Late Pleistocene/Early Holocene seafaring in the Aegean: new obsidian hydration dates with the SIMS-SS method

N. Laskaris a,*, A. Sampson b, F. Mavridis c, I. Liritzis a

a Laboratory of Archaeometry, University of the Aegean, Department of Mediterranean Studies, Rhodes 85100, Greece
b University of the Aegean, Department of Mediterranean Studies, Rhodes 85100, Greece
c Ephorate of Palaeoanthropology and Speleology of Southern Greece, Ministry of Culture and Tourism, Ardettou 34 B, 11636 Athens, Greece

Abstract

Archaeological evidence regarding the presence of obsidian in levels that antedate the food production stage could have been the result of usage or intrusion of small obsidian artifacts from overlying Neolithic layers. The new obsidian hydration dates presented below employing the novel SIMS-SS method, offers new results of absolute dating concordant with the excavation data. Our contribution sheds new light on the Late Pleistocene/Early Holocene exploitation of obsidian sources on the island of Melos in the Cyclades reporting dates c. 13th millennium - end of 10th millennium B.P.

1. Introduction

Seafaring before the Neolithic (c.7th millennium B.C.) constitutes a controversial issue in Aegean Archaeology and generally in the Mediterranean (Cherry, 1990, 1992; Broodbank, 2006; Mavridis, 2003, 2007; Sampson, 2008; Sampson et al., 2010). However, current evidence from systematic research in different parts of the Aegean started gradually changing this picture and opened up new dynamics for understanding the character of exploitation and the importance of early coastal and island environments, see the example of Crete (Kopaka and Matzanas, 2009; Strasser et al., 2010), the new site of Ouriakos on the island of Lemnos (dated according to preliminary evidence to the end of the Pleistocene and possibly to the beginning of the Holocene c.12 000 B.P., N. Eustratious, pers. com. 17/9/2010), and the new Middle Palaeolithic (~ 80 000–35 000 BP) site in Agios Eustratios Island (pers. com. A. Sampson). Our contribution sheds new light on the Late Pleistocene/Early Holocene (ca.12th millennium BP) exploitation of obsidian sources on the island of Melos in the Cyclades.

The main source of information for these early visits on the island of Melos comes from Franchthi cave in the Argolid (Perlès, 1987, 1990). Provenance studies of the material from this site indicated its Melian origin (Renfrew et al., 1965; Renfrew and Aspinall, 1990, 269), but obsidian hydration dating was not applied to the artifacts recovered. In the case of Franchthi cave, obsidian finds consisted of a few pieces (Perlès, 1987, 142–145, Renfrew and Aspinall, 1990), dating to the end of the Upper Palaeolithic (ca.35 000–11 000 B.P.), while the use of obsidian continues during the Mesolithic (~9600–6800 B.C.), rising to 3% of the lithics in Upper Palaeolithic levels (Runnels, 1995, 720, Perlès, 1999, 314, Broodbank, 2006, 208). Regarding the presence of obsidian at Franchthi, two routes have been considered as possible: a direct one of c. 120 km with islets in between and another one through Attica that included crossings of c. 15–20 km between islands (Sampson, 2002, 2010; Broodbank, 2006, 209). The presence of obsidian in mainland and island sites indicates that these exploitations included successful return journeys.

The new obsidian hydration dates presented below (Table 1), employing the novel SIMS-SS method, offer a new reliable source of absolute dating. Since the archaeological evidence of the presence of obsidian in levels that antedate the food production stage could have been the result of trade or the intrusion of younger age obsidian artifacts from the overlying Neolithic layers (see the discussion regarding Cyclops cave on the island of Youra, Sampson, 2003; Kaczanowska and Kozłowski, 2008, 172; Sampson, 2010a) that exist in all sites discussed here, the novel SIMS-SS method was employed to confirm excavation data (Sampson, 2010a).
2. The SIMS-SS obsidian hydration dating method

Since Friedman and Smith (1960) first report on the Obsidian Hydration Dating, the potential of obsidian as a chronometer in archaeology has been subjected to several drawbacks and detailed studies (Anovitz et al., 1999; Rogers, 2008; Hull, 2001) to improve the method. In fact, the classical approach to obsidian hydration dating (OHD) uses optical microscopy to read hydration rims, makes approximate corrections for temperature history by calculation, and computes age from the square-root-of-time dependence of rim thickness on age. Though in several cases it seems successful (e.g. in the western United States and Australia, where most work has been made) it is not widely used by archaeologists (Liritzis and Laskaris, 2011b).

Amongst several drawbacks is the exponent of time (Stevenson, 1991; Ebert et al., 1999; Ebert et al., 2008). The dependence on the first 1/2 power of time was established by Friedman and Smith (1960) and is empirically derived from a set of well known archaeological criteria and procedures that reduce the propagation of errors and maximize the efficiency of the method (Liritzis and Laskaris, 2009, 2010; Laskaris, 2010; Liritzis and Laskaris, 2011). These criteria and procedures that reduce the propagation of errors and maximize the efficiency of the method (Liritzis and Laskaris, 2009, 2010; Laskaris, 2010; Liritzis and Laskaris, 2011). These criteria and procedures that reduce the propagation of errors and maximize the efficiency of the method (Liritzis and Laskaris, 2009, 2010; Laskaris, 2010; Liritzis and Laskaris, 2011). These criteria and procedures that reduce the propagation of errors and maximize the efficiency of the method (Liritzis and Laskaris, 2009, 2010; Laskaris, 2010; Liritzis and Laskaris, 2011).

The rationale of the SIMS-SS dating method is based on the modelling of the diffusion water profile, especially along the first 1–10 μm. The formation of a saturation layer near the exterior of the obsidian tool surface is a crucial and basic parameter in the diffusion age modelling. In fact, since the cutting of an artifact by prehistoric man, water from ambient humidity enters rapidly and presumably perpendicularly to the obsidian’s surface. In the first 1–5 μm the diffusion is faster and saturation occurs, while subsequently a slower diffusion rate continues from this layer towards the interior of the blade (Liritzis et al., 2004; Liritzis, 2006).

The age calculation procedure is separated into two major steps. The first step concerns the calculation of a 3rd order fitting polynomial of the SIMS profile. The second stage regards the determination of the saturation layer, i.e. its depth and concentration. The whole computing process is implemented in the stand-alone software created in Matlab (version 7.0.1) software package with a graphical user interface and executable under Windows XP (Liritzis, 2004; Liritzis and Ganetos, 2006). The software uses the age equation proposed earlier (eq. (1)) (Liritzis and Diakostamatiou, 2002; Liritzis et al., 2004) in order to calculate the age in years.

$$T = \frac{(C_i - C_s)^2}{4D_{s,eff} \frac{\partial C_s}{\partial x} x=0} \left( \frac{1.128}{1 - 0.177kC_s} \right)^2$$

In the above mentioned equation, $C_i$ is the concentration of the intrinsic water, $C_s$ the saturation concentration, $k$ is a factor derived from a correlation of the non-dimensional profile with a family of curves by Crank (1975) and $D_{s,eff}$ is the effective diffusion coefficient calculated using the depth of saturation layer ($X_s$) with errors attached the 1sigma standard deviation of respective data processing. In fact $D_{s,eff}$ is empirically derived from a set of well known ages and equation (2) as the effective value of the diffusion coefficient $D_s$ for $C=C_s$, and $k$ is derived from the family of Crank’s curves (Liritzis and Diakostamatiou, 2002). It is:

$$D_{s,eff} = a D_s + b \left( 10^{22} D_s \right)$$

where $D_s = (1/\partial C/\partial x)^2 \times 10^{-11}$ assuming a constant flux and taken as unity. The eq. (2) and assumption of unity is a matter of further investigation.

In Fig. 1 the hydration profile of sample YR-2 (Youra Island, Cyclops’s Cave, Greece) is shown along with the two diffusion mechanisms and the main attributes of saturation concentration and depth, as well as the intrinsic concentration. The SIMS-SS method includes a wide range of suitability criteria and procedures that reduce the propagation of errors and maximize the efficiency of the method (Liritzis and Laskaris, 2009, 2011a, Laskaris, 2010; Liritzis and Laskaris, 2011). These criteria and procedures along with the Taylor’s error propagation statistics provide overall valid and reliable results.
The SIMS method is based on the bombardment of the sample with a beam of primary ions and the measurement of the backscattered secondary ions emerged from the formed crater; the latter application is considered non-destructive in archaeometry/archaeological science due to the fact that the area of the crater is only of a few square microns. The measured profile differs from its ideal theoretical (step function) shape and has a sigmoid (S-like) shape. In the SIMS-SS dating method this sigmoidal profile is modelled with a 3rd order polynomial. The reason for this is to create a polynomial that describes best the experimental data and use it for the calculation of the effective diffusion coefficient \( D_e \). A significant factor to this fitting is the sufficient modelling of the hydrated region and of the tail, because the hydrated region represents the present condition while the tail represents the initial non-hydrated phase of the artifact. For the efficient calculation of the best fitting polynomial Liritzis and Laskaris (2009, 2011a) proposed the use of a procedure that involves repeated polynomial fittings and leads to a polynomial that describe in the best way the hydrated and the un-hydrated region.

These new procedures and criteria were tested with a comparison of SIMS-SS ages with independent methods for a wide variety of obsidian samples from all over the world (Liritzis et al., 2008a; Liritzis and Laskaris, 2009; Laskaris, 2010). The commensurability between the archaeological expected ages and the SIMS-SS ages is quite high and reinforces the validity and wide applicability of the novel dating approach (http://www.rhodes.aegean.gr/tms/sims-ss).

3. Implications for archaeology: Early exploitation of the obsidian sources on the Island of Melos

The dates of Table 1 represent the only effort made so far for dating the obsidian artifacts, of Late Pleistocene/Early Holocene age (ca.12 000 BP), themselves. Also Table 1 includes three calculated ages for artifacts from Middle Neolithic layers (80 000–35 000 BP) of the Sarakeno Cave (Sampson, 2008b). It is suggested that the exploitation of the obsidian sources on the island of Melos could have been an even earlier phenomenon in relation to what was known so far from Franchthi cave. The rest of the dates are in accordance with the evidence from Franchthi cave, where obsidian is present from the 11th millennium B.P. levels, while its presence continues during the Lower Mesolithic (2nd half of the 10th millennium B.P.), reaching its peak in the Upper Mesolithic (Perlès, 1987, 1995, 186). The SIMS-SS dates of Table 1 from the site of Kerame in Ikaria (Sampson, 2006, 2010; Sampson et al., 2008), Youra cave in Sporades (Sampson, 2008a) and Maroulas on Kythnos (Sampson et al., 2002, 2010) manifest that during the Mesolithic a rather well established system of obsidian exploitation and circulation existed, a phenomenon that has its routes even earlier, as the SIMS-SS dates from sites such as the Schisto cave in Attica (Mavridis and Kormazopoulou, 2009) indicate. Furthermore obsidian artifacts have recently been found in two other Mesolithic sites in Greece, one in the island of Naxos and the other one in the small island of Halki, Dodecanese (Sampson personal comm). As pointed out by Perlès (1995, 186) “the economy of the Late Pleistocene and especially at the end of it presents many characteristics of a Mesolithic economy” (c. 13th millennium - end of 10th millennium B.P.). Exchange systems therefore brought obsidian in the eastern (Ikaria) and the north-west Aegean (Cyclops cave in Sporades), while it even reached coastal inland sites of mainland Greece such as Attica (Schisto cave) though not yet found in mainland sites. Possibly through sites in this latter region obsidian was also brought to the Peloponnese (see Franchthi cave and also finds from cave 1 in the Kleisoura Gorge, Argolid - Koumoulazelis et al., 2003, 177) (see Fig. 2). It is evident that the novel SIMS-SS method has important applications in the relevant work and can aid researchers to address specific questions to their excavation data.

![Image](http://www.rhodes.aegean.gr/tms/sims-ss)
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References


