A Funerary Rite Study of the Phoenician–Punic Necropolis of Mount Sirai (Sardinia, Italy)

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ABSTRACT A recent excavation in the Phoenician–Punic necropolis of Mount Sirai, located in the south-western part of Sardinia, Italy, has brought to light a number of tombs contextually attributed to a period from the early 6th to early 5th century BC, which is simultaneous with the beginning of the Carthago influence in Sardinia. Among the interred burials recently brought to light, the skeletal remains, sometimes of two superposed bodies, are found in a primary position and with fine anatomic connection. Some of the bones were visually stained, suggesting they were possibly subjected to fire treatment. In order to ascertain more objectively whether the bodies were subjected to burning, the bones from all the tombs were investigated by powder X-ray diffraction (XRD) and Fourier Transform infra-red (FT-IR) spectroscopy techniques. After excluding the role of important diagenetic effects, from line broadening/sharpening analysis of hydroxylapatite in the bones according to the Rietveld method, it was evaluated that the bodies were probably subjected to a temperature regime from 300 to 700°C. These data were supplemented and confirmed by an analysis of the splitting factor (SF) of apatite phosphate peaks in the infra-red spectrum of the bones. Our results indicate the existence of a rite intermediate between incineration and inhumation. This sort of ‘semi-combustion’, perhaps limited to the period of the early 5th century BC, appears to be peculiar just to this site.

Key words: Phoenician–Punic necropolis; burned bones; powder X-ray diffraction (XRD); infra-red spectroscopy (FT-IR); funerary rite

Introduction

Historical background to the site

The site of Mount Sirai, located in the south-western part of Sardinia near the city of Carbonia, was established around 740 BC and very likely inhabited by the Phoenicians from the nearby city of Sulcis (today known as S. Antioco). Its peopling from an anonymous settlement close to the actual village of Portoscuso was also suggested, but appears to be unlikely.

It is documented that around the year 540 BC, Carthago decided to subject the island to military occupation, but a coalition of Phoenician cities in Sardinia, certainly involving Sulcis and Mount Sirai, firmly resisted this expansion. However, a few years later Carthago organised a second military expedition that defeated the Phoenician alliance. The population of Mount Sirai was massacred and the city almost completely destroyed. It is estimated that after this event only a dozen families were inhabiting the village.

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This situation remained approximately the same until 360 BC, when Carthago decided to strengthen various Sardinian sites, including Mount Sirai.

After the year 238 BC, coincident with the change of domination from Carthago to Rome, the so-called neo-Punic period, the fortress of Mount Sirai was completely demolished. A new city plan included four large building arrays. Around 110 BC, the inhabitants of Mount Sirai, probably because they inhabited a naturally well-defended hill, were deported by Rome within a framework of repression of frequent insurrectional riots. So the site was abandoned and only inhabited sporadically (Bartoloni, 2000).

An initial excavation was carried out between 1963 and 1966 AD (Barreca, 1964; Amadasi & Brancoli, 1965, Amadasi, 1966, 1967). After a break during the 1970s, investigations were resumed in 1980 by the groups led by P. Bartoloni and M. Botto (Bartoloni, 2000; Botto & Salvadei, 2005). These systematic excavation campaigns originally involving a large graveyard area were further continued between 2005 and 2007 (Guirguis, 2006).

Overall, it was established that the Phoenicians adopted mostly incineration rites for their dead, similar to other Phoenician cities of Sardinia (Nora, Tharros, Portoscuso, Bitia and Pani Loriga) and of other territories of the western Mediterranean Sea (Bartoloni, 1981, 1990, 1995, 1996, 2003; Bartoloni & Tronchetti, 1981)

In the years between 1981 and 1987, 75 ground tombs of Phoenician attribution were dated between the late 7th century and ca. 525 BC, when the incineration rites were mainly practiced. Nevertheless, cases of inhumation were also coexisting. This may have derived from the local population, enforced by subsequent Carthago influence. As a matter of fact, it seems likely that the inhumation rite survived during and after the Carthaginian period because it was previously practiced by the inhabitants of Nuragic origin who contributed, together with the Phoenicians, to the population of the first urban nuclei of Sardinia (Barreca, 1985a,b; Bartoloni, 1985; Ugas & Lucia, 1987).

It is also accepted that, after the conquest of Mount Sirai by the Punics from Carthago dated 525 BC (Bartoloni et al., 1997), and during later repopulation of the site by new colonists, the funerary rite changed suddenly. Thus, incineration was replaced by inhumation, according to what was well-established in Carthago as well as amongst the northern African populations (Bartoloni, 1981, 1996). In this respect, it is also worth noting another Punic custom, consisting of the storage of infant bodies inside transportation amphora (‘enkythrismoś’).

General considerations about the recent Mount Sirai tombs

The most recent excavations of the site have brought to light 18 tombs contextually attributed to a period from the early 6th to the early 5th century BC, which coincides with the beginning of the Carthago influence in Sardinia.

In this type of interred burial the skeletal remains, sometimes of two superposed bodies (see Figure 1), were discovered in a primary position and with very good anatomical connection (see Figure 2a and 2b). Note also that tomb 16 was actually an ‘enkythrismoś’ with a few infant remains inside (Figure 3).

Figure 1. Tomb 8 with two overlapped bodies. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

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Figure 2. The bodies of (a) tomb 6 and (b) tomb 12 respectively, from where the primary position and good anatomical connection can be appreciated. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Figure 3. Tomb 16 consists of a transportation amphora (‘enkythrismós’) containing the remains of a child. This figure is available in colour online at www.interscience.wiley.com/journal/oa.
In some bodies a dark-brown colour was observed on the bones that may be attributed to a burning process (see Figure 4). Numerous post-depositional and post-burial agents affect and potentially alter skeletal material (Gifford, 1981). However, it is often difficult to interpret such agents due, in part, to the absence of known signatures of certain taphonomic processes.

In order to ascertain using objective tools whether all the bodies were subjected to burning and to what extent, the bones recovered from tombs were investigated by both powder X-ray diffraction (XRD) and Fourier Transform infrared (FT-IR) techniques which, under specific assumptions, have been demonstrated to be able to discriminate the degree of fire treatment to which bones were possibly subjected (Shipman et al., 1984; Shahack-Gross et al., 1997; Enzo et al., 2007).

The XRD technique was first applied to archaeological subjects in 1964 (Perinet, 1964). Later Bonucci and Graziani (1975) demonstrated that high temperatures of fire treatment induce a growth of the average crystallite size of hydroxylapatite (HA), which can be measured relatively well by the line broadening/sharpening analysis of diffraction peaks.

In the first critical study of its kind, Shipman et al. (1984) investigated the microscopic morphology of various osteological materials and used X-ray diffraction in order to assess whether specimens of unknown taphonomic history were burnt, and the maximum temperature reached by those specimens. Like the previously cited studies, these investigations were based on the fact that heating bones causes a sharpening of diffraction patterns, attributed to increased crystallite size and decreased lattice strain of osteological phases.

For simple evaluations, the line-broadening analysis of XRD patterns may be applied just to the (002) reflection at half height of hexagonal apatite (Sillen, 1989; Tuross et al., 1989; Hedges et al., 1995; Hedges & Millard, 1995). The limits of a single line profile approach for determining average crystallite size are well known (Wagner,
1966). In fact, more complex crystallinity indices have been developed, although in a limited angular range (e.g. 30–40° in 2θ using CuKα radiation) (Bartsikokas & Middleton, 1992, Person et al., 1995).

Since the overall XRD peak broadening is actually related to the inverse of the domain size extension and to the degree of lattice disorder (also referred to as microstrain), we have recently updated the X-ray line-broadening approach by collecting patterns in an extended angular range (15°–140° in 2θ), employing long times of acquisition and using the Rietveld refinement method (Piga et al., 2007a,b, 2008), in analogy with the approach suggested by Michel et al. (1995). This method is supposed to be more reliable for a precise description of the growth phenomena induced in the hydroxylapatite (HA) micro-(or nano-)crystals as a function of fire treatment, since it is not limited to the analysis of a few selected peaks, but evaluates the broadening of all diffraction peaks collected.

To further support the XRD results, the same bone specimens have been investigated by FT-IR spectroscopy, whose absorption bands are related to the bond strength of carbonate and phosphate groups of apatite (Weiner & Bar-Yosef, 1990; Lee-Thorp & Van der Merwe, 1991; Rink & Schwarcz, 1995; Sillen & Sealy, 1995; Stiner et al., 1995; Sillen & Parkington, 1996; Wright & Schwarcz, 1996; Shahack-Gross et al., 1997). The phosphate and carbonate absorption bands of apatite are generally constituted by overlapped lines whose width decreases as a function of treatment temperature, according to an empirical crystallisation index also called splitting factor (SF). In analogy to the work of Surovell and Stiner (2001), we have produced a calibration for the splitting factor SF (Weiner & Bar-Yosef, 1990) as a function of selected temperatures using a recent human bone.

The calibration procedure for IR bands has the same grounds as that used to evaluate the broadening/sharpening effects observed in the XRD pattern, although the basics of interaction between light radiation and matter in the two techniques here considered are completely different.

### Materials and methods

Table 1 reports a list of bone specimens from the 18 tombs of the Mount Sirai necropolis which...
were examined by XRD and FT-IR. According to the context, the tombs are attributed to a period encompassing the end of 6th to the beginning of the 5th century BC.

Samples of c. 0.5 g were prepared for XRD by hand-grinding with an agate mortar and pestle until reduced to a sufficiently fine powder. The X-ray diffraction patterns were recorded overnight using Bruker D8, Philips PW-1050, Siemens D-500 and Rigaku D/MAX diffractometers in the Bragg–Brentano geometry with CuKα radiation (λ = 1.54178 Å). The goniometer was equipped with a graphite monochromator in the diffracted beam and the patterns were collected with 0.05° step size. The X-ray generator worked at a power of 40 kV and 30 mA, and the resolution of the instruments (divergent and antiscatter slits of 0.5°) was determined using α-SiO₂ and α-Al₂O₃ standards free from the effects of reduced crystallite size and lattice defects. The powder patterns were collected in the angular range 15°–140° in 2θ, with a counting time of 40 sec per point, and were analysed according to the Rietveld method (Rietveld, 1967) using the programme MAUD (Lutterotti et al., 1998). This is an efficient approach that evaluates quantitatively the amount, structure and microstructure parameters of mineralogical phases while also taking into account the instrumental parameters. While the average crystallite size parameter (also referred to as domain size) does not depend on the order of reflections, the lattice strain does. The program calculates numerically the convolution equations in order to correctly distinguish and evaluate both terms in the experimental peak broadening. Also, one important advantage of the Rietveld method is that no standard is required for quantitative evaluation of phases, thus minimising the work on sample preparation.

The ground powders were mixed with KBr in the weight ratio 1:100 respectively to make pellets suitable for FT-IR spectra, which were collected with a JASCO FT 480 spectrometer in terms of absorbance vs wavenumber ν in the range 400–4500 cm⁻¹. Particularly, the data for the phosphate band ν₄(PO₄) in the range 500–700 cm⁻¹ were processed using standard non-linear least-squares fitting procedures incorporated in the Origin® software, assuming a polynomial background of order 1 or 2 and symmetric Pearson VII type functions for the transmitted line shape. An advantage of using Pearson VII functions is the possibility of accounting for a shape parameter m changing continuously from Gauss (m = ∞) to Cauchy (m = 1) and even to super-Lorentzian (1 > m > 0) according to the nature of the absorbing processes involved (Enzo & Parrish, 1983).

The human samples from Sassari ossuary graveyard used for FT-IR calibration were heat-treated with a heating rate of 20°C/min at selected temperatures (200–1000°C) in air using a NEY muffle furnace. In particular, the cluster of bands of HA in the range 500–700 cm⁻¹ is analysed because it is generally recognised as the most reliable zone to define the splitting factor SF as a function of temperature treatment.

Results and discussion

FT-IR calibration

We have produced a calibration of the FT-IR band sharpening after treating a sample of human bone at various temperatures. For a quick and reliable measure of the FT-IR sharpening, Stiner et al. (1995), after making reference to the ν₄(PO₄) groups from 500 to 700 cm⁻¹, defined the quantity SF as the sum of intensities at 565 and 600 cm⁻¹, divided by the intensity of the valley between them. This requires a careful and objective determination of the background, which might be affected by different absorbing/emitting energy modes according to the chemical composition or thermal treatment to which bones were subjected. In the absence of overlapping bands, one may reasonably trace a straight line connecting the two minima from the right to the left-hand side of the cluster. An alternative, more elegant method can make use of a non-linear least-squares approach according to Michel et al. (1996) that we have applied to our data for an untreated bone using symmetrical Pearson VII functions as shown in Figure 5.
The data relevant to our calibration at the quoted temperatures are presented in Figure 6. We can observe that the two main bands of the peak cluster at ca. 565 cm\(^{-1}\) and 600 cm\(^{-1}\) respectively, becoming sharper as the temperature increases. Also, as this sharpening proceeds, for temperatures between ca. 700 and 800\(^\circ\)C a further band emerges at 634 cm\(^{-1}\) and persists until 1000\(^\circ\)C.

One sees that the data points of the experimental spectrum can be satisfactorily accounted for by a cluster of four bands (full lines) because of the presence of one shoulder at ca. 573 cm\(^{-1}\) and one more weak and broadened at ca. 635 cm\(^{-1}\) respectively. The decomposition of the cluster in terms of individual best-fit Pearson VII functions is in excellent agreement with results obtained by Michel et al. (1995) and suggests that the background may lie below what is instinctively expected.

In particular, the parameters of the linear background are correlated to the shape character \(m\) of the Pearson VII functions. In turn, a super-Lorentzian character, which seems to be the case with the line at ca. 560 cm\(^{-1}\), may be related to a wide or multimodal distribution of active IR states. Nevertheless, to be homogeneous with similar studies so far reported in the literature, we have proceeded according to the simplified approach illustrated by Surovell & Stiner (2001).

In Table 2 we report the experimental values for SF as a function of treatment temperature. The plot of the SF as a function of applied temperature (data points) shows a logistic behaviour (see Figure 7), in analogy with the calibration of XRD data, that, however, was involving the growth of the HA microcrystals and not the frequency of the active bands. Even in this case the logistic function was fitted to the data and referred to as a calibration curve. It is possible to argue that the FT-IR information occurs in the same temperature range as XRD (i.e. the SF increases for temperatures higher than 600\(^\circ\)C and the process appears complete at ca. 1000\(^\circ\)C).

Sillen and Stiner (2001) reported slightly different data for similar heat treatments. In particular the SF values were similar to ours for temperatures below 600\(^\circ\)C, but increased suddenly at ca. 750\(^\circ\)C to decrease slightly to values around 6.5 at high temperatures.

Various reasons can be advanced to explain the discrepancies in FT-IR SF values from different laboratories. As already pointed out, among the various sources of subjectivity in evaluation of SF, the choice of the background appears crucial. In fact, if we examine our cluster of bands at high temperatures, we may suspect for the background behaviour that a parabola may be more suitable than a linear trend. In both cases the experimental data are very well reproduced even with sophisticated methods, but it is clear from a comparison of the numerical analyses reported in Figure 8a and 8b that the values of SF may oscillate. However, the subjectivity is sensibly reduced when dealing with low-temperature
treatments because the intensity levels of the valley are quite insensible to the alternative choices of background.

Keeping in mind these general limitations, which to a certain extent are common to all experimental techniques, we have proceeded to estimate the temperatures from the FT-IR SFs measured in the bones of Mount Sirai tombs.

Table 2. The data of FT-IR SF from the phosphate bands of apatite as a function of treatment temperature

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>Splitting Factor SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not burned</td>
<td>3.1</td>
</tr>
<tr>
<td>200</td>
<td>3.16</td>
</tr>
<tr>
<td>300</td>
<td>3.23</td>
</tr>
<tr>
<td>400</td>
<td>3.26</td>
</tr>
<tr>
<td>500</td>
<td>3.39</td>
</tr>
<tr>
<td>600</td>
<td>3.73</td>
</tr>
<tr>
<td>700</td>
<td>4.09</td>
</tr>
<tr>
<td>800</td>
<td>5.04</td>
</tr>
<tr>
<td>900</td>
<td>6.82</td>
</tr>
<tr>
<td>1000</td>
<td>6.94</td>
</tr>
</tbody>
</table>

XRD and FT-IR analysis on Mount Sirai remains

In Figure 9 we show some experimental diffraction patterns (data points) and the relevant Rietveld fit (full lines) for some osseous specimens that are of peculiar significance for the Mount Sirai necropolis context brought to light in the recent excavation. It is worth remembering that the sequence of X-ray peaks represents an overlapping fingerprint of the mineralogical phases of the specimen. These phases were easily retrieved according to an automatic search-match procedure. Subsequently, the nature of phases is confirmed with the Rietveld fit and evaluated quantitatively after the refinement stage.

As expected, the XRD analysis points to the presence of HA as the main mineralogical phase, which is accompanied by varying quantities of calcite (CaCO3) up to a maximum level of 31 wt.%. Sometimes, small quantities of quartz and clay minerals were also observed at the limits of the detection range.
At the moment we attribute calcite to an exogenous origin with respect to the osseous material, since the presence of carbonate units \( \text{CO}_2^- \) that may substitute for phosphate groups \( \text{PO}_4^{3-} \) in the apatite structure, and that can be separated during the deposition times of the bones, may amount to not more than 7–8 wt.% (Wopenka & Pasteris, 2005).

The varying amount of calcite found in some Mount Sirai bones may be related to the tufa ground that was filling the excavated sepulchres, capped on top by flat stones. It is likely that the ground penetrated into the burial through the interstices of the top due to weathering effects. The fact that small amphorae and other ceramics with narrow necks were discovered empty inside, further supports this hypothesis.

Table 3 collects the average domain size of HA microcrystals (or crystallites) after separating the

![Figure 7](image1)

**Figure 7.** FT-IR SF behaviour as a function of temperature treatment (data points) and the best-fit logistic function (full line) used for calibration. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

![Figure 8](image2)

**Figure 8.** The data for a bone specimen heat-treated at 1000°C (data points) may be fitted equally well whether considering (a) parabolic or (b) linear background behaviour, giving rise to some arbitrariness in the evaluation of SF. This figure is available in colour online at www.interscience.wiley.com/journal/oa.
Figure 9. XRD patterns of some bones from the Monte Sirai necropolis. In (b) the patterns are restricted to the range from 30 to 39° in 2θ, where originally a Crystallisation Index was defined. This entire collection of XRD patterns points out the important approximations assumed in determining the microstructural properties of Hydroxylapatite (HA) just from one or few selected peak profiles. With the Rietveld method the goodness of fit between the calculated and experimental pattern is measured in terms of numerical agreement factors, so this approach appears the most complete for evaluating experimental data quality (i.e. signal-to-noise-ratio) and/or the credibility of model assumptions simultaneously. This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Table 3. XRD average crystallite size, their estimated temperature, calcite wt.%, FT-IR SF, and its estimated temperature for the bones considered

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Average crystallite size (Å)±5</th>
<th>Estimated temperature/°C with XRD technique</th>
<th>Wt.% calcite</th>
<th>Splitting Factor (SF) calculated/±0.05</th>
<th>Estimated temperature/°C with FT-IR technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomb 248</td>
<td>224</td>
<td>600</td>
<td>0</td>
<td>3.53</td>
<td>590</td>
</tr>
<tr>
<td>Tomb 253</td>
<td>264</td>
<td>&lt;750</td>
<td>0</td>
<td>4.45</td>
<td>710</td>
</tr>
<tr>
<td>Tomb 245</td>
<td>241</td>
<td>650</td>
<td>0</td>
<td>3.83</td>
<td>639</td>
</tr>
<tr>
<td>Tomb 256</td>
<td>290</td>
<td>≥700</td>
<td>0</td>
<td>4.26</td>
<td>690</td>
</tr>
<tr>
<td>Tomb 257</td>
<td>240</td>
<td>650</td>
<td>0</td>
<td>4.2</td>
<td>670</td>
</tr>
<tr>
<td>Tomb 255</td>
<td>205</td>
<td>400</td>
<td>31</td>
<td>3.27</td>
<td>410</td>
</tr>
<tr>
<td>Tomb 7</td>
<td>233</td>
<td>≥650</td>
<td>&lt;1</td>
<td>4.23</td>
<td>680</td>
</tr>
<tr>
<td>Tomb 3-1</td>
<td>252</td>
<td>650</td>
<td>4</td>
<td>3.67</td>
<td>620</td>
</tr>
<tr>
<td>Tomb 236</td>
<td>245</td>
<td>650</td>
<td>0</td>
<td>4.21</td>
<td>660</td>
</tr>
<tr>
<td>Tomb 3-2</td>
<td>187</td>
<td>≥300</td>
<td>29</td>
<td>3.25</td>
<td>390</td>
</tr>
<tr>
<td>Tomb 5</td>
<td>260</td>
<td>650</td>
<td>3</td>
<td>5</td>
<td>760</td>
</tr>
<tr>
<td>Tomb 6</td>
<td>250</td>
<td>650</td>
<td>14</td>
<td>3.61</td>
<td>605</td>
</tr>
<tr>
<td>Tomb 14 D</td>
<td>220</td>
<td>600 &lt; T &lt; 700</td>
<td>0</td>
<td>3.59</td>
<td>610</td>
</tr>
<tr>
<td>Tomb 14 B</td>
<td>222</td>
<td>600 &lt; T &lt; 700</td>
<td>0</td>
<td>3.71</td>
<td>625</td>
</tr>
<tr>
<td>Tomb 15</td>
<td>172</td>
<td>Not burned</td>
<td>3</td>
<td>2.99</td>
<td>Not burned</td>
</tr>
<tr>
<td>Tomb 8-1</td>
<td>251</td>
<td>650</td>
<td>5</td>
<td>4.2</td>
<td>670</td>
</tr>
<tr>
<td>Tomb 8-2</td>
<td>248</td>
<td>650</td>
<td>12</td>
<td>4.45</td>
<td>710</td>
</tr>
<tr>
<td>Tomb 10</td>
<td>258</td>
<td>650</td>
<td>15</td>
<td>3.96</td>
<td>650</td>
</tr>
<tr>
<td>Tomb 12</td>
<td>220</td>
<td>600 &lt; T &lt; 700</td>
<td>20</td>
<td>3.59</td>
<td>610</td>
</tr>
<tr>
<td>Tomb 13</td>
<td>202</td>
<td>500</td>
<td>14</td>
<td>3.97</td>
<td>650</td>
</tr>
<tr>
<td>Tomb 16</td>
<td>218</td>
<td>≥650</td>
<td>5</td>
<td>3.55</td>
<td>600</td>
</tr>
</tbody>
</table>
component due to lattice strain from broadening (column 2), the relevant temperatures to which the bones were probably subjected according to our recent studies (Piga et al., 2007b, 2008) (column 3) and the percentage of calcite (column 4). The temperature values retrieved from the SF of FT-IR bands are also reported in column 5 of Table 3, and appear to be in overall agreement with the XRD determinations, except for tombs 3-1, 5 and 13, respectively. The temperatures estimated by FT-IR (column 7) appear to be slightly higher than the corresponding values obtained by XRD.

Overall, all bodies seem to have been fired to temperatures not higher than 700°C. In the case of Tomb 13 we determined a fire temperature of 300°C, but this value has a relatively high associated variance because below 500°C the XRD line-broadening may not be very precise. In fact, both techniques may not be reliable to assess cremations carried out at temperatures lower than 500°C. In any case, the FT-IR and XRD data confirm unambiguously that all the bodies brought to light in the recent Mount Sirai excavation (except for Tomb 15) were burnt.

The specimen from tomb 15 shows an average domain size of 172 Å, in close agreement with values determined in inhumated bones (Piga et al., 2007b, 2008). This observation allows us to exclude an important role for diagenetic effects in the sharpening of XRD lines, as was advanced by Sillen and Le Gros (1991) in the case of ancient bodies buried in acid grounds. Actually, the limestone-based (calcite) ground of our burials should maintain a chemically alkaline character to the local environment (pH/C25/C8.2), which should preserve the microstructure of bones rather than deteriorating it in terms of apparent growth of crystallites, with consequent unreliable estimates for fire temperature (Hare, 1980).

The precise modalities according to which the bodies were fired are not totally clear, as neither traces of combustion nor charcoal or wood were recognised at the bottom or in the walls of burials, or in the funerary ceramic miscellanea. Because of this absence it seems that the bodies were fired first and only later were the items buried in the tomb.

An alternative possibility is that the bodies were first fired in the ‘ustrinum’ (i.e. the site dedicated to funeral pyres), discovered nearby the grave area during the recent excavations, and later transferred and deposed into the burials together with the funerary items. However, preservation of the anatomic connection during transportation appears difficult to explain, unless the combustion process occurred with limited time of residence at the maximum fire intensity.

As a matter of fact, the ‘pugilistic attitude’ (Knight, 1996) observed also by Bohnert et al. (1998) is absent in the bodies of Mount Sirai, where arms and phalanxes are in a perfect supine position. It should also be mentioned that Bohnert observed the pugilistic attitude for ca. 10 min after flame spray fired the body at a constant temperature of 720°C. However, this situation appears to be quite different from what occurs in a real process of cremation. Nevertheless, it is still possible that an intense fire carried out in the ‘ustrinum’ for a short time did not completely destroy the bodies, allowing their subsequent transportation to the tombs.

In any case, it is possible that the typical rite documented here was simply aiming at eliminating the fleshy parts of the bodies. If this is the case, we could identify the rite as a hygienic/cleaning process, maybe adopted for deaths due to contagious diseases and/or infection pathologies.

However, even the simple hygienic motivation cannot be entirely convincing. The care given to the bodies, the valuable items found in the tombs and the persistent adoption of this practice across the ages suggest that the ‘semi-combustion’ process also had a symbolic motivation, probably related to faiths well-established in the community of the necropolis.

We may hypothesise that between the 6th and 5th centuries BC at the start of the Punic domination, part of the population of Mount Sirai, related to the original Phoenician community from near-east Mediterranean, strongly maintained the funerary practice of cremation. This is demonstrated by the temporal evolution in the necropolis of the 6th century BC that evidenced the coexistence of a row of tombs with hypogeal rooms and of another row with ground burials.

Other literature on Phoenician and Punic customs (Bénichou-Safar, 1982; Rodero Riaza,
2001) does not report observations similar to the case of Mount Sirai here discussed.

Conclusion

Recent excavations still continuing at Mount Sirai have brought to light 18 tombs, contextually attributed to a period from the early 6th to the early 5th century BC, showing the skeletons in a primary position and fine anatomic connection.

A comparative analysis using powder X-ray diffraction and Fourier Transform Infrared spectroscopy established that all the bodies examined, except for Tomb 15, were fired before burial in a temperature range from 300 to 700°C.

The issues stimulated by this result have been essentially developed for understanding the technical practice of the firing process and the anthropological meaning of the rite.

This investigation has allowed assignment of the sepulchres with time continuity from the 6th to the 5th century BC, and allowed us to ascertain to a very fine level of detail the conversion from incineration rite to inhumation, demonstrating the practice of an intermediate process of ‘semi-combustion’.

It will be a challenge for future work extended to other Sardinian sites to assess whether the data collected at Mount Sirai corresponds to a situation common to other Sardinian cities, or rather represents the result of a local and peculiar culture, possibly typical of the Sulcis territory, being so dense with Phoenician–Punic locations.

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