Provenance study of the limestone used in the cremation rite: the case of Cova de sa Prior (Binigaus, Menorca)

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Fontaine, L., Hayen, R., Van Strydonck, M., De Mulder, G. and Anglada Fontestad, M. 2016. Provenance study of the limestone used in the cremation rite: the case of Cova de sa Prior (Binigaus, Menorca). *Boll. Soc. Hist. Nat. Balears,* 59: 187-201. ISSN 0212-260X. Palma de Mallorca.

Because hardly any charcoal is found in the lime burial of Cova de sa Prior as well as in many other lime burials on the Balearic islands, the question was raised if the cremation ritual was performed on site or not . Samples of the lime conglomerate and lime lumps were compared with limestone from the cave itself as well as from the area around the cave. Thin-section petrography of the lime conglomerate and lumps gave no relevant information about the provenance of the limestone used for the cremation rite, but preserved structures of the source rock found in an incompletely burned limestone fragment showed that most probably the limestone comes from the direct vicinity of the cave or even from within the cave itself.
Key words: *limestone, lime burials, cremation ritual, Cova de sa Prior, Binigaus, Menorca.*

PROCEDÈNCIA DE LA CALCÀRIA UTILITZADA EN EL RITUAL DE CREMACIÓ: EL CAS DE COVA DE SA PRIOR (BINIGAUS, MENORCA). L'absència gairebé absoluta de carbons a l'enterrament en calç de la cova de sa Prior, així com a molts altres enterraments d'aquest tipus a les illes Balears, va fer plantejar si el ritual de cremació hauria tingut lloc a l'interior de la cova o no. Es varen comparar mostres del conglomerat i dels pilots de calç amb la roca calcària de la mateixa cova i dels seus voltants. La petrografia de la làmina prima del conglomerat i els pilots de calç no va proporcionar informació rellevant sobre la procedència de la calcària utilitzada al ritual de cremació, però les restes inalterades conservades a un fragment de roca calcària cremat de manera incompleta evidenciaren que, molt probablement, la matèria primera prové de l'entorn directe de la cova o, fins i tot, del seu interior.
Paraules clau: *pedra calcària, enterraments de calç, ritual crematori, Cova de sa Prior, Binigaus, Menorca.*

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Recepció del manuscrit: 21-nov-16; revisió acceptada: 30-des-16.

Introduction

Lime burials, relicts of a special kind of cremation rite, are one of the most enigmatic features within the Balearic Protohistory (Veny 1977; Waldren 1982; Guerrero *et al.*, 2005). It is estimated that about a hundred of these deposits exist on the islands of Mallorca and Menorca, although some are still not catalogued as archaeological sites given that they are often found in natural caves or rock shelters hidden from view. In contrast to their low visibility in the field, the material of the lime burial itself is often still pristine, bright white even after more than 2000 years of exposure. The apparent pristine state of the lime burial is in strong contrast with the grey-brownish colour of the surrounding cave walls (Fig. 1).

At first sight, the lime burials appear as a chaotic mixture of lime, bones and in some cases also (iron and bronze) artefacts. Before being incinerated on a pyre, the bodies were covered in a yet unidentified manner with very fine crushed limestone (Van Strydonck *et al.,* 2015a; 2015b). Due to the heat of the pyre, the limestone was then transformed in quicklime. Hence, the lime burial was originally an accumulation of bone fragments and quicklime deposits. Only afterwards, as the quicklime recarbonated, the 'spongy' block of calcium carbonate (calcite) and cremated bones, as we recognize it today, was formed.

Since the lime conglomerate contains only little amounts of charcoal, it is obvious that the lime and the bones were washed out of the remains of the pyre before being deposited in the caves or rock shelters. This raises the question whether or not the cremation ritual was executed on site or not. In this study the characteristics of the lime from the lime burial are compared to the characteristics of the limestone found within the cave and its immediate surroundings in order to designate the most probable origin of the limestone used in the ritual and to locate the place where the cremation took place.

Fig. 1. Piece of the lime burial from Cova de sa Prior with a cremated bone (top).
Fig. 1. *Fragment de l'enterrament en calç de la Cova de sa Prior amb un os cremat (part superior).*

Site description

The site of Cova de sa Prior is located in the barranc de Binigaus, municipality of Es Migjorn Gran (N39°56.023' E004°02.281) (Fig. 2, red dot). The entrance to the cave is located in the upper part of the cliff and is orientated to the East. The cave measures about 13m in length (Fig. 3), while its maximum height amounts to more than 7m. Visually two main limestone banks can be distinguished on the cave walls. The lower bank shows a high degree of granular disintegration, while the upper bank has a more compact structure. At the back of the cave an old collapse of stones closes off a deeper part of the cave.

From a geological point of view, the cave is located on the Migjorn block, where limestone is ubiquitous due to the development of a marine sedimentary basin during the Upper Miocene (Tortonian stage between 11 and 7 Ma). According to the detailed geological map of the area three carbonate facies basically outcrop in the surroundings of the cave, all of them deposited in the context of a carbonate platform with associated reef structure.

These carbonate facies can be thus considered as stratigraphic equivalents because they reflect the lateral environmental variation from the lagoon (back-reef facies) to the reef itself (front-reef facies) and the reef slope (fore-reef facies).

Sample selection

Two types of samples were taken from the lime burial of the Cova de sa Prior to study the provenance of the 'calcareous raw material' used for the cremation rite: (a) the lime conglomerate from in between the bones in combination with well-individualized lime lumps, and (b) an incompletely burned lump (limestone fragment). The lime conglomerate and the well-individualized lime lumps (up to several tens of cm^3) were mainly sampled in 2015, though one sample was included from the preliminary investigations performed in 2014. The incompletely burned limestone fragment was found in 2015 and has a rounded shape (max. diameter of 2.4 cm).

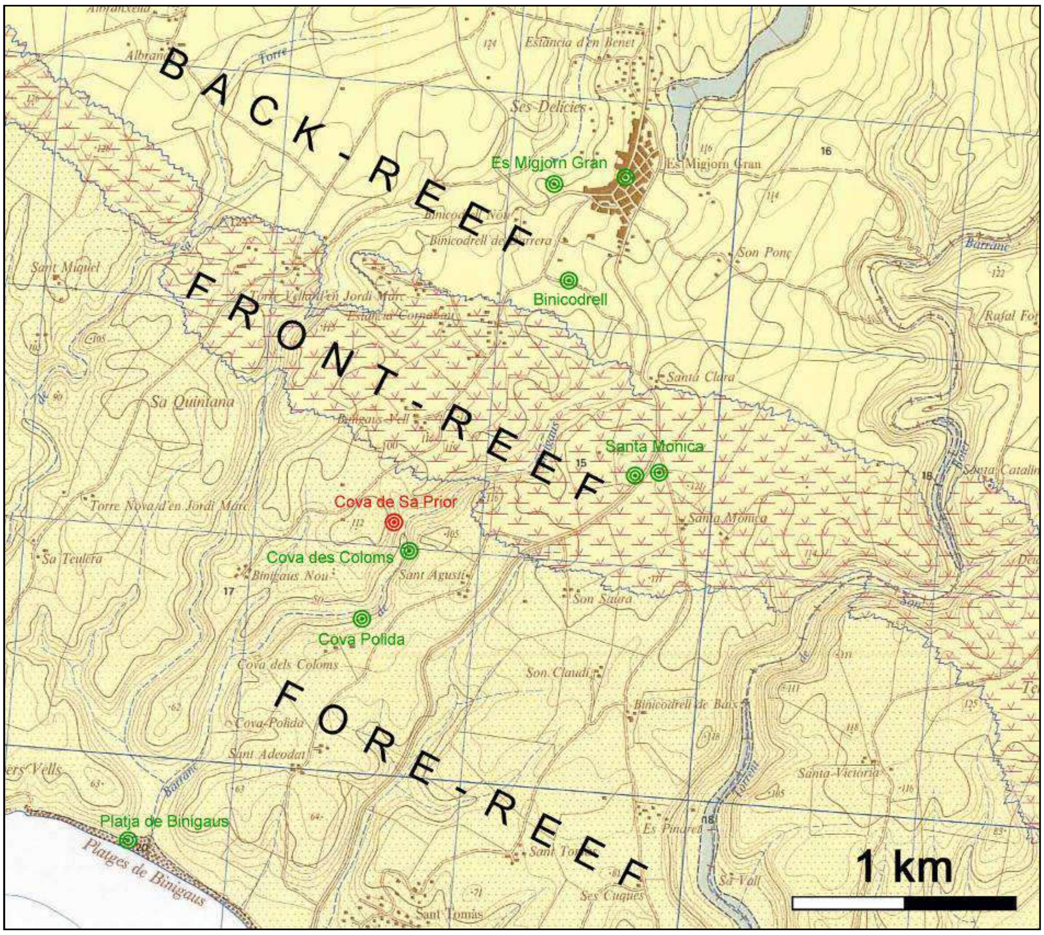

Fig. 2. The location of the cave (red) in the carbonate platform (fore-reef facies) and the sampling spots (green) of the surrounding limestone facies. Extract of the geological map of the area (IGME, 1989).

Fig. 2. *Localització de la cova (en vermell) a la plataforma carbonatada (fàcies fore-reef) i punts de mostreig (en verd) de la fàcies calcària circumdant. Extracte del mapa geològic de l'àrea (IGME, 1989).*

Fig. 3. The white grey colour marks the lime-burial (Photo M. Van Strydonck).
Fig. 3. *El color gris blanquinós indica l'enterrament en calç (Foto M. Van Strydonck).*

As mentioned already, rock samples were collected from the cave as well as from its surroundings. A first set of two rock samples were taken within the cave itself from both the lower and the upper limestone banks (see site description). Both of them are located in the fore-reef facies. Two other samples from the fore-reef facies were collected in the Cova des Coloms and the Cova Polida, respectively, further away from the site in the barranc de Binigaus. The back-reef facies was sampled on three different locations: one at Binicodrell and the two others at the village of Es Migjorn Gran (in an abandoned quarry at the border of the village and in an underground shelter within the village centre). Concerning the front-reef, two samples were taken at Santa Monica on two different spots.

An overview of the collected samples is given in Table 1. The GPS coordinates (and altitude) were provided by a Garmin eTrex® 20x.

Table 1. Location and visual description of the samples.
Taula 1. *Localització i descripció visual de les mostres.*

<table>
<tr><th colspan="2">Type</th><th>Code</th><th>Location</th><th>Description</th></tr>
<tr><td colspan="2" rowspan="7">LIME CONGLOMERATE AND LUMPS</td><td>E3</td><td>Cova de sa Prior, lime burial (2015)</td><td>large lime lump (max. diameter = 2.4 cm), white, powdered</td></tr>
<tr><td>E6</td><td>Cova de sa Prior, lime burial (2015)</td><td>fragment affected by micro-karst formation, white</td></tr>
<tr><td>E14A</td><td>Cova de sa Prior, lime burial (2015)</td><td>very large individualized lime lump (dimensions : 6.0 x 4.5 x 2.7 cm), white, heavily powdered</td></tr>
<tr><td>E14B</td><td>Cova de sa Prior, lime burial (2015)</td><td>fragment affected by granular disintegration (mm-sized particles), weakly yellowish</td></tr>
<tr><td>E15A</td><td>Cova de sa Prior, lime burial (2015)</td><td>lime-rich fragment, white</td></tr>
<tr><td>E15B</td><td>Cova de sa Prior, lime burial (2015)</td><td>lime-rich fragment in contact with bone, white</td></tr>
<tr><td>S2</td><td>Cova de sa Prior, lime burial (2014)</td><td>fragment affected by micro-karst formation, white</td></tr>
<tr><td colspan="2">INCOMPLETELY BURNED LUMP</td><td>E4</td><td>Cova de sa Prior, lime burial (2015)</td><td>limestone fragment (max. diameter = 2.7 cm), white</td></tr>
<tr><td rowspan="10">ROCK SAMPLES</td><td rowspan="3">BACK-REEF</td><td>E19</td><td>Es Migjorn Gran, abandoned quarry
N 39°56.788'
E 004°02.766' (+97 m)</td><td>hard limestone</td></tr>
<tr><td>E21</td><td>Binicodrell
N 39°56.574'
E 004°02.837' (+111 m)</td><td>hard limestone</td></tr>
<tr><td>E27</td><td>Es Migjorn Gran, underground shelter</td><td>soft limestone</td></tr>
<tr><td rowspan="2">FRONT-REEF</td><td>E22</td><td>Santa Monica I
N 39°56.077'
E 004°02.998' (+106 m)</td><td>hard limestone</td></tr>
<tr><td>E23</td><td>Santa Monica II
N 39°56.079'
E 004°03.114' (+111 m)</td><td>hard limestone</td></tr>
<tr><td rowspan="5">FORE-REEF</td><td>E16</td><td>Cova de sa Prior, wall of the cave (bottom)</td><td>hard limestone, weakly orange</td></tr>
<tr><td>E17</td><td>Cova de sa Prior, wall of the cave (entrance)
N 39°56.023'
E 004°02.281' (+81 m)</td><td>soft limestone, weakly yellowish</td></tr>
<tr><td>E20</td><td>Cova des Coloms
N 39°55.963'
E 004°02.314' (+64 m)</td><td>hard limestone</td></tr>
<tr><td>E26</td><td>Cova Polida
N 39°55.781'
E 004°02.192' (+47 m)</td><td>hard limestone</td></tr>
<tr><td>E25</td><td>Platja de Binigaus (cliff)
N 39°55.253'
E 004°01.462' (-1 m)</td><td>hard limestone, beige</td></tr>
</table>

Methods

Thin-section petrography was used to identify the main mineralogical characteristics of the different samples. For this, a polarizing microscope (Axioplan, Zeiss) was used, equipped with a high resolution digital camera (DeltaPix Invenio 5DII).

Further, simultaneous thermal analyses (STA), consisting of thermogravimetric analyses (TGA) coupled with differential scanning calorimetry (DSC), were carried out on the samples of the lime burial (with a Netzsch STA 449 F3 Jupiter®). For that, approximately 30 to 45 mg of a manually crushed sample was heated to 1200°C at a rate of 20°C/min. In absence of organic compounds, the weight loss between 200 and ca. 625°C can generally be attributed to the loss of water chemically bound to hydraulic compounds. The ratio between this weight loss and the total weight loss between 200 and 800°C is indicative for the 'hydraulicity index' of the (now completely carbonated) lime of the burial (Bakolas et al. 1998). Simultaneous thermal analyses were also performed on the collected rock samples to look at possible similarities with the samples lifted from the burial. However, in the case of the rock samples, the 'hydraulicity index' is rather a measure of the amount of impurities (other than quartz grains) instead of the assessment of its hydraulic properties.

Results of the petrographic characterization

Petrographic characterization of the rock samples

The petrographic examination made it possible to characterize in detail the three types of carbonate facies encountered in the area. Furthermore, some differences occurring within a single facies could be established. Table 2 summarizes the microscopic observations. Figs. 4 to 7 give an idea of the aspect of the main carbonate facies under low magnification.

The rock samples from the back-reef facies are bioclastic packstones (Fig. 4) characterized by abundant fragments of echinoids (skeletal plates and urchin spines) and some foraminifera. They contain a small fraction (<10%) of detrital grains, mainly made of fine quartz grains (< 300 µm) with sometimes a few (greenish) glauconite grains.

The rock samples from the back-reef facies exhibit, as could be expected, boundstones (Fig. 5). They are largely recrystallized, to such an extent that the primary structures are often strongly obliterated. However, coralline red algae and tabulate corals can still be recognized. Very fine quartz grains (<150 µm), if present, are scarce (<1%).

Unsurprisingly, the samples collected in the fore-reef facies (according to the detailed geological map of the area) are bioclastic rudstones-floatstones (limestones made of transported grains derived from the reef, Fig. 6), except for the sample E25 (bioclastic packstone, Fig. 7). This last was lifted from the cliff along the current beach and testifies a more distal marine environment with regard to the reef (a lot of foraminifera with a few echinoids fragments are observed). The main fossil grains of the bioclastic rudstones-floatstones are coralline red algae, tabulate corals, echinoids, bryozoans, brachiopods, bivalves and foraminifera. Of interest, samples lifted from the sedimentary layers forming the wall of the cave (E16 and E17) exhibit very few detrital grains (fine to very fine quartz grains, absence of glauconite). On the other hand, the samples of the same facies taken close to the Cova des Coloms and close to the Cova Polida show a slightly higher detrital fraction (fine to very fine quartz grains with a few glauconite grains).

Petrographic characterization of the lime conglomerate and lumps

Table 3 summarizes the microscopic observations on the lime conglomerate and the lumps found within the lime burial. Figures 8 to 10 give an idea of the general aspect of the thin-sections under low magnification. Unfortunately, information

Table 2. Summary of the microscopic observations on the thin-sections of rock samples.
Taula 2. *Resum de les observacions microscòpiques de les làmines primes de les mostres de roca.*

Carbonate facies	*Code*	*Thin-section*	*Fossil content*	*Detrital grains*	*Binder*	*Petrographic description*
BACK-REEF	E19	X1612 Fig. 4	echinoids (+++) foraminifera (+)	<5% fine quartz grains <1% glauconite	microspar	slightly sandy bioclastic packstone
	E21	X1614	echinoids (++) bivalves (+) foraminifera (+)	<5% fine quartz grains <1% glauconite	microspar	slightly sandy, coarse porous bioclastic packstone
	E27	X1620	echinoids (++) foraminifera (+) pellets (+)	<10% fine quartz grains	microspar	sandy bioclastic packstone
FRONT-REEF	E22	X1615 Fig. 5	coralline red algae (++) tabulate corals (++)	no	microspar and sparry calcite	largely recrystallized boundstone
	E23	X1616	coralline red algae (++) tabulate corals (++)	<1% very fine quartz grains	sparry calcite	very slightly sandy, completely recrystallized boundstone
FORE-REEF	E16	X1609	coralline red algae (+) tabulate corals (+) echinoids, bryozoans, brachiopods, bivalves, foraminifera	<1% very fine quartz grains	microspar	very slightly sandy, coarse porous bioclastic rudstone-floatstone
	E17	X1610 Fig. 6	coralline red algae (+) tabulate corals (+) echinoids, bryozoans, brachiopods, bivalves, foraminifera	<1% fine quartz grains	microspar	very slightly sandy, coarse porous bioclastic rudstone-floatstone
	E20	X1613	tabulate corals (+) echinoids (++) bryozoans, brachiopods, bivalves, foraminifera	<5% fine quartz grains <1% glauconite	microspar	slightly sandy, coarse porous bioclastic rudstone-floatstone
	E26	X1619	tabulate corals (+) echinoids (++) bryozoans, brachiopods, bivalves, foraminifera	<5% very fine quartz grains <1% glauconite	microspar	slightly sandy, coarse porous bioclastic rudstone-floatstone
	E25	X1618 Fig. 7	foraminifera (+++) echinoids (+)	<1% very fine quartz grains	micrite	slightly sandy, compact bioclastic packstone

provided by microscopic examination of the thin-sections of the lime conglomerate and lumps is quite disappointing. Indeed, preserved structures of the source rock for the lime production are very scarce and, if any, difficult to connect with fossils identi-

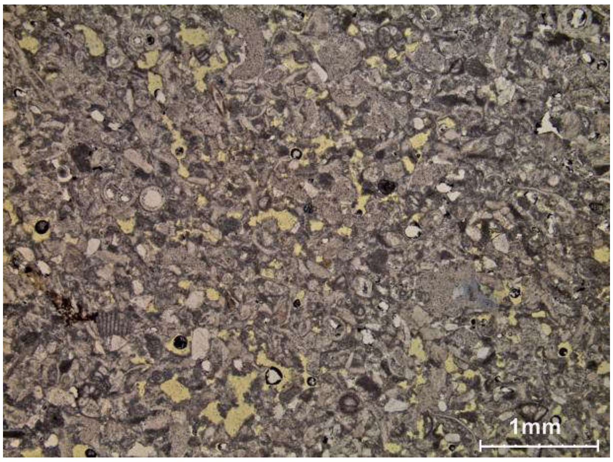

Fig. 4. Photomicrograph of the sample E19 (X1612). Slightly sandy bioclastic packstone – Es Migjorn Gran, abandoned quarry.

Fig. 4. *Fotomicrografia de la mostra E19 (X1612). Paquet bioclàstic lleugermanent sorrenc – Es Migjorn Gran, pedrera abandonada.*

Fig. 5. Photomicrograph of the sample E22 (X1615). Largely recrystallized boundstone (coralline red algae still recognizable, red arrows) – Santa Monica I.

Fig. 5. *Fotomicrografia de la mostra E22 (X1615). Pedra àmpliament recristal·litzada (algues coral·lines encara reconeixibles, fletxes vermelles) – Santa Mònica I.*

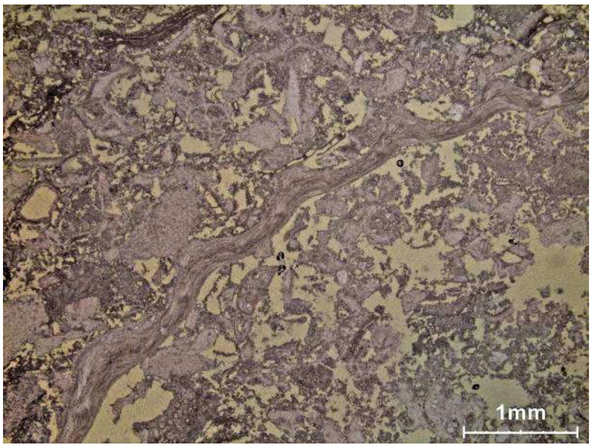

Fig. 6. Photomicrograph of the sample E17 (X1610). Very slightly sandy, coarse porous bioclastic rudstone-floatstone (shell of brachiopod visible in the middle) – Cova de sa Prior, wall of the cave, at the entrance.

Fig. 6. *Fotomicrografia de la mostra E17 (X1610). (closca d'un braquípode visible al centre). Pedra bioclàstica lleugerament sorrenca, porosa – Cova de sa Prior, paret de la cova, a l'entrada.*

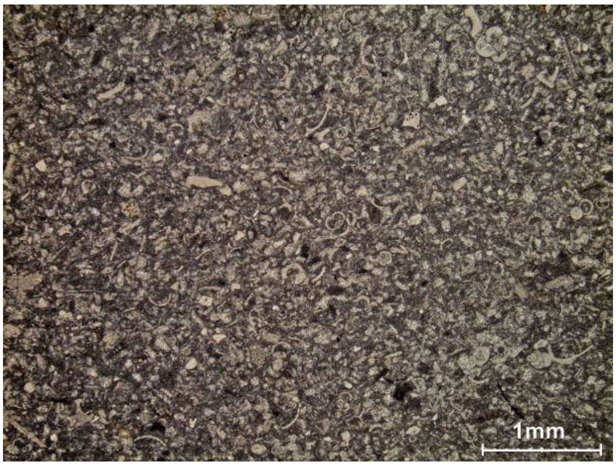

Fig. 7. Photomicrograph of the sample E25 (X1618). Very slightly sandy, compact bioclastic packstone – Platja de Binigaus, cliff.

Fig. 7. *Fotomicrografia de la mostra E25 (X1618). Bloc bioclàstic compacte, lleugerament sorrenc – Platja de Binigaus, penya-segat.*

fied within the rock samples. For example, sample E14B (Fig. 9) clearly shows numerous circle-shaped holes, but a definitive interpretation for such structures is not easy to find. The lime conglomerate itself is microcrystalline to finely crystalline (micrite to microspar) and very fine quartz grains (<150 µm) can occasionally be found. The occurrence of microspar suggests a later recrystallization of the (initially micritic) lime conglomerate.

Most of the samples show dissolution cracks induced by meteoric water percolation in the karstic cave. These cracks are often coated with secondary deposits of sparry (coarse crystalline) calcite (samples E6, E15A, E15B and S2). Figs. 12 and 13 give a closer look at these coatings.

Petrographic characterization of the incompletely burned lime lump

Unlike the samples of the lime conglomerate and lumps, the observation of the thin-section of the incompletely burned lime lump (sample E4, Fig. 11) gives reliable information on the source rock for the cremation rite (Table 3). Relatively well-preserved structures of tabulate corals (Fig. 14) and foraminifera (Fig. 15) can be found, whereas (very fine) quartz grains are scarce (<1%).

As the rock samples from the fore-reef facies, lifted from the sedimentary layers forming the wall of the cave (samples E16 and E17), exhibit similar bioclasts (Figs. 16 and 17) while they are at the same time characterized by a very low quartz content without the presence of glauconite, the limestone for the cremation rite was most probably taken from the direct vicinity of the cave or even from within the cave. The coarse porous texture of this rock and the relatively low crystallinity of its calcite binder (microspar) could have made the transformation of the stone into lime hydrate easier (as a normal pyre with wood as fuel was probably used). One might suppose that the analysed incompletely

Type	*Code*	*Thin-section*	*Paste/Binder*	*Quartz grains*	*Dissolution cracks*	*Preserved structures of the source rock*
LIME CONGLOMERATE AND LUMPS	E3	X1600	micrite/microspar	yes, <1%, very fine	no	no
	E6	X1602	micrite/microspar	yes, <1%, very fine	yes, with coatings of sparry calcite	no
	E14A	X1603 Fig. 8	micrite/microspar	yes, <1%, very fine	no	no
	E14B	X1604 Fig. 9	micrite/microspar	no	no	yes, circle-shaped
	E15A	X1605	micrite/microspar	no	yes, with coatings of sparry calcite	no
	E15B	X1606	micrite/microspar	no	yes, with coatings of sparry calcite	no
	S2	X1608 Fig. 10	micrite/microspar	no	yes, with coatings of sparry calcite	no
INCOMPLETELY BURNED LUMP	E4	X1601 Fig. 11	pseudospar	yes, <1%, very fine	no	yes, tabulate corals and foraminifera

Table 3. Summary of the microscopic observations on the thin-section of the lime conglomerate and lumps (and the incompletely burned lump).

Taula 3. *Resum de les observacions microscòpiques de les làmines primes del conglomerat i fragments de calç (i del fragment cremat de manera incompleta).*

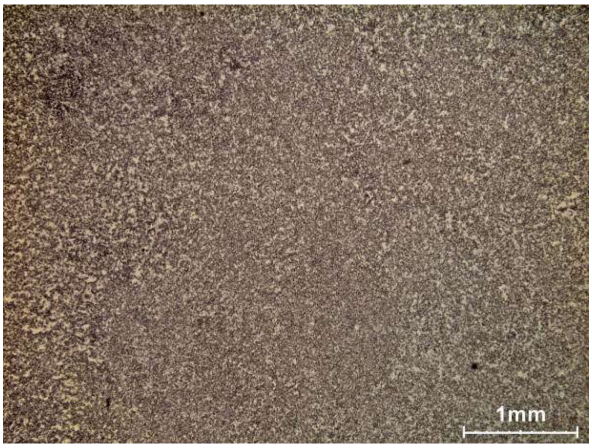

Fig. 8. Photomicrograph of the sample E14A (X1603) – Cova de sa Prior, lime burial (2015).
Fig. 8. *Fotomicrografia de la mostra E14A (X1603) – Cova de sa Prior, enterrament en calç (2015).*

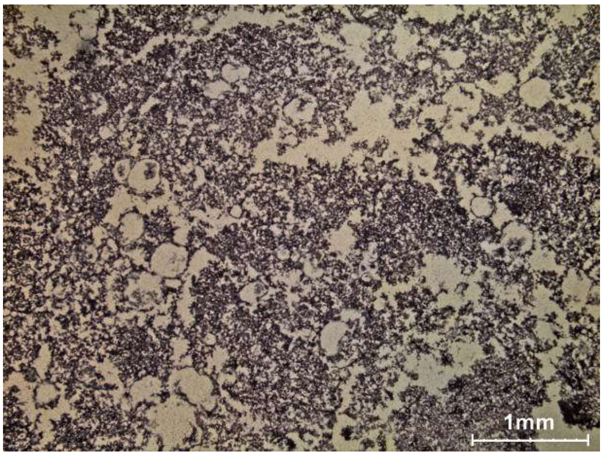

Fig. 9. Photomicrograph of the sample E14B (X1604) – Cova de sa Prior, lime burial (2015). Circle-shaped holes can be observed.
Fig. 9. *Fotomicrografia de la mostra E14B (X1604) – Cova de sa Prior, enterrament en calç (2015). Es pot observar la presència de forats circulars.*

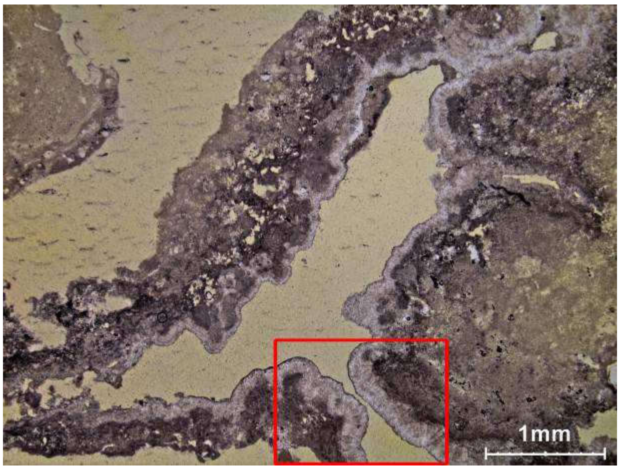

Fig. 10. Photomicrograph of the sample S2 (X1608) – Cova de sa Prior, lime burial (2014). Dissolution cracks with secondary coatings of sparry calcite are clearly visible.
Fig. 10. *Fotomicrografia de la mostra S2 (X1608) – Cova de sa Prior, enterrament en calç (2014).*

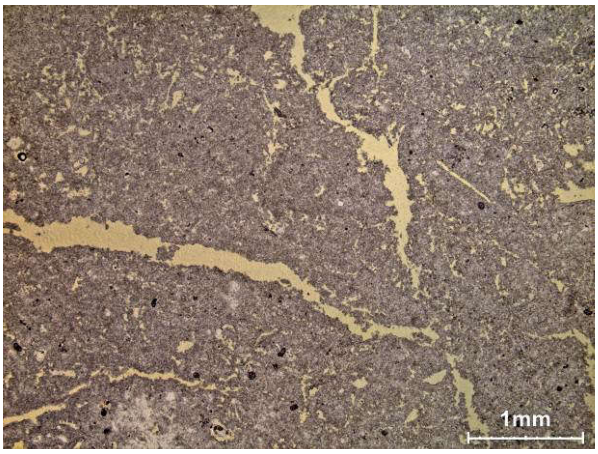

Fig. 11. Photomicrograph of the sample E4 (X1601) – Cova de sa Prior, lime burial (2015).
Fig. 11. *Fotomicrografia de la mostra E4 (X1601) – Cova de sa Prior, enterrament en calç (2015).*

burned lime lump has been preserved because of its dimension and the higher crystallinity of its calcite binder (pseudospar).

Results provided by simultaneous thermal analysis

Thermal analysis of the rock samples

Results provided by STA (Table 4, see Fig. 18 for an example of an analysis diagram) evidence that all of the rock samples

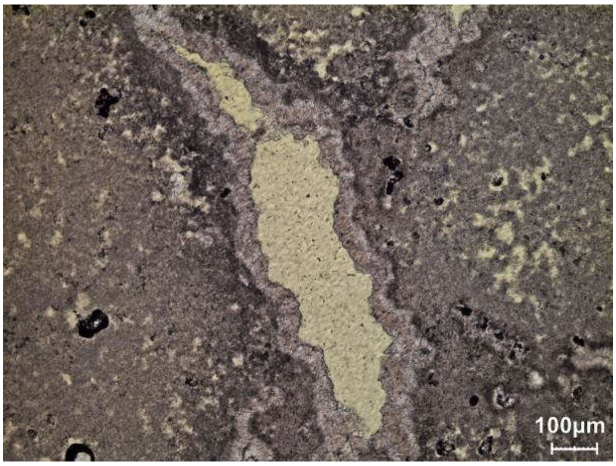

Fig. 12. Detail view of the sample E6 (X1602) showing secondary calcite deposits – Cova de sa Prior, lime burial (2015).
Fig. 12. *Vista de detall de la mostra E6 (X1602) que mostra els dipòsits de calcita secundària – Cova de sa Prior, enterrament en calç (2015).*

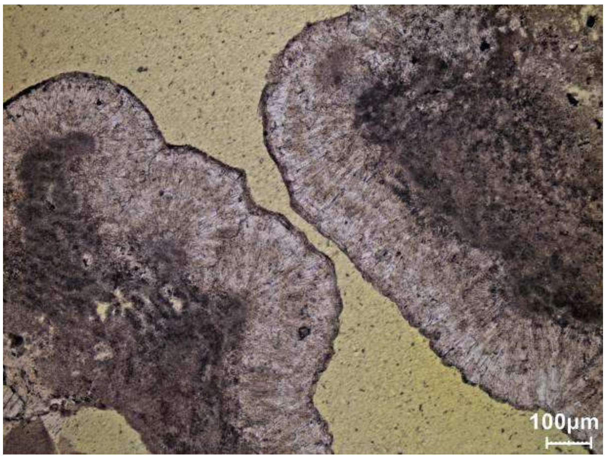

Fig. 13. Detail view on secondary calcite deposits (zoom on the zone indicated by the red frame on Fig. 10) – Cova de sa Prior, lime burial (2014).
Fig. 13. *Vista de detall dels dipòsits de calcita secundària (ampliació del requadre vermell de la Fig. 10) – Cova de sa Prior, enterrament en calç (2014).*

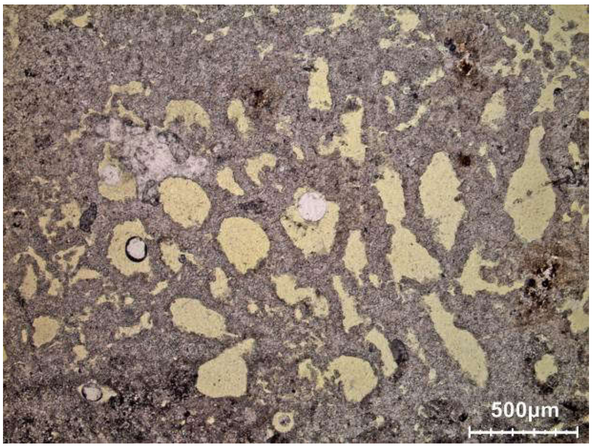

Fig. 14. Preserved structure of coral in the incompletely burned limestone fragment (sample E4, X1601).
Fig. 14. *Estructura conservada de corall a un fragment de calcària parcialment cremada (mostra E4, X1601).*

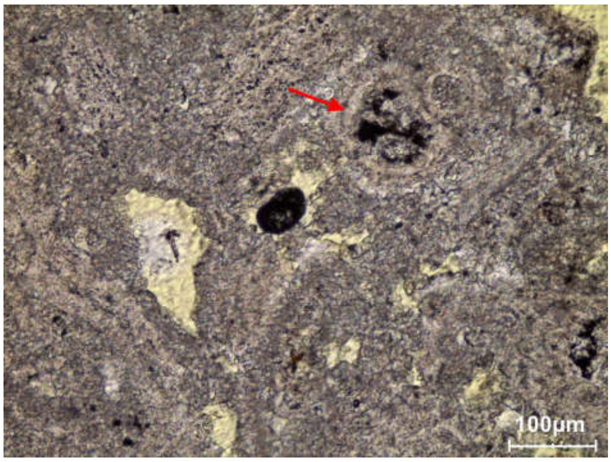

Fig. 15. Preserved foraminiferal test (red arrow) in the incompletely burned limestone fragment (sample E4, X1601).
Fig. 15. *Evidència preservada de foraminífer (fletxa vermella) a un fragment de calcari parcialment cremat (mostra E4, X1601).*

(except sample E27, Fig. 19) are characterized by a very high calcium carbonate content (around 90%) and contain only a low level of impurities (the hydraulicity index is generally <0.6%).

The lower $CaCO_3$-content of sample E27 can be attributed to its relatively higher quartz content (close to 10% according to petrographic analysis). The slightly higher 'hydraulicity index' of sample E16 is

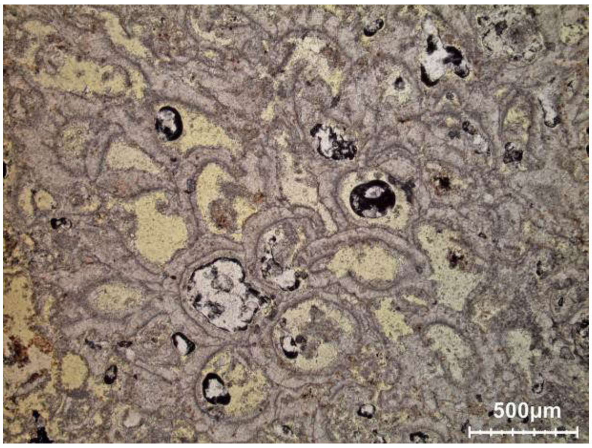

Fig. 16. View on a tabulate coral in a rock fragment lifted from the wall of the cave (sample E16, X1609).
Fig. 16. *Vista d'un corall tabular en un fragment de roca procedent de la paret la cova (mostra E16, X1609).*

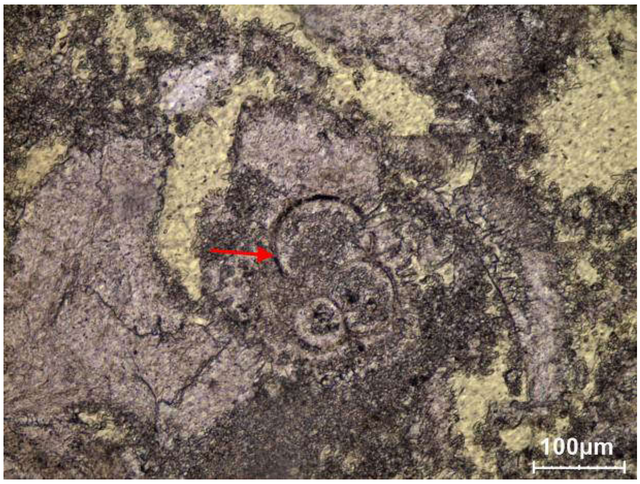

Fig. 17. View on a foraminiferal test (red arrow) in a rock fragment lifted from the wall of the cave (sample E17, X1610).
Fig. 17. *Vista d'una evidència de foraminífer (fletxa vermella) a un fragment de roca procedent de la paret la cova (mostra E17, X1610).*

probably related to the presence of a low amount of iron oxides, henceforth the weakly orange colour of this sample. These iron oxides probably contain chemically bound water, which will evaporate (dehydration) in the temperature range between 200 and ca. 625°C. The higher 'hydraulicity index' of sample E26 (3.3%) cannot be easily explained (presence of organic compounds?). The samples of the fore-reef facies are characterized by a higher peak of decarbonation (> 800°C) because of their higher degree of crystallization.

Carbonate facies	*Code*	*Weight loss (%) [200 – ca. 625°C]*	*Weight loss (%) [ca. 625 – 800°C]*	*Hydraulicity index (%)*	*$CaCO_3$ (%)*	*Peak temperature of decarbonation (°C)*
BACK-REEF	E19	0.13	40.95	0.3	93.13	792.3
	E21	0.01	40.33	0.0	91.72	790.4
	E27 Fig. 19	0.08	31.25	0.3	71.07	790.4
FRONT-REEF	E22	0.13	42.64	0.3	96.97	808.3
	E23	0.05	42.92	0.1	97.61	811.4
FORE-REEF	E16	1.01	41.68	2.4	94.79	773.1
	E17 Fig. 18	no	39.17	—	89.08	783.2
	E20	0.25	41.43	0.6	94.22	794.8
	E26	(1.39)	40.62	(3.3)	92.38	788.7
	E25	0.04	41.27	0.1	93.86	776.1

Table 4. Results provided by STA (rock samples).
Taula 4. *Resultats proporcionats per les STA (mostres de roca).*

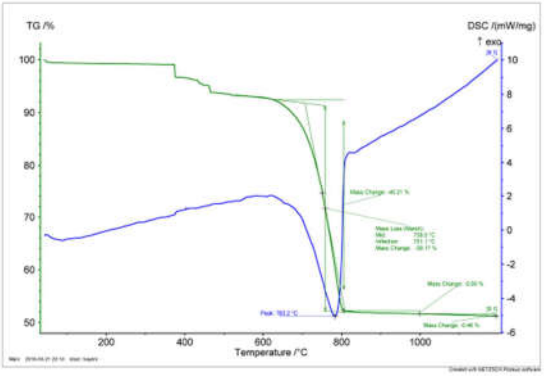

Fig. 18. STA-diagram of sample E17.
Fig. 18. *Diagrama STA de la mostra E17.*

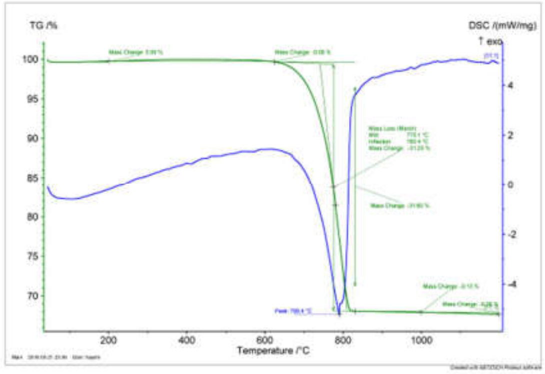

Fig. 19. STA-diagram of sample E27.
Fig. 19. *Diagrama STA de la mostra E27.*

Thermal analysis of the lime conglomerate and lumps

Results provided by STA (Table 5, see Fig. 20 for an example of an analysis diagram) evidence that all of the samples of the lime conglomerate and lumps are characterized by a very high calcium carbonate content (around 90%) and a significant 'hydraulicity index' (from 5.9 to 10.5%). The apparent hydraulicity is here however probably indicative for the presence of organic compounds. The incompletely burned lime lump shows a lower hydraulicity index (1.7%, Fig. 21). Such value suggests the use of quite pure limestone for the lime production. The presence of a shoulder at higher temperatures (between 800 and ca. 900°C) on all the TG-curves of the samples from the lime burial (Table 5) can be related to the presence of secondary calcite deposits, and to the partly recrystallization of the micritic lime paste.

Table 5. Results provided by STA (lime conglomerate and lumps, and incompletely burned lump).
Taula 5. *Resultats proporcionats per les STA (conglomerats i fragments calcaris, i fragments cremats de manera incompleta).*

Type	*Code*	*Weight loss (%) [200 – ca. 625°C]*	*Weight loss (%) [ca. 625 – 800°C]*	*Hydraulicity index (%)*	*$CaCO_3$ (%)*	*% $CaCO_3$ related to the shoulder [800 – ca. 900°C]*	*Peak temperature of decarbonation (°C)*
LIME CONGLOMERATE AND LUMPS	E3	2.61	38.57	6.3	87.72	5.79	757.9
	E6	2.64	39.22	6.3	89.19	3.24	777.9
	E14A	4.41	37.76	10.5	85.87	4.60	755.0
	E14B	2.77	39.90	6.5	90.74	2.47	767.8
	E15A	2.72	38.35	6.6	87.22	6.06	749.5
	S2 Fig. 20	2.49	40.09	5.9	91.17	8.79	769.8
INCOMPLETELY BURNED LUMP	E4 Fig. 21	0.72	41.31	1.7	93.95	2.13	784.4

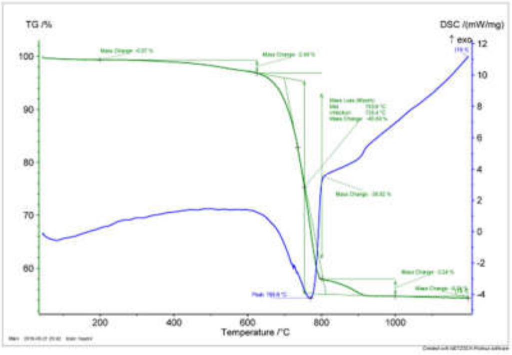

Fig. 20. STA-diagram of the sample S2.
Fig. 20. *Diagrama STA de la mostra S2.*

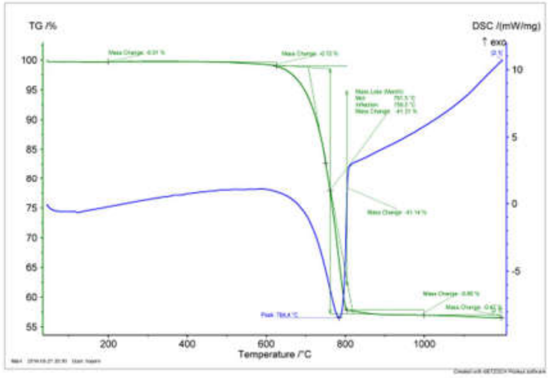

Fig. 21. STA-diagram of the sample E4.
Fig. 21. *Diagrama STA de la mostra E4.*

Conclusion

Thin-section petrography of the lime conglomerate and lumps gives no relevant information about the provenance of the limestone used for the cremation rite. Results provided by simultaneous thermal analysis suggest the use of a quite pure limestone as calcareous raw material ($CaCO_3$-content around 90%), with a very low amount of quartz. However, preserved structures of the source rock for the lime production were found in an incompletely burned limestone fragment. This fragment consists of a very slightly sandy limestone (quartz content <1%, in the absence of glauconite) containing fragments of tabulate corals and foraminiferal tests. These features suggest that limestone from the fore-reef facies (bioclastic rudstones-floatstones) was likely to be used as source rock for the cremation rite. Indeed, limestone from the back-reef facies can be ruled out based on the fossil content and the higher detrital fraction. Due to the high recrystallization degree (lack of well-preserved fossil structures) of the limestone of the front-reef facies, this potential source rock can also be ruled out. Indeed, the use of such a stone as source material would have required higher temperatures to be reached during the cremation in order for the well-crystallized carbonates to decompose.

Since the cave itself is located in the fore-reef facies, it is hence most probable that the limestone comes from the direct vicinity of the cave or even from within the cave itself. We can thus suppose, as a working hypothesis based on the parsimony principle, that the cremation ritual was executed close to the cave.

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