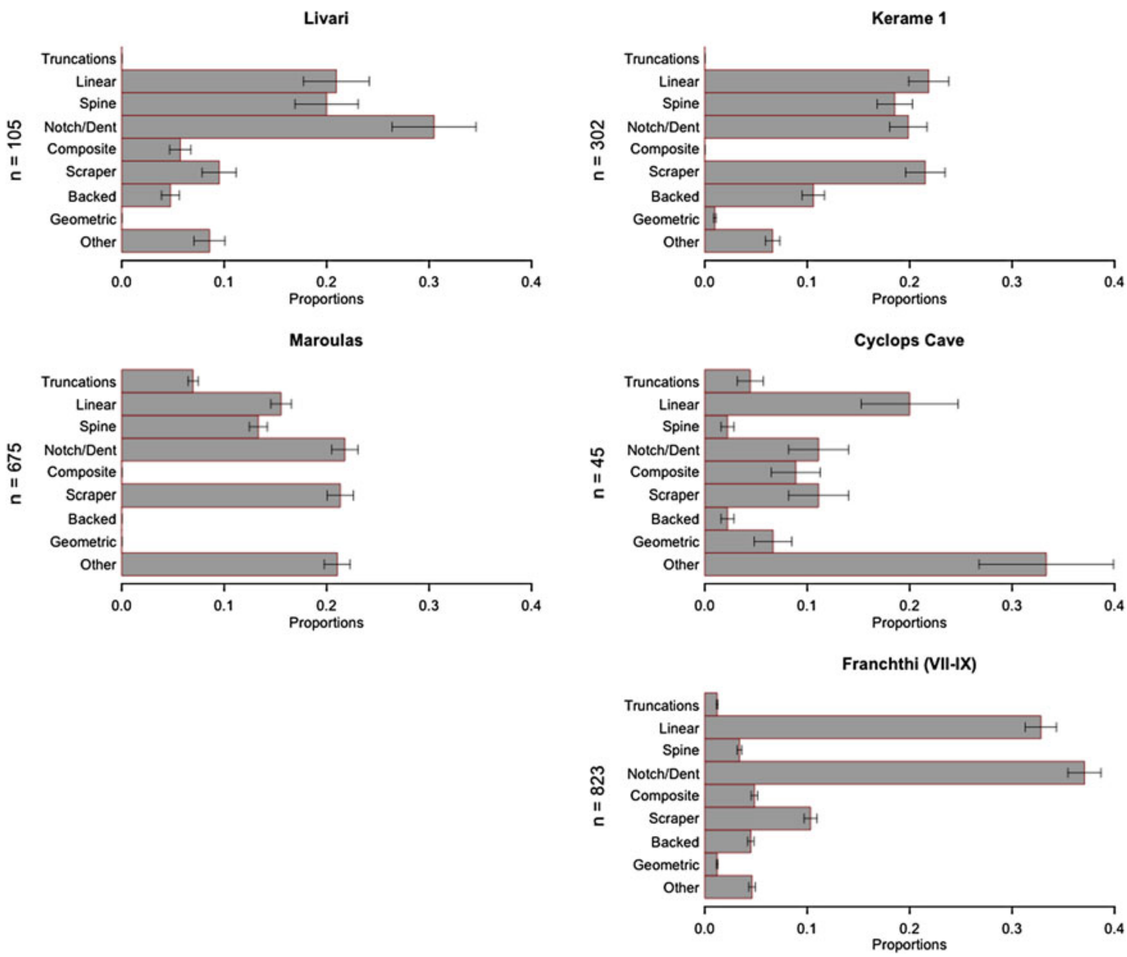

Fig. 7. Composition of lithic assemblages at the major southern Aegean Mesolithic sites discussed in the text (D. Contreras).

features more characteristic of Final Palaeolithic assemblages (Perlès 1987), *i.e.* the Livari material is potentially of earlier Mesolithic date (Phase VII in Franchthi terms).

While strong links can be established with the Franchthi lithics, Livari is ultimately better viewed as part of the 'early Holocene Aegean island lithic tradition' (Figs 1 and 7, Table 3) as defined by Sampson, Kaczanowksa and Kozlowski (2010, 68–9) through reference to excavated material from Maroulas on Kythnos in the Cyclades (early–mid ninth millennium BC), the Cave of the Cyclops on Youra in the Sporades (*c.*8600–7800 BC), and Kerame 1 on Ikaria in the northern Aegean (Sampson 2008; Sampson, Kaczanowksa and Kozlowski 2010, 2012). These assemblages are again flake-dominated, with denticulates, notches, perforators, scrapers and backed pieces, but have few opposed platform cores compared with mainland sites (n = 3/11 at Livari). The Cyclops Cave aside, these insular assemblages also have notable quantities of 'spines', which is a further distinction from the Franchthi material (Fig. 7).

ELEMENTAL CHARACTERISATION OF THE LIVARI OBSIDIAN BY EDXRF

In order to know where the Livari obsidian originated it was necessary to undertake a chemical characterisation study of the four artefacts' raw materials. The aim of such an analysis is to generate an elemental profile that could be matched exclusively with the chemical signature

Table 3 Comparing relative proportions of flakes and blades/bladelets, and their retouched tool-types, from Mesolithic Livari and Late Pleistocene – Early Holocene material from the mainland and insular Aegean.

Site	Date	Flake	Blade(let)	Retouch	Linear	'Spine'	Notch/Dent.	Composite	Scraper	Backed	Geom.	Other
Livari	?M	88%	12%	44%	23%	20%	24%	10%	12%	4%	3%	6%
Franchthi VI	UP	91%	9%	n.d.	9%	–	8%	–	7%	40%	28%	7%
Franchthi VII	LM	97%	3%	n.d.	34%	3%	33%	4%	11%	8%	2%	6%
Franchthi VIII	UM	95%	5%	7%	34%	4%	41%	5%	10%	–	–	6%
Franchthi IX	FM	n.d.	n.d.	n.d.	28%	3%	46%	12%	3%	1%	3%	2%
Kerame 1	LM	97%	3%	n.d.	22%	19%	20%	–	22%	11%	1%	7%
Maroulas	LM	97%	3%	11%	19%	16%	26%	–	24%	3%	4%	8%
Cyclops Cave	L/UM	93%	7%	25%	20%	2%	11%	9%	11%	2%	7%	33%

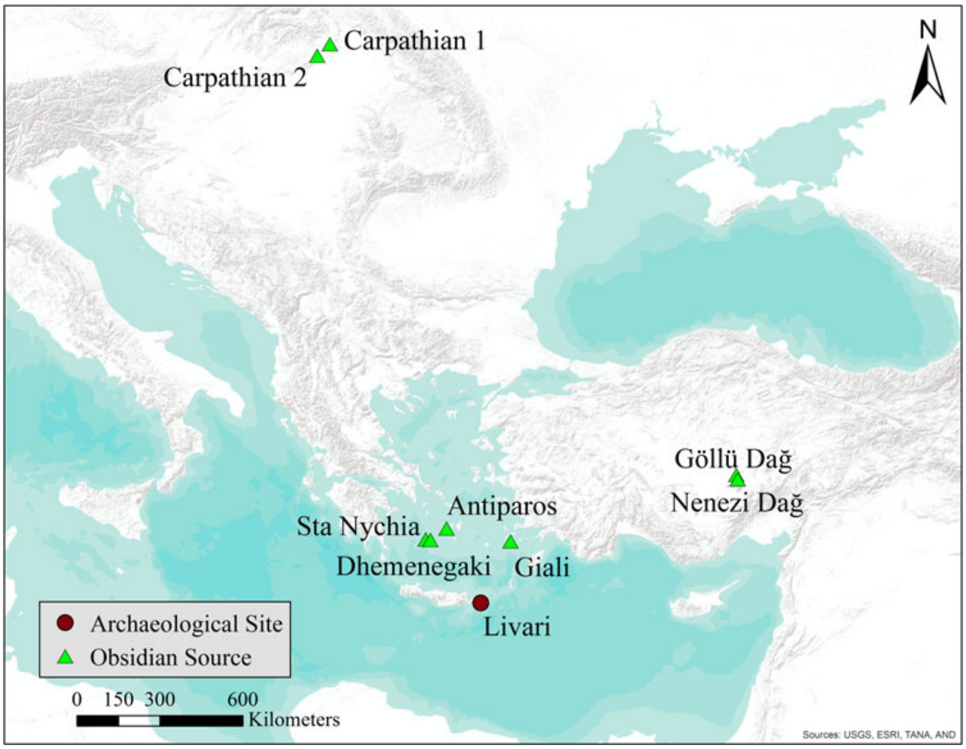

Fig. 8. Livari and the major obsidian sources of the region (K. Freund).

produced under the same analytical conditions from geological samples of known origin (*cf.* Pollard and Heron 2008, 75–87). The raw materials under consideration come from the three Aegean islands where obsidian occurs naturally (Fig. 8), namely Melos and Antiparos in the Cyclades, and Giali in the Dodecanese (Renfrew, Cann and Dixon 1965). The two Melian sources of Sta Nychia (Adhamas) and Dhemenegaki provided the most important raw materials for prehistoric tool production, first exploited by Upper Palaeolithic populations of the Greek mainland, thereafter circulating throughout the Aegean, and well represented on Cretan sites from the earliest Neolithic (Carter 2009, 202–4).

Obsidian from Giali was used from the Mesolithic (Sampson, Kaczanowksa and Kozlowski 2012, 19), though its spherulitic character seems to have largely restricted its use for tool-making to local Dodecanesian populations (Carter 2009, 201–2; Georgiadis 2008). On Crete, small quantities of Giali obsidian are attested from Early Neolithic Knossos (Evans 1994, 5), but thereafter the raw material was largely ignored until the Bronze Age, at which point it was employed for the manufacture of prestige groundstone items (Carter *et al.* 2016). While the obsidian from the Soros Hill source on Antiparos has an excellent knapping quality, it is only available in pebbles and small cobbles, thus restricting its tool-making utility; it seems to have only ever been used by local communities from the Late Neolithic and has never been documented on Crete (Carter and Contreras 2012).

The study also included geological samples from the central Anatolian sources of Göllü Dağ and nearby Nenezi Dağ (Fig. 8), as small amounts of these materials are known from Crete, albeit thus far exclusively from Bronze Age contexts (Bellot-Gurlet, Pelon and Séfériadès 2008; Carter and Kilikoglou 2007). We also considered obsidian from Slovakia and Hungary (the Carpathian 1 and 2 sources), which has been documented from later Neolithic sites in the Aegean, though none from Crete as yet (Kilikoglou *et al.* 1996; Milić 2014).

The elemental data pertaining to Aegean, central Anatolian and Carpathian obsidian source samples used in this study were also run by the McMaster Archaeological XRF Lab (MAX Lab) under the same analytical conditions as the Livari artefacts.

Analytical procedures

The four artefacts were analysed whole and non-destructively at the MAX Lab by a Thermo Scientific *ARL Quant'X* EDXRF spectrometer. XRF techniques are well established in Aegean obsidian characterisation studies, and are capable of discriminating the products of all sources known to have been used by the region's prehistoric populations (De Francesco, Crisci and Bocci 2008; Frahm, Doonan and Kilikoglou 2014; Milić 2014). The artefacts were first cleaned in an ultrasonic tank with distilled water for ten minutes, then mounted on a sample tray with the flattest surface possible positioned as the X-ray target. The analytical protocols and methods followed those devised by Shackley (2005, appendix; Poupeau *et al.* 2010, 2711).

The spectrometer is equipped with an end window Bremsstrahlung, air-cooled, Rh target, 50 watt, X-ray tube with a ≤7.6 micron (0.3 mil) beryllium (Be) window, an X-ray generator that operates from 4 to 50 kV in 1 kV increments (current range, 0–1.98 mA in 0.02 mA increments), and an Edwards RV8 vacuum pump for the analysis of elements below titanium (Ti). Data is acquired with a pulse processor and analogue to digital converter.

In the study we ran the artefacts under two analytical conditions. The pieces are first run under a Mid Zb analysis condition with the X-ray tube operated at 30 kV using a 0.05 mm (medium) Pd filter in an air path for 200 seconds livetime to generate X-ray intensity Kα-line data for elements titanium (Ti), manganese (Mn) and iron (Fe), zinc (Zn), gallium (Ga), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), lead (Pb) and thorium (Th). The second is a High Zb analysis condition with the X-ray tube operated at 50 kV using a 0.63 mm (thick) Cu filter in an air path to detect the element barium (Ba).

Trace element intensities were converted to concentration estimates by employing a least-squares calibration line ratioed to the Compton scatter established for each element from the analysis of international rock standards. These comprise AGV-2 (andesite), BCR-2 (basalt), BHVO-2 (hawaiite), BIR-1a (basalt), GSP-2 (granodiorite), QLO-1 (quartz latite), RGM-2 (rhyolite), SDC-1 (mica schist), STM-2 (syenite), TLM-1 (tonalite), and W-2a (diabase) from the US Geological Service [USGS], plus JR-1 and JR-2 (both obsidian) from the Geological Survey of Japan. In turn, the USGS standard RGM-2 is analysed during each sample run to check machine calibration and accuracy, with a maximum of 19 artefacts, plus standard, per analysis. The data is then translated directly into Excel for Windows software for manipulation and analysis.

In Excel form, data is normalised to the standard reference sample – RGM-2 – prior to further analysis and plotting. This process consists of determining the relative error in the standard sample's concentration measurements and applying this difference to the individual artefacts analysed for each tray processed by the instrument. This procedure ensures source and artefact data results are consistent based on the reference, thus providing a more accurate match between chemical fingerprints.

Results: raw material sources

The elemental concentrations of the Livari artefacts and RGM-2 standard, analysed together in a single run, are presented in Table 4. Provenance was assigned through comparing the artefacts' chemical signatures with those of the Aegean, central Anatolian and Carpathian source samples.

Using a Sr/Zr *v.* Rb/Sr ratio plot, the artefacts' elemental profile can be clearly matched with that of obsidian from the Sta Nychia source on Melos (Fig. 9). The data is expressed in ratio form not only as a means of distinguishing the source materials in a binary format, rather than the ternary discriminant plots that have previously been employed in Aegean studies (Carter and Kilikoglou 2007, fig. 3; Frahm, Doonan, and Kilikoglou 2014, fig. 7; Milić 2014, figs. 3–4), but also because of concerns surrounding the elemental data. Experimentally it has been demonstrated that small samples can be problematic for EDXRF because if the detector's field of view extends beyond the artefact's margins, then the relative deficit in X-rays from the object will result in lower-than-expected elemental concentration values (Davis *et al.* 1998, 169). The Livari microliths, all under 1.5 cm long/wide and ≤0.4 cm thick (Fig. 6), presented just such a problem for us, as evidenced by lower counts for many of the targeted elements compared with

Table 4 Elemental compositions of Livari obsidian artefacts as determined by EDXRF (values expressed in ppm [parts per million]).

Sample	Ti	Mn	Fe	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th	Source
LV OBS 1	1131	467	10598	3	68	14	116	95	19	120	9	656	14	15	Sta Nychia
LV OBS 2	1323	467	11741	5	70	14	112	89	16	114	7	583	14	7	Sta Nychia
LV OBS 3	1057	357	8998	16	123	9	91	79	17	99	8	497	7	2	Sta Nychia
LV OBS 4	1300	489	11166	10	119	17	123	102	19	123	9	531	18	12	Sta Nychia
RGM-2	1519	311	13978	21	40	22	146	105	23	231	9	786	24	9	Standard

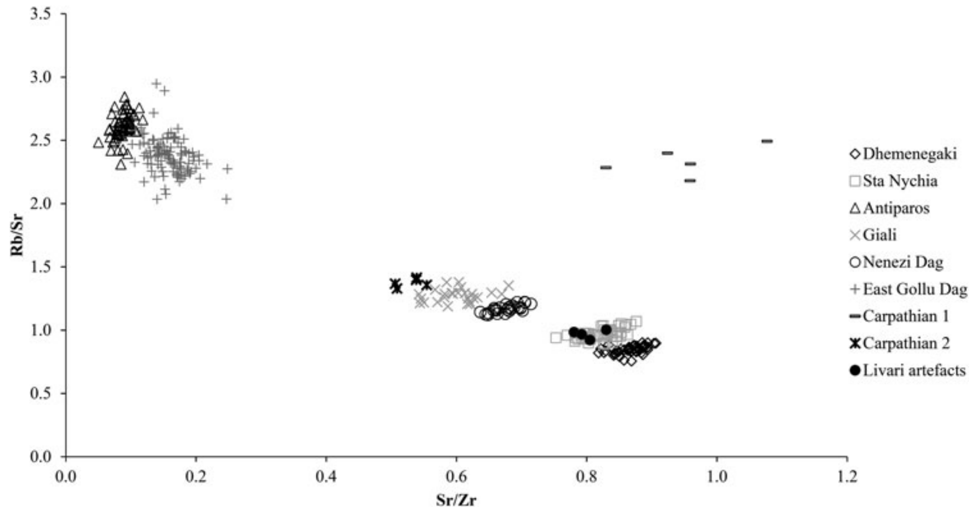

Fig. 9. Bivariate ratio plot of Sr/Zr *v.* Rb/Sr for Livari artefacts and geological samples from pertinent Aegean, Anatolian and Carpathian obsidian sources.

what one should expect from source samples, not least Ti, Mn, Fe, plus Sr, Zr, Ba and Th (Table 5). Conversely, the Zn values were anomalously high. In this case the issue is probably instrumental, as this element recurrently trends high compared with expected values, on both the MAX Lab's *Quant'X* and that from our collaborator's UC Berkeley instrument (Hancock and Carter 2010; Poupeau *et al.* 2010). It was possible to resolve all of these problems, and to successfully source the Livari artefacts' raw materials, by working with elemental ratios rather than absolute values.

THE LIVARI DATA IN CONTEXT

To appreciate the significance of the Livari obsidian assemblage we need to consider more generally the consumption of Melian obsidian during the Late Pleistocene to Early Holocene.

Lower–Middle Palaeolithic (Middle Pleistocene)

A major recent development in the field concerns alleged earlier Palaeolithic activity in the Aegean Basin (Runnels 2014). The only claimed use of obsidian during this period comes from Melos itself, namely a biface from a surface assemblage from Triadon Bay, while similar items are also reported from the Sta Nychia source (Runnels 2014, 217; see also Chelidonio 2001). Given that this is all surface material, it remains to be proved that Melian obsidian was being exploited in the Middle Pleistocene.

Upper Palaeolithic (Late Pleistocene)

The earliest well-dated evidence for the use of these resources comes from Upper Palaeolithic contexts on the Greek mainland (Fig. 1, Table 6), specifically an artefact from a Late Pleistocene stratum in the Schisto Cave in Attica dated by an obsidian hydration method to 14,539 ± 1280 BP (Laskaris *et al.* 2011, 2477, table 1; Mavridis *et al.* 2013, 253). A larger assemblage is published from the Franchthi Cave, whose oldest securely dated material comes from the eleventh millennium cal BC, lithic phase VI (Perlès 1987, 142–3). Obsidian is in fact reported from strata extending back to the Middle Palaeolithic at Franchthi; however, in each of these instances the material was believed to be intrusive from later levels (Table 6). These 12

Table 5 Mean elemental values with standard deviations for Melos source samples (Dh. = Dhemenegaki; SN = Sta Nychia) and Livari obsidian artefacts as determined by EDXRF (values expressed in ppm [parts per million]).

Sample	Ti	Mn	Fe	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th
Dh. (n = 50)	1371 ± 82	467 ± 31	12719 ± 730	7 ± 4	40 ± 4	14 ± 3	110 ± 7	113 ± 5	19 ± 2	131 ± 5	9 ± 3	607 ± 58	15 ± 3	12 ± 4
SN (n = 51)	1288 ± 133	470 ± 46	11369 ± 1246	7 ± 4	39 ± 6	13 ± 2	117 ± 7	99 ± 5	19 ± 2	121 ± 4	9 ± 2	644 ± 70	15 ± 3	14 ± 3
Livari (n = 4)	1203 ± 130	445 ± 59	10626 ± 1181	9 ± 6	95 ± 30	14 ± 3	111 ± 14	91 ± 10	18 ± 2	114 ± 11	8 ± 1	567 ± 69	13 ± 4	9 ± 6

Table 6 Mesolithic Aegean sites with obsidian: date, proportion of assemblage, linear distance from source (Dh. = Dhemenegaki; SN = Sta Nychia).

Site	Region	Period	Date	Obsidian	Km to Melos	Comments
Franchthi Cave (0)	Argolid	Middle Palaeolithic	pre-40,000 BP	1	135	contaminated
Franchthi Cave (II)	Argolid	Upper Palaeolithic (Aurignacian)	23rd mill. BP	4	135	contaminated
Franchthi Cave (III/IV)	Argolid	Upper Palaeolithic / mixed	mixed	1	135	'likely contaminated'
Franchthi Cave (VI)	Argolid	Final Palaeolithic	11th mill. BC	12 (<1%)	135	3 SN
Franchthi Cave (VI/VII)	Argolid	F. Pal. / Lower Mesolithic	11th mill. BC	7 (0.2%)	135	
Klisoura Cave I	Argolid	Upper Palaeolithic (Aurignacian)	20th mill. BP	1 (0.1%)	170	contaminated
Ulbrich Cave (IV–V, VII)	Attica	Upper Palaeolithic	n.d.	unknown	190	No quantified data
Schisto Cave	Attica	Upper Palaeolithic	15th mill. BP	1 (0.8%)	150	
Franchthi Cave (VII)	Argolid	Lower Mesolithic	8500–8000 BC	40 (0.1%)	135	4 SN, 1 Melos
Franchthi Cave (VIII)	Argolid	Upper Mesolithic	8000–7500 BC	300+ (2.8%)	135	1 SN, 1 Dh., 1 Melos
Franchthi Cave (IX)	Argolid	Final Mesolithic	7200–7000 BC	1 (0.2%)	135	possibly intrusive
Klisoura Cave I	Argolid	Lower Mesolithic	8700–8000 BC	3 (0.2%)	170	
Klisoura Cave I	Argolid	Upper Mesolithic	8th mill. BC(?)	2 (0.1%)	170	
Ulbrich Cave (II–III)	Argolid	Mesolithic	n.d.	unknown	190	No quantified data
Schisto Cave	Attica	Upper Pal. – Lower Mesolithic	10,000–9300 BC	1 (0.8%)	150	
Cyclops Cave, Youra	Sporades	Lower–Upper Mesolithic	8600–7000 BC	15 (8.4%)	295	
Maroulas, Kythnos	Cyclades	Lower Mesolithic	8800–8600 BC	1911 (31.1%)	75	2 Melos
Kerame 1, Ikaria	Dodecanese	Lower Mesolithic	n.d.	972 (26%)	170	
Livari	Crete	Lower Mesolithic	n.d.	4 (1.6%)	235	

Fig. 10. Aegean Mesolithic sites with Melian obsidian by proportion of chipped-stone assemblage (K. Freund). (The Ulbrich Cave is marked in Fig. 1, but is not included here because of the lack of quantified data.)

obsidian artefacts (three retouched), constitute a mere <1% of the total lithic phase VI assemblage (Perlès 1987, 142–3). Three pieces of obsidian were sourced to Sta Nychia, though it should be noted that they were irradiated together, with the resultant data a blended chemical signature of the three (Renfrew and Aspinall 1990, 263–4). While an unconventional analytical process (they were too small to analyse individually), the source assignation seems accurate given the high yttrium value (Renfrew and Aspinall 1990, table XLI).

Tiny quantities of obsidian are also reported from throughout the Early Upper Palaeolithic – Mesolithic sequence of another Argive site, the Ulbrich Cave (Table 6). Unfortunately, the 1920s excavation has never been published fully and there are concerns that obsidian from early strata were intrusive (Galanidou 2003, 108–9). Finally, we might note that preliminary reports of the Klisoura Cave excavations mentioned a piece of obsidian from an Early Upper Palaeolithic stratum of the twentieth millennium BP (Koumouzelis *et al.* 2001, 524–5, tables 1 and 4); this piece is now believed to have come from a deposit with intrusive Mesolithic material (J. Kozlowski, pers. comm.).

Mesolithic (Early Holocene)

Mainland hunter-gatherers continued to procure Melian obsidian into the Mesolithic (ninth–eighth millennia cal BC), as evidenced at the Franchthi, Ulbrich, Klisoura 1 and Schisto caves (Fig. 10). Obsidian remained a tiny proportion of these chipped-stone assemblages (0.1–2.8%), although in absolute terms the Upper Mesolithic assemblage from the Franchthi Cave is relatively large, with over 300 pieces (Table 6). This site also provides us with the most temporally nuanced Early Holocene dataset. In the Lower Mesolithic lithic phase VII assemblage (n = 40, *c.*0.1%), the presence of a core, cortical flakes (one retouched) and splintered pieces indicates that obsidian was worked locally, having been procured as raw and/or part-decorticated nodules (Perlès 1990b, 30, 36, figs. 4–5). Five artefacts were analysed, the raw materials of four being sourced to Sta Nychia and one 'to Melos' (Durrani *et al.* 1971; Renfrew and Aspinall 1990).

The Upper Mesolithic (lithic phase VIII) obsidian assemblage is the proportionally largest of all Early Holocene mainland assemblages (2.8%), the material imported in the form of raw nodules that were then flaked on site (Perlès 1990b, 48, Fig. 10). That blanks longer than 1 cm were retouched at a higher rate than those made from local raw materials suggests that obsidian had for the first time taken on a specific role within the community's lithic tradition (Perlès 1990b, 48). Three pieces were sourced, one to Sta Nychia, one to Dhemenegaki, and one 'to Melos'

(Durrani *et al.* 1971; Renfrew and Aspinall 1990). Only one obsidian artefact, possibly intrusive, came from the Final Mesolithic phase IX (Perlès 1990b, 85).

Staying in the Argolid (Fig. 10), the Klisoura Cave material comprised a flake and chip from Layer 3 (Upper Mesolithic), plus three pieces from Layer 5a (Lower Mesolithic), including a retouched bladelet and a burin spall (Kaczanowksa, Kozlowski and Sobczyk 2010, 188–90, tables 10–11; Koumouzelis, Kozlowski and Ginter 2003, 113, 117, figs. 8.4: 30, 8.5: 28, 29). While obsidian is reported throughout the Mesolithic sequence of the Ulbrich Cave, there is unfortunately no quantified data, or descriptions of the artefacts (Galanidou 2003, 107–8). Finally, an obsidian microlith was found at Kandia 5, a Mesolithic survey site in the Argolid (Runnels *et al.* 2005, 270), while one of the two pieces of obsidian from the Schisto Cave in Attica should date to the Early Holocene at 9,533 ± 1198 BP (Laskaris *et al.* 2011).

It is when we turn to insular populations of the Cyclades, Sporades and northern Aegean that we find evidence for the procurement and working of significantly larger quantities of obsidian at this time (Fig. 10, Table 6). At the Lower Mesolithic village of Maroulas on Kythnos obsidian represented almost a third (31%) of the chipped-stone assemblage, the material imported as raw or part-decorticated nodules and worked on site (Kaczanowksa and Kozlowski 2013, 21). At Kerame 1 on Ikaria, Melian obsidian comprised a quarter of the Lower Mesolithic assemblage, while the distinctive white spotted obsidian from Giali constituted a further 15% (Sampson, Kaczanowksa and Kozlowski 2012, 19–20, fig. 13). In contrast to Maroulas, the inhabitants of Kerame 1 imported largely decorticated nodules, rather than unmodified raw materials. Two obsidian artefacts from this assemblage were sourced to Melos, and hydration dated to 11085 ± 3282 and 10152 ± 1643 BP (Laskaris *et al.* 2011). To the north, the Cyclops Cave on Youra in the Sporades generated 15 pieces of obsidian from its Lower Mesolithic sequence, some 8% of the chipped stone, a mix of knapping debris and end products (blades), with just over half the artefacts (n = 8) retouched into formal tools (Kaczanowksa and Kozlowski 2008, 170, tables 8.1–8.2). Obsidian hydration dates from three of the Cyclops Cave artefacts spanned 10968 ± 640–12017 ± 1875 BP (Laskaris *et al.* 2011).

Finally, we have the Livari data, the first such material from Early Holocene Crete. Here obsidian comprises a tiny proportion of the site's chipped stone, proportionally comparable to that from the mainland assemblages of Franchthi VII and the Klisoura Cave (Table 6).

DISCUSSION AND CONCLUSIONS

So what conclusions can be drawn concerning the circulation and consumption of Melian obsidian by the Late Pleistocene – Early Holocene hunter-gatherers of the Aegean? Firstly, despite the recent claimed discoveries of Lower and Middle Palaeolithic in the Aegean basin (Runnels 2014), it remains the case that the earliest use of Aegean (Melian) obsidian dates to the Late Pleistocene, an era when we also witness the establishment of hunter-gatherer populations on Cyprus (Simmons 1999), maritime ventures that part-represent the 'birth of Mediterranean seafaring' (Broodbank 2006, 208–11).

Secondly, the fact that the Livari artefacts were characterised as being made of Melian obsidian came as no surprise, as these were the primary sources exploited by Cretan communities throughout later prehistory (Carter 2009, 202–4). Moreover, at virtually every Upper Palaeolithic and Mesolithic Aegean site where obsidian is reported, the material only ever has the visual appearance and/or chemical composition of Melian raw materials. Only at the northern Aegean Mesolithic community of Kerame 1 (Ikaria) is there evidence for the procurement of *both* Giali and Melos obsidian (Kaczanowksa and Kozlowski 2013, 20, 22; Sampson, Kaczanowksa and Kozlowski 2012, 19).

That the Livari artefacts were all made of Sta Nychia obsidian is suggestive, given that eight of the nine pieces associated with the Late Pleistocene – Early Holocene strata at the Franchthi Cave also came from this source (Table 6). While the sample sizes are too small to make a convincing claim that one Melian source was preferred by these hunter-gatherers, it is important to remind ourselves that Sta Nychia and Dhemenegaki may have been exploited quite differently over time, despite the fact that they are only 12 km apart (*cf.* Carter 2003). Indeed, the sources of Göllü Dağ and Nenezi Dağ in central Anatolia (Fig. 8) had radically distinct histories, yet lay only 7 km from one another (*cf.* Carter and Milić 2013, 496–7, fig. 2). Recent obsidian sourcing projects suggest that – at least from a Cretan prehistoric perspective – there were distinct periods of raw material preference, with a clear bias towards Sta Nychia obsidian during the second millennium cal BC (Carter and Kilikoglou 2007; Carter and Kilikoglou in preparation). As to whether these shifting raw material choices were related to changing transportation technologies (paddled versus sailing craft) and/or the reconfiguration of quarry docking points due to post-glacial sea-level changes (*cf.* Lambeck 1996), it is impossible to say at this juncture. To clarify this issue one would ideally undertake detailed bathymetric studies around the Melian coastline in conjunction with the results of a major sourcing study of Upper Palaeolithic to Late Bronze Age assemblages.

The fact that the Livari chipped stone contained only a tiny proportion of obsidian was also quite unsurprising given the site's location. This is not a geographical issue *per se*, but a period-specific one, given that obsidian was the dominant raw material for the Bronze Age burial assemblage (Carter 2015). In short, the Mesolithic sites with obsidian-rich assemblages are island-based populations who could directly access seafaring routes to the Cyclades, with far smaller quantities being accessed by mainland communities and/or those on distant coastlines such as Livari; linear distance from source is on its own an insufficient explanation for these distribution patterns (Fig. 10, Table 6). The locational influence upon raw material consumption patterns is of great interest given previous claims for differences in knapping traditions between insular and continental Mesolithic populations. Here we return to the alleged existence of an 'early Holocene Aegean island lithic tradition', as defined by Sampson, Kaczanowksa and Kozlowski (2010, 68–9), who juxtaposed the assemblages of the Cyclops Cave, Maroulas and Kerame 1 with that of the Franchthi Cave. While differences certainly exist between these sites' assemblages, as for example between their respective core technologies and tool-types, the distinction between island-based and mainland assemblages is perhaps not as clear-cut as originally suggested (Fig. 7). Moreover, these may be false dichotomies if the inference is that different traditions represent different populations.

The question here is whether these Mesolithic settlements of the Cyclades, Sporades and northern Aegean constituted perennial communities, or 'merely' seasonal occupations inhabited by hunter-gatherers who spent winter on the mainland and/or larger islands such as Crete. Powell's study of the fish remains from the Cyclops Cave led her to claim that the site was probably only seasonally occupied, specifically during those periods 'when the sailing season allowed sailors to travel to Youra from the nearby mainland' (Powell 2011, 175). Similarly, Kerame 1 is viewed as a 'seasonal base', while only Maroulas is considered to have been a 'permanent or semi-permanent' settlement by the excavator (Sampson 2014, 67). Accordingly, one might view the major distinctions in Mesolithic levels of obsidian consumption, and the subtle differences in knapping traditions between these insular and continental sites, as reflecting seasonal activities and environmental factors rather than more deeply-rooted cultural differences. Indeed, it may have been the case that the inhabitants of Franchthi (or an analogous Argive/Attic site) were spring-/summer-based residents of sites such as Maroulas, returning to the mainland during the autumn with a range of resources they had collected from the islands, such as Melian obsidian, dried fish, shells or andesite (*cf.* Perlès 2001, 34–7).

While a case can be made for some of these Greek mainland / Aegean island populations being linked by cyclical mobile residency patterns part-driven by the mainlanders' seasonal exploitation of such high-yield migratory fish as tunny (Perlès 1987, 144–5; 2001, 28), one wonders if Livari's relationship with Aegean resources may have been articulated in a slightly different manner. The small amount of obsidian at Livari, and the fact that the items are in the form of ready-made implements, suggests that in this case the group procured them through intermediary exchange, rather than making their own forays into the Aegean (*cf.* Renfrew 1975, 46–8). If/when Mesolithic camp sites are discovered on Crete's north coast, one wonders if they will have obsidian-rich toolkits (as we see in later prehistory [Carter 2007, 691–2]), and by implication their occupants will have been the trade partners of those subsisting along the southern littoral.

Above and beyond where these interactions took place, we might also consider the exchange of obsidian as an avowedly social act, the kind of interaction that underpinned the initiation and maintenance of interpersonal relations, something that may have occurred at specific times and places within the cycles of these hunter-gatherers' lives. One obvious locus of connectivity would have been the obsidian quarries themselves. Based on ethnohistorical accounts of quarrying by small-scale societies, it is reasonable to suggest that the Melian obsidian sources would have been powerful places in the landscape, imbued with group histories (given their antiquated histories of use by the Early Holocene), and renowned arenas of gathering, exchange, marriage, feasting and the sharing of knowledge (*cf.* Hampton 1999; Jones and White 1988; McKenzie 1983; Taçon 1991 *inter alia*). The exploitation of Melian obsidian would thus have represented one of the means by which Mesolithic Aegean cultural (lithic) traditions came to be produced and reproduced.

Returning to the artefacts themselves, an interesting aspect of these Late Pleistocene – Early Holocene data is that the obsidian was being flaked and modified in the same way as those artefacts made from local cherts, *i.e.* there were common tool-making traditions, irrespective of raw material (Kaczanowksa and Kozlowski 2013, 20–4). With freshly flaked obsidian being significantly sharper than chert, radiolartite *inter alia*, it might have been reasonable to expect that obsidian was being procured to fulfil a particular function, perhaps as specialised cutting implements. Yet the Livari evidence suggests otherwise, with the tools' form implying a range of uses, namely a borer/perforator, two small cutting implements and a carving and/or spokeshave-like tool (Fig. 6). Only at Lower Mesolithic Maroulas was obsidian preferred for blade/bladelet manufacture and retouched tools (Sampson, Kaczanowksa and Kozlowski 2010, 42), while at Upper Mesolithic Franchthi (lithic phase VIII) obsidian blanks longer than 1 cm were retouched at a higher rate than those made from local chert (Perlès 1990b, 48). Dedicated use-wear studies are the only way to clarify the relationship between raw material and tool function (*cf.* Astruc 2002; Vaughan 1990).

In considering the issue of functionality, one might broaden the question – particularly with regard to the Livari and Greek mainland data – to how we interpret rare objects of distant materials. This is an important and often under-theorised question that recurrently faces archaeologists. Tykot (2011) offers us a useful distinction between 'exotica', *i.e.* something non-local or foreign that is 'appreciated by the local culture' (*i.e.* has some recognised use-value), and 'eccentric', namely distant and unusual media whose value might be constructed primarily with reference to its difference, rather than its utility (*cf.* Helms 1988). In the early Aegean, were these obsidian artefacts simply a component of a larger toolkit, stored and used alongside implements of other raw materials, or were they treated differently, consumed in non-utilitarian fashions, and perhaps employed as ritual paraphernalia, or apotropaic tokens (*cf.* Nakamura 2010)? Alas, the contextual information that might help us comprehend the role of these obsidian artefacts in the lives of these hunter-gatherer communities is largely absent from our Aegean case studies, not least at Livari, where all the material came from mixed deposits.

One final important point to take from this study is that the Livari obsidian provides the first evidence for pre-Neolithic maritime connectivity between the inhabitants of Crete and the Cyclades. In a period prior to the advent of sailing craft such a voyage would probably have involved paddling a counter-clockwise route from eastern Crete via the southern Dodecanese and then into the Cyclades via Amorgos (Agourides 1997, 11, fig. 5). We thus have a situation whereby migrant farmers coming out of south-western Anatolia (or along the Mediterranean coast), on arriving in Rhodes or Karpathos, might thus have learned of the safest routes to Crete through interaction with indigenous hunter-gatherer populations. The modest Livari obsidian assemblage can therefore be viewed as contributing to the evidence to support the hypothesis that the establishment of a Neolithic economy on Crete was a planned affair (Broodbank and Strasser 1991), with Anatolian seafarers drawing on ancient routes and maritime knowledge, rather than launching into waters unknown (Carter *et al.* in preparation).

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Κατανάλωση οψιανού κατά το Ύστερο Πλειστόκαινο- Πρώιμο Ολόκαινο στο Αιγαίο: πλαισιοποιώντας τα νέα δεδομένα από τη Μεσολιθική Κρήτη

Σε αυτό το άρθρο παρατίθεται η ανάλυση τεσσάρων τεχνέργων από οψιανό από τη Μεσολιθική θέση Λιβάρι Σκιάδι, μια από τις σπάνιες προ- Νεολιθικές θέσεις στην Κρήτη. Η ανάλυση με τη χρήση EDXRF ταυτίζει τις πρώτες ύλες με την περιοχή Στα Νύχια στη Μήλο; σε συνάρτηση με άλλα δεδομένα, προτείνεται ότι αυτή αποτελούσε την προτιμώμενη πηγή μηλιακού οψιανού για τους πληθυσμούς του Ανώτερου Πλειστόκαινου- Πρώιμου Ολόκαινου. Το υλικό από το Λιβάρι αποτελεί τον αρχαιότερο μηλιακό οψιανό στην Κρήτη και κατ' επέκταση τα πρώτα στοιχεία για τις επαφές των κατοίκων της με τα νησιά των Κυκλάδων. Ιδωμένος στα πλαίσια μιας ευρύτερης ανασκόπησης του οψιανού που χρησιμοποιείτο στο Ανώτερο Παλαιολιθικό- Μεσολιθικό Αιγαίο, υποδεικνύεται ότι οι βασικοί καταναλωτές αυτών των πρώτων υλών ήταν ομάδες με βάση τα νησιά που είχαν άμεση πρόσβαση στις θαλάσσιες διόδους που οδηγούσαν στις Κυκλάδες. Προτείνεται ότι οι διαφορές μεταξύ νησιωτικών και ηπειρωτικών λιθοτεχνικών συνόλων (επιλογών τεχνικής και πρώτων υλών) ενδεχομένως ήταν αποτέλεσμα εποχικών, και περιβαλλοντικών επιδράσεων, και δεν αντιπροσώπευαν προϊόντα διαφορετικών πληθυσμών. Τέλος, ορισμένα σύνολα δεδομένων, όπως και το Λιβάρι, υποδεικνύουν την πρόσκτηση οψιανού μέσω μεσαζόντων. Αυτές οι ανταλλαγές θεωρούνται αναμφίβολα με όρους κοινωνικούς, με την ανταλλαγή δώρων ως θεμελιώδη τρόπο μέσω του οποίου δημιουργούνται και συντηρούνταν δεσμοί μεταξύ ομάδων, ενώ η διακίνηση του οψιανού μπορεί να ιδωθεί ως ένας από τους μηχανισμούς με τους οποίους διαμορφώνονταν και αναπαράγονταν οι πολιτιστικές παραδόσεις του Μεσολιθικού Αιγαίου.