

RADIOCARBON DATING THE EXPLOITATION PHASES OF THE GROTTA DELLA MONACA CAVE IN CALABRIA, SOUTHERN ITALY: A PREHISTORIC MINE FOR THE EXTRACTION OF IRON AND COPPER

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ABSTRACT. Grotta della Monaca is a karstic cave in Calabria (southern Italy) that plays an important role in reconstructing the oldest strategies for the acquisition of mineral resources in the Mediterranean. In fact, systematic archaeological excavations carried out by the University of Bari allowed the identification of intense prehistoric mining activities aimed at the exploitation of iron and copper ores. Archaeological evidence suggests different phases of frequentation of the cave spanning from the Upper Paleolithic, Neolithic, Copper and Bronze ages up to the Middle Ages. In order to establish an absolute time-frame for the different phases, a radiocarbon dating campaign was carried out and the results presented in this paper.

INTRODUCTION

Since 2000, a research mission of the University of Bari has been investigating, in collaboration with the Italian Ministry of Cultural Heritage, Soprintendenza per i Beni Archeologici di Calabria, an underground cave of great archaeological interest in the northwestern region of Calabria (Figure 1). Known since the 19th century, the cave has been the object of repeated speleological explorations mainly after World War II.



Figure 1 Site location

The cave, called Grotta della Monaca, is characterized by a majestic entrance (600 m asl) dominating the upper valley of the Esaro River (Figure 2). Extending for 355 m in triassic dolomitic limestone, the cave is formed by various places characterized by different volumes and morphologies (galleries, chambers, narrow passages) (Figure 3) and contains abundant mineralization of iron

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(limonite, lepidocrocite, goethite, hematite, yukonite) and, in smaller amounts, of copper (malachite, azurite, brochantite, libethenite, sampleite) (Dimuccio et al. 2005). These mineral resources have strongly conditioned the human usage as the cave was used since prehistory for the exploitation of both iron and copper minerals (Larocca 2010, 2012).

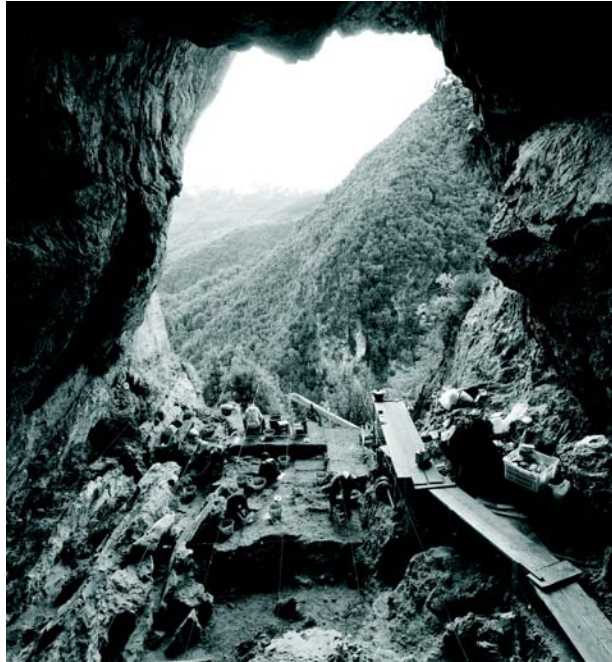


Figure 2 Entrance of the cave during the archaeological excavations



Figure 3 General cavity plan (red lines mark the 3 main cave sectors: pre-cave; Bats' room; Terminal galleries)

The exploitation of iron minerals is mainly related to the extraction iron oxides and hydroxides like goethite. Archaeological evidence suggests that goethite mining episodically started already in the Upper Paleolithic and intensified during the Neolithic and the Copper Age (Larocca 2010). These extractive activities are archaeologically testified by hundreds of digging traces still visible in the cave deposits, characteristic of the use of bone tools.

The extraction of goethite overlaps, during the 4th millennium BC, with the exploitation of copper minerals, mainly malachite. This second mining phase is characterized by the use of new tools, now made of stone, but which do not seem to completely replace the bone-made ones. The prehistoric

extractive activities in the Grotta della Monaca stopped during the Bronze Age, when the inner sectors of the cavity, previously used for the exploitation of iron and copper, started to be used for funeral purposes, as testified by the remains of ~30 buried individuals. Mining mainly of iron minerals in the galleries of the initial part of the cave resumed much later in the Medieval period, and carried out using metallic tools.

Radiocarbon dating analyses were conducted at the CEDAD (Centre for Dating and Diagnostics), Department of Engineering for Innovation, University of Salento, Italy, in order to define the overall framework of the various stages of frequentation based on the archaeological evidence. The definition of a clear chronological framework is usually difficult in paleo-mine contexts mainly because of the lack of clear stratigraphies to be used as reference. Archaeological excavations allow essentially to identify the final and most recent extractive activities, which, in most of the cases, strongly disturb or even completely delete the testimonies related to the more ancient exploitation activities. Furthermore, in the case of Grotta della Monaca, the coexistence of both mining and funeral activities in the same areas makes it significantly more difficult to identify, and thus understand, the dynamics related to human presence. In this objectively complex situation, ¹⁴C dating presented a fundamental contribution to the distinction and functional identification of the different phases related to the human frequentation of the cave.

SAMPLE SELECTION AND METHODS

Twenty-four charcoal and bone samples were selected and analyzed for this study as summarized in Table 1. The samples were chosen in different areas of the cave corresponding to the different occupation/exploitation phases as identified based on archaeological excavations (Table 1). Both chemical processing and accelerator mass spectrometry (AMS) ¹⁴C dating were carried out at CEDAD (Calcagnile et al. 2004).

Charcoal samples were pretreated with the standard acid-alkali-acid (AAA) protocol used at CEDAD (D'Elia et al. 2004), while collagen extraction of bone samples followed the Longin protocol (Longin 1971). Purified sample material was then combusted to carbon dioxide at 900 °C in a sealed quartz tube together with copper oxide and silver wool (D'Elia et al. 2004). The released CO₂ was reduced at 600 °C to graphite by using H₂ as reducing agent and iron powder as catalyst. The graphite-iron powder mixture was then pressed in the aluminum target holder of the sputtering ion source of the AMS system where ¹⁴C/¹²C and ¹³C/¹²C ratios were measured. Measured ¹⁴C/¹²C ratios were then corrected for isotopic mass fractionation by using the δ¹³C term measured with the accelerator and for sample processing and machine background (Calcagnile et al. 2005).

RESULTS AND DISCUSSION

¹⁴C dating results are summarized in Table 1 as conventional ¹⁴C ages, which were then calibrated into calendar years by using OxCal v 4 software (Bronk Ramsey 2009) and IntCal09 data (Reimer et al. 2009). Results of calibration are shown in Figures 4 and 5. The analysis of the ¹⁴C data allow to immediately confirm the long “life” of the cave spanning from the Paleolithic to the Middle Ages.

Determining the oldest phase of frequentation of the cave was obtained through ¹⁴C analysis of the sample LTL3580A, a human ulna intentionally put under a large calcareous boulder likely for ritual purposes. The sample was dated to 16,761 ± 100 BP (18,285–17,621 cal BC) corresponding to the Upper Paleolithic (Figure 4).

¹⁴C dating of charcoal samples taken from residues of wooden torches found in the 2 branches called *Buca delle impronte* and *Ramo delle vaschette* (Figure 3) enabled identifying the most intense

Table 1 Summary of the analyzed samples, the laboratory codes, the archaeological phase and the measured conventional ^{14}C age.

Sample ID	Material	Archaeological phase	^{14}C age
LTL3580A	Human ulna	Paleolithic	$16,761 \pm 100$ BP
LTL3587A	Charcoal	Neolithic/Copper Age	5827 ± 55 BP
LTL5395A	Charcoal		5247 ± 45 BP
LTL3588A	Charcoal		5245 ± 50 BP
LTL5092A	Charcoal		5216 ± 45 BP
LTL5093A	Charcoal		5194 ± 45 BP
LTL3583A	Charcoal		5183 ± 50 BP
LTL3584A	Charcoal		5010 ± 50 BP
LTL5396A	Charcoal		5002 ± 55 BP
LTL3582A	Charcoal		4935 ± 45 BP
LTL3581A	Charcoal		4880 ± 45 BP
LTL3579A	Goat horn		4684 ± 50 BP
LTL5089A	Bone	Bronze Age	3308 ± 50 BP
LTL5090A	Bone		3270 ± 45 BP
LTL5085A	Bone		3263 ± 45 BP
LTL5088A	Bone		3247 ± 45 BP
LTL5084A	Bone		3204 ± 45 BP
LTL5087A	Bone		3192 ± 45 BP
LTL5091A	Charcoal		3111 ± 50 BP
LTL5393A	Charcoal	Medieval	2791 ± 55 BP
LTL3586A	Charcoal		700 ± 35 BP
LTL3585A	Charcoal		618 ± 45 BP
LTL5394A	Charcoal		580 ± 45 BP
LTL5094A	Charcoal		568 ± 40 BP

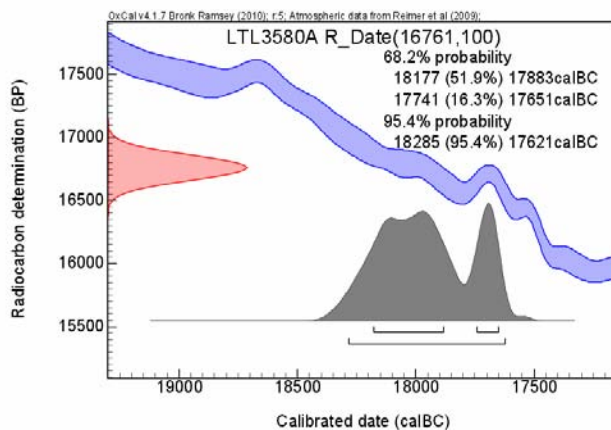


Figure 4 Calibration of the conventional ^{14}C age of sample LTL3580A

period of exploitation of the cave mainly for iron minerals from the second half of the 5th millennium BC to the first half of the 4th millennium BC (Figure 5). In the most remote sector of the cave, a goat horn (sample LTL3579A), probably used as a tool and then abandoned after it was broken, assigns the last prehistoric mining of the cave to 3640–3360 cal BC.

¹⁴C Dating Exploitation Phases of Grotta Della Monaca

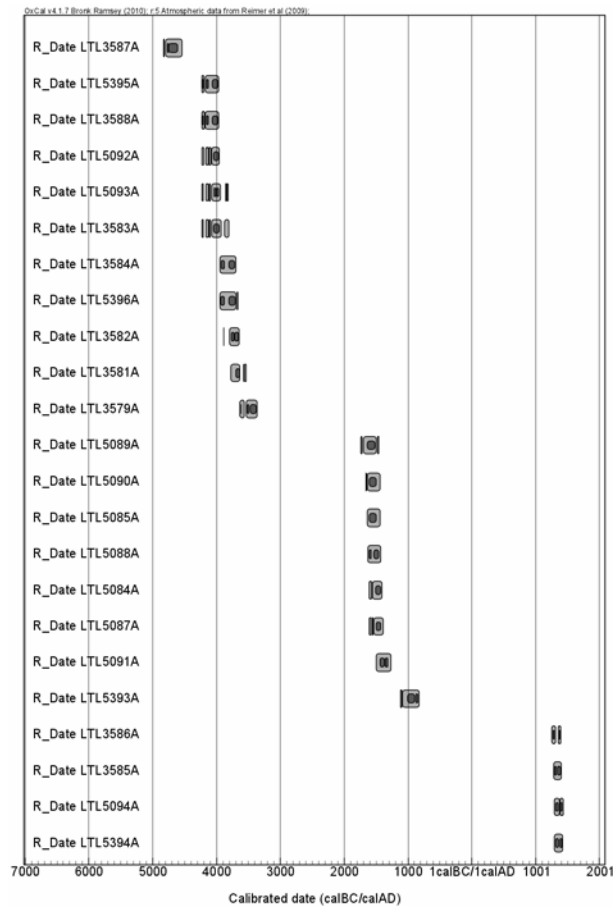


Figure 5 Calibrated ¹⁴C ages of the analyzed samples

About 2000 yr later, after the end of the mining activities, the cave was used for funeral purposes as testified by different human remains that were all dated to the 2nd millennium BC (Bronze Age). After this period, a gap in the frequentation of the cave is observed until the Late Middle Ages as shown by the ¹⁴C dating results obtained on 4 samples all dated to the period between the 12th and the 13th centuries AD.

CONCLUSIONS

¹⁴C dating performed on both charcoal and bone samples selected from different areas of the Grotta della Monaca Cave, allowed to absolutely date the different occupation/exploitation phases of this site. The results highlighted the presence of a Paleolithic burial and to establish that the most intense period of exploitation of the mineral resources of the cave spanned about 1000 yr from the Late Neolithic to the beginning of the Copper Age. The analysis of bones from the burials indicates that this site was used as a hypogean burial ground during the 2nd millennium BC. The last use of the cave for mining activities is also documented during the Middle Ages by the results obtained on 4 charcoal samples.

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