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Wood selection for firesetting: First data from the Neolithic cinnabar mine of Spaccasasso (South Tuscany, Italy)

Federico Poggiali [a,*], Mauro Paolo Buonincontri [b], Alessia D'Auria [b], Nicoletta Volante [a], Gaetano Di Pasquale [b]

[a] Dipartimento di Scienze Storiche e dei Beni Culturali, Università degli Studi di Siena, 53100 Siena, Italy
[b] Dipartimento di Agraria, Università degli Studi di Napoli Federico II, 80055 Portici, Italy

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ABSTRACT

This paper presents the preliminary results of the analysis of charcoal remains from the Neolithic cinnabar mine of Spaccasasso. Cinnabar is a mineral that was used as a pigment by different cultures worldwide since the Neolithic period. Firesetting was one of the most common mining techniques used for breaking rock to extract ores and minerals from prehistoric times up to the invention of explosives. Anatomical identification of the fuelwood used for mining provides important information about ancient mining techniques. The results show a preference for the use of *Erica* as a fuelwood, associated with evergreen and deciduous oaks. These data are coherent with the pollen records from nearby sites on the Thyrrenian coast that show the dominance of a mixed deciduous and evergreen oak forest with elements of maquis shrubland. These results are preliminarily discussed considering the heat values and the physiological state of the most common Mediterranean fuelwoods. They suggest a fuelwood selection based on the empiric knowledge of which woody plants serve as the best fuel for firesetting by Late Neolithic Populations.

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1. Introduction

This study presents preliminary anthracological data from the Spaccasasso archaeological site, located on the Uccellina Mountains, in the Maremma Regional Natural Park in Southern Tuscany (central Italy). Since 2004, the Laboratory of Prehistoric Archaeology at the Department of Historical Science and Cultural Heritage (University of Siena), has undertaken a multi-disciplinary project on the prehistoric archaeological potential of the Maremma Regional Natural Park and the surrounding area.

Spaccasasso cave had a long occupation, dating back at least to the Neolithic period. It has evidence of firesetting related to the extraction of cinnabar, a red pigment of natural mercury sulfide (HgS) forming from magmatic and thermal activities. Cinnabar is present in small quantities worldwide and it has been recognised and mined since prehistoric times in many areas around the world (Europe, Near East, China and America) for its characteristic red colour (also known as vermillion) and, later, to produce mercury.

Cinnabar has been used as a pigment since the Neolithic period and is mainly recorded in funerary contexts, dispersed throughout human remains or only on specific artefacts. In the Italian peninsula, cinnabar traces were recognised in a few sites located in northern and central Italy dating to the Neolithic and Chalcolithic periods (end 7th – mid-4th millennium BC) (Volante, 2016a, b).

Out of Italy, cinnabar is better known in prehistoric archaeological contexts. In the eastern Mediterranean (mid-8th – 6 th millennium BC), it is recorded in the Levant (Nigel Goring-Morris, 2005), Anatolia (Çamurcuoğlu, 2015) and the Balkans (Gajić-Kvaščev et al., 2012; Mioč et al., 2004). However, in Anatolia, the only evidence of cinnabar extraction is dated to the Roman-Greek period (Yildiz and Bailey, 1975). For the western Mediterranean region, cinnabar is recorded in several Iberian sites dated from as early as the Neolithic and Chalcolithic periods (Domingo et al., 2012; Hunt-Ortiz et al., 2011; Martínez Fernàndez et al., 1999; Martin-Gil et al.,1995).

Beyond the Mediterranean area, cinnabar was found in many North and South American archaeological sites, where it was used as a pigment for mask making as well as on other ceremonial

* Corresponding author.
E-mail addresses: federico.poggiali87@gmail.com (F. Poggiali), mauropaolo.buonincontri@unina.it (M.P. Buonincontri), alessia-dauria@hotmail.it (A. D'Auria), nicoletta.volante@unisi.it (N. Volante), gaetano.dipasquale@unina.it (G. Di Pasquale).

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artefacts in some Andean cultures (Cooke et al., 2013). It was also used as body paint by North American tribes (Heizer and Elsasser, 1980). In China, during the 2nd millennium BC, cinnabar was used as a pigment. From the iron age, it also became an important source of mercury. (Goals, 1999).

The use of firesetting in mining activities was widely diffused until the introduction of explosives in the 17th century. After the 17th century, firesetting became less frequent but remained in use until the late 19th century in several northern and central European mines and in the 20th century for the extraction of hard rocks, like granite, in Asia (Ancel and Py, 2008). The use of pyres, to soften or crack the working face and for extracting ores, is described by Agricola in *De* Re *Metallica* (16th century AD) as one of the most important mining techniques. Diodorus Siculus in the 1st century BC and Pliny the Elder in the 1st century AD also mention this technique. Firesetting has also been recorded in Europe as early as the 4th millennium BC (Py et al., 2012.; Willies and Weisgerber, 2000).

The earliest evidence of firesetting comes from a Neolithic flint mine in western Germany, where charcoal analysis shows a preference for deciduous oak wood (Willies and Weisgerber, 2000). Archaeological findings related to firesetting techniques in prehistoric European mines become more frequent during the Bronze Age and they are associated with the mining of copper ore. In the copper mining district of Cabrières, in southern France, the use of firesetting is assumed to have been used at the end of the 3rd millennium BC. This hypothesis is based on the rounded shape of the rock faces and the presence of scarce charcoal remains (Ambert, 2002). In Austrian Alps mines, charcoal analyses of remains from firesetting activities (10th-8th century BC) demonstrate a selective use of mountain softwood taxa, *Picea abies* and *Abies alba* (Pichler et al., 2013; Heiss et al., 2008). Evidence of firesetting has also been found in Early/Middle Bronze Age copper mining sites in Wales (2nd millennium BC). Evidence of firesetting dated to the Early Bronze Age comes from the French and Swiss Alps (Della Casa et al., 2016; Barge and Talon, 2012). Moreover, the southern French Alps district has several sites dated to the medieval period that have evidence of firesetting. These were analysed and investigated in numerous studies that demonstrated the impact of this activity on the landscape and helped to develop a methodology related to mining and firesetting (Py et al., 2013, 2015). Experimental archaeological studies focused on firesetting techniques have also been made (Timberlake, Craddock, 2013; Timberlake, 2007).

This study aims to investigate the possibility that the charcoal remains discovered at Spaccasasso resulted from firesetting techniques in a cinnabar mine. These analyses provide data of wood selection for firesetting activity and provide information on the Late Neolithic vegetation of the study area. Moreover, the charcoal analysis may also give information about the earliest exploitation of woody plants in the Uccellina Mountain area.

2. Study area

2.1. Landscape and vegetation cover

Uccellina mountains are in the Maremma Regional Natural park along the northern coast of the Tyrrhenian Sea in central Italy. The climate is typical of the Mediterranean region with rainfall ranges between 500 and 750 mm per year. The minimum average temperatures of the coldest months (January and February) range from 2.9 °C to 3.3 °C. The park covers 10.000 ha and the protected zone includes a large range of Mediterranean ecosystems. The Uccellina Mountains reach a maximum elevation of 417 m asl at Poggio Lecci. North of the Uccellina Mountains, the Ombrone River plain extends for nearly 20 km from the coast. Morphological and sedimentological analyses carried out on the sediment of the Ombrone River show that at about 6000 B P the sea-level was approximately the same as the present. However, the alluvial coastal plain to the north of the site was occupied by a lagoon which began to be filled in by sediments from the Ombrone river already in the middle Holocene. This process ended with the complete filling of the lagoon in the 3rd-2nd century BC (Bellotti et al., 2004; Pizziolo, Volante, 2015).

The current vegetation of the area is dominated by Mediterranean shrubland and evergreen oak forest, dominated by *Quercus ilex* (holm oak), *Arbutus unedo* (strawberry tree), *Pistacia lentiscus* (mastic), *Phillyrea latifolia* (mock privet), and *Myrtus communis* (common myrtle). *Pinus pinea* (stone pine) forests, planted in modern times, are also present in the area. *Olea europaea* (olive) groves are present in some areas, and specifically on the hill were the archaeological site is located.

The Spaccasasso site (42°39′N, 11°05′E) is located on a limestone hill on the inner slope of the Uccellina Mountains (Fig. 1). The archaeological excavation is set at the base of a sub-vertical rock-shelter, formed by massive limestone rocks. The rock formation is characterised by cinnabar veins resulting from deposits of mercury sulphide related to past thermal activity.

2.2. Archaeological background

The area of the park presents important archaeological and historical heritage spanning from the Palaeolithic to the modern period. The oldest evidence, dating back to the Middle Paleolithic, ca. 50.000 B P, comes from a cave located inside the park (Grotta della Fabbrica). Another important site dated to the transition from the Copper Age to the Early Bronze Age is Grotta dello Scoglietto. There are also later archaeological sites present in the park, such as the temple from the first century B.C. dedicated to Diana Umbronensis and the medieval abbey of San Rabano. They testify to the long-span of occupation and the importance of this coastal area through the millennia.

The site discussed in this paper, Spaccasasso mine, is located 125 m asl, on the north-west side of Spaccasasso hill. The mining activity created a small flat plane closed on one side by a high rock face (Fig. 1). This rock face contains some cavities, among which is a small cave that has already been investigated. This cave had disturbed archaeological deposits, spanning a long time period, including the scattered remains of more than 120 individuals, attributed indefinitely to the late Copper Age. Other artefacts, like pottery, beads, coins and fragments of glass were found and date from the Early and Middle Bronze Age to Late Antiquity (5th-6th cen. AD) (Cavanna and Pellegrini, 2007).

The ongoing archaeological investigation, conducted by the University of Siena from 2004, focused initially on a funerary structure of secondary deposition, found at the base of the rock face where the cave opens. The area, which is about 2.5 square meters wide, is delimited on the western side by large rock debris, probably resulting from the oldest mining activities, and on the southern and northern sides by medium-size stones that form a sort of wall. This funerary chamber contained the remains of at least 60 individuals with ceramic and other burial offers. Human bones found in this chamber were radiometrically dated. The radiometric measures cover a period that spans between the 4th millennium and the end of the 3th millennium BC (Volante, 2016a, b, 2014, Volante and Pizziolo, 2015; Volante and Sarti, In press).

The chalcolithic funerary evidence, consisting of the funerary chamber and the cave, extended over an area that was created by the Neolithic mining of cinnabar. This cinnabar mining is still being investigated. The last usage phase of the cinnabar mine was discovered under the first layers of stone and debris which

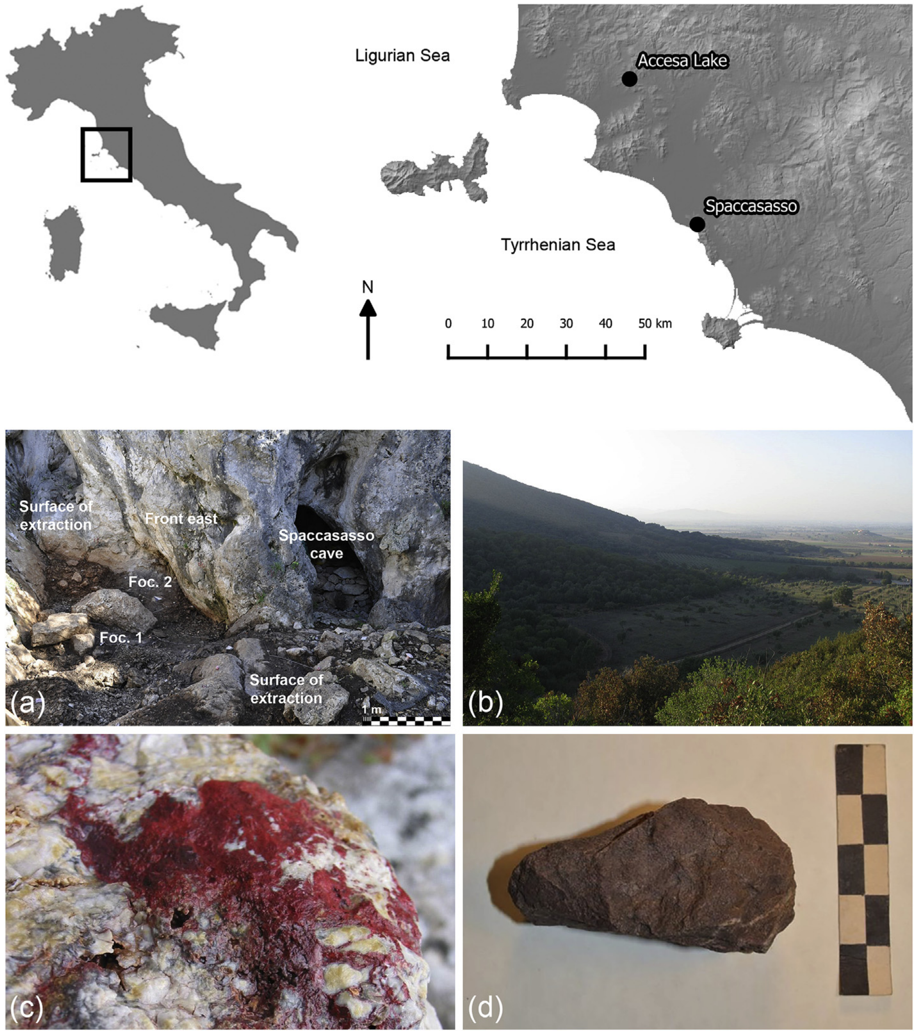

Fig. 1. Study area in the Southern Tuscany (central Italy): location of the archaeological site of Spaccasasso and the pollen site of Accesa Lake. In the pictures below: (a) The archaeological firesetting area with two different surface of extraction (b) The landscape of the Uccellina Mts. and the current schlerophyllous evergreen vegetation cover; (c) Cinnabar on a stone from Spaccasasso; (d) stone pick axe found at Spaccassaso.

characterise the abandoned layers of the cave. This study investigates evidence related to this last phase of mining activity.

Two different mining fronts were identified during the recent investigation, called “front east” and “front south”. The mining layers consist of limestone debris and fragmented greenstone and quartzite tools in the shape of hammerstones mixed with sediment (Fig. 1). These two different kinds of raw materials and tools are also spread on an artificial fan-shaped rock formation located on the hill beneath the cave and extending many meters down the slope. In these mining layers, abundant ash and scattered charcoal fragments were also found, with thin curved fragments of limestone rocks and fragments of hammerstone. The charcoal fragments were mainly concentrated the two areas, associated with the two old mining fronts. The presence of macro-charcoal in layers which present thin flakes of limestone in a plane-convex shape, ashes, and micro-charcoal mixed with hammerstone fragments, are all indicators of firesetting techniques. The use of firesetting to drill the rock is also attested by the presence of niches with sub-elliptic shapes or “heels” on the rock walls (Ambert, 2002; Willies and Weisgerber, 2000; Timberlake and Craddock, 2013; Volante 2016b). Further analyses of the hammerstone and other raw material are currently underway, but the preliminary analysis of the raw material of the hammerstone showed microcrystalline gabbro.

3. Material and methods

The two mining fronts, “front east” and “front south” were excavated during the campaign of 2015 (Fig. 1). In the deposit, dispersed charcoals were found mixed with waste stone rubble and fragments of hammerstone. These charcoals were interpreted as the result of a single event of firesetting, probably from a single pyre that was placed in a natural recess at the base of the rock face. Two areas of this deposit appeared less disturbed and were named Foc1 and Foc2. The largest fragments of charcoal found during the archaeological excavation came from these two features and were mostly handpicked to avoid fragmentation. The soil from these areas was sampled and bucket flotated. The charcoal fragments were then dried and sieved using a 4.0 and 2.0 mm mesh and sorted under a stereozoom microscope.

The taxonomical identification was carried out by observing the three anatomical planes under a reflected light microscope, with magnifications between 100× and 1000×, and then compared to wood anatomy atlases (e.g. Greguss, 1955; Schweingruber, 1990), and the references collection of the Lab of vegetation history and wood anatomy at the Università di Napoli Federico II.

A total of 440 fragments of charcoal were observed and the data obtained is expressed by the relative frequency spectra (%) of all the

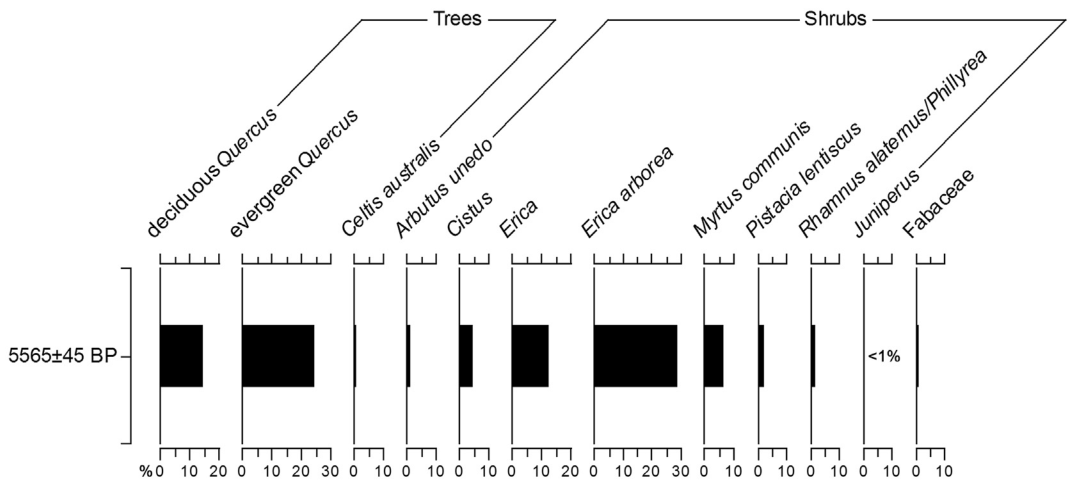

Fig. 2. Charcoal analysis data of firesetting at Spaccasasso.

charcoal remains (Fig. 2). Only charcoal fragments larger than 2 mm in diameters were observed because they better represent the floristic diversity of the assemblage.

An unidentified fragment of charcoal found in this layer was dated using AMS by CEDAD- Radiocarbon Dating and IBA Facility (University of Lecce), giving the result of LTL15348A 5565 ± 45 B P, 4490BC (95.4%) 4330BC Cal 2 sigma. The radiocarbon date was calibrated using the software OxCal Ver. 3.10 (Bronk Ramsey, 2001), considering the Reimer et al. calibration curve (Reimer et al., 2013; Volante, 2016b).

4. Results

The anthracological data obtained consists of 12 taxa that are typical (Fig. 2) of the mixed Mediterranean evergreen and deciduous vegetation. *Erica* is the most characterising taxon, which represents 41.6% of the total charcoals identified. *Erica arborea*, identifiable by ray width (Vernet et al., 2001), accounts for 28.9% of total taxa. Evergreen *Quercus* is the second most frequent taxon, comprising 24.9% of the fragments identified. Among other evergreen taxa, *Myrtus communis* (6.6%) and *Cistus* (4.6%) have a more defined presence, while *Arbutus unedo*, *Pistacia lentiscus* and *Rhamnus alaternus/Phillyrea* do not exceed 2.0%.

Broadleaved trees are also recorded: deciduous *Quercus* is the best represented (14.7%), while *Celtis australis* does not exceed 1%. Some charred fragments (0.9%) were identified as *Fabaceae*.

5. Discussion

The charcoal assemblage of Spaccasasso may provide documentation about human choices of fuelwood related to mining activity. Several authors have demonstrated that fuelwood collection by prehistoric communities most frequently responds to the “Principle of Least Effort” (Shackleton and Prins, 1992). Therefore, the selection and collection of fuelwood could be correlated to availability in the vicinity of the archaeological site (Pena-Chocharro et al., 2000; Zapata et al., 2003; Asouti and Austin, 2005; Marston, 2009).

According to the charcoal record, the Late Neolithic miners of Spaccasasso have been supplied with fuelwood from a mixed forest and evergreen maquis. The closest pollen data (Fig. 1) of the Accesa Lake (157 m a.s.l. about 50 km inland) confirm the existence in the mid-7th millennium BP of a well-established evergreen and deciduous oak-dominated forest with *Erica* dominating the shrubland (Drescher-Schneider et al., 2007). Interestingly, the pollen records of Massaciuccoli (0 m a.s.l. about 140 km further north) and Maccarese Lakes (3 m a.s.l. about 130 km to the south) showed a similar vegetation cover, suggesting a significant presence of mixed forest along the coast of eastern Liguria and the northern Tyrrhenian (Colombaroli et al., 2007; Di Rita et al., 2010).

In the anthracological record of Spaccasasso (Fig. 2), the genus *Erica* is predominant (41.6%), while evergreen and deciduous *Quercus*, which in this area consists in Q. ilex, Q. pubescens and Q. cerris respectively, account for 24.9% and 14.7%. The predominance of Erica, particularly *E. arborea*, may indicate its effective prevalence in the vegetation nearby the site. Nevertheless, ethnographic and archaeological research have demonstrated that the availability of the species around a site is not the only parameter which should be considered in the analyses of firewood exploitation conducted by a human community. Many authors stress that the results of species abundance in firewood activities could also be based on wood properties and physicochemical characteristics, as well as the morphology and the physiological and phenological state of wood (Théry-Parisot, Meignen, 2000; Théry-Parisot, 2001). Experimental research in fire setting practices has shown that fire setting techniques would need to reach a temperature between 300 °C, when many rocks become more fragile, and 600 °C, when almost all rocks are seriously damaged (Willies and Weisgerber, 2000). Other authors showed that the temperatures can easily go up to 800 °C and over in the context of underground firesetting (Ancel and Py, 2008). In Comparing the means of Higher Heating Value (HHV) in the combustion of Mediterranean species (Table 1), it can be observed that *Quercus* and *Erica* are among the genera that produce the most heat during combustion (Doat and Valette, 1981; Dimitrakopoulos and Panov 2001; Madrigal et al., 2011). Since defining fuel wood collection practices only according to species is simplistic and reductive (Théry-Parisot 2001), it is important to evaluate the influence of other proprieties in the selection of wood. *E. arborea* has the characteristic of drying out its above ground parts not reached by light if in shade or covered by forest canopy. These above ground parts, characterised by long branches with small diameters, are an ideal and perhaps preferred source of fuel to obtain rapidly dry fuelwood . Consequently , the high amount of *Erica* could represent an opportunistic gathering of the best fuel in the area, since this genus combines a relatively easy to collect dry fuelwood with good HHV. Both important characteristics for firesetting activities related to the extraction of cinnabar.

Interestingly, two millennia later, during the Iron Age, *Erica* was

Table 1
Mean of Higher Heating Value (HHV) of the taxa recorded in Spaccasasso.

Mean of Higher Heating Values			
Species		HHV (kJ/g)	References
Arbutus unedo	Leaves	21,467	Dimitrakopoulos and Panov 2001
Arbutus unedo	Leaves	20,869	Doat and Valette 1981
Arbutus unedo	Twigs	19,07	Dimitrakopoulos and Panov 2001
Cistus ladanifer	Twigs and leaves	21,24	Madrigal et al., 2011
Cistus laurifolius	Twigs and leaves	21,44	Madrigal et al., 2011
Cistus salvifolius	Twigs	19,046	Dimitrakopoulos and Panov 2001
Cistus salvifolius	Leaves	18,654	Dimitrakopoulos and Panov 2001
Cytisus scoparius	Twigs and leaves	21,05	Madrigal et al., 2011
Erica arborea	Leaves	24,058	Doat and Valette 1981
Erica arborea	Leaves	23,586	Dimitrakopoulos and Panov 2001
Erica arborea	Twigs and leaves	22,86	Madrigal et al., 2011
Erica arborea	Twigs	19,343	Dimitrakopoulos and Panov 2001
Juniperus oxycedrus	Twigs and leaves	20,34	Madrigal et al., 2011
Pistacia lentiscus	Leaves	20,264	Dimitrakopoulos and Panov 2001
Pistacia lentiscus	Twigs	18,916	Dimitrakopoulos and Panov 2001
Quercus cerris	Leaves	22,8	Todaro et al., 2007
Quercus cerris	Twigs	20,7	Todaro et al., 2007
Quercus ilex	Leaves	20,69	Dimitrakopoulos and Panov 2001
Quercus ilex	Leaves	20,279	Doat and Valette 1981
Quercus ilex	Twigs and leaves	19,81	Madrigal et al., 2011
Quercus ilex	Twigs	19,568	Dimitrakopoulos and Panov 2001
Quercus pubescens	Twigs and leaves	19,9	Todaro et al., 2007

the preferred fuel (98%) in the iron melting furnaces of the closest Etruscan sites on the Tyrrhenian coast at ca. 30 km north of Spaccasasso (Mariotti Lippi et al., 2000). The properties of heat and the long combustion of *Erica* wood are well known in southern Tuscany even in modern times, and its charcoal was the most preferred by blacksmiths until recently. Similarly, in central France, during the Medieval and Modern periods, the artisanal use of *Erica* as fuelwood led to the management of uncultivated areas where the shrub was literally cultivated (Durand et al., 2009). *Erica* species are tolerant to disturbance and can regenerate quickly after cutting, grazing, fire, and other forms of disturbance by the presence of a lignotuber, which assists the shrub in re-sprouting after disturbance (Riba, 1998). Therefore, it is reasonable to suggest that Spaccasasso could represent the oldest evidence of an expertise that survived for a long period in the mining activity of the northern Thyrrenian.

According to Table 1, many shrubs of the Mediterranean maquis, present in the anthracological record, show high levels of HHV only slightly inferior to *Erica* (Doat and Valette, 1981; Dimitrakopoulos and Panov 2001; Madrigal et al., 2011). Nevertheless, evergreen and deciduous oak represent the second and third most used taxa in the fire setting activities of Spaccasasso. According to pollen data, in the mid-7th millenium BP a mixed oak forest distinguished the western coast of the central Italian peninsula (Colombaroli et al., 2007; Drescher-Schneider et al 2007; Di Rita et al., 2010). In particular, the alternating dominance of deciduous *Quercus* and *Q. ilex* (evergreen) is unquestionable in the Early and Mid-Holocene history of the southern Tuscany vegetation cover (Drescher-Schneider et al 2007). According to regional anthracological data, *Erica* and open maquis spread only in the 3rd century AD due to the intensive agriculture and livestock grazing that characterised the Roman economic system (Di Pasquale et al., 2014). In the Late Neolithic, the miners of Spaccasasso could have collected the fuelwood in undisturbed forest environments where *Q. ilex*, *Q. pubescens* and *Q. cerris*, dominating the Meso-Mediterranean tree forest, produced more combustible biomass. *Erica* was likely not present as undergrowth but in open woodland with maquis shrubland and scattered trees. Consequently, the miners of Spaccassaso chose the best resources in terms of collecting, HHV and biomass (Doat and Valette, 1981; Dimitrakopoulos and Panov 2001; Todaro et al., 2007; Madrigal et al., 2011). The activity of firesetting at Spaccasasso represents probably one of the oldest productive activities in this area not connected to farming or grazing.

6. Conclusion

The charcoal record of Spaccasasso is the oldest example of the technique of firesetting for the extraction of cinnabar yet found in the Italian peninsula. The data indicates that *Erica*, and in particular *E. arborea*, was the plant most utilized by Late Neolithic human communities, together with other evergreen and deciduous species. The vegetation cover suggested by the data, taking into account some distortion due to human selection, matches that indicated by the pollen diagrams of the Accesa Lake and the northern Tyrrhenian coast, showing and confirming a noticeable presence of the deciduous *Quercus* in an area currently dominated by *Q. ilex* forest and maquis.

The preferential selection of *Erica* suggests an opportunistic strategy in fuelwood collection. Some characteristics of *Erica*, especially the possibility to easily obtain easily dry wood with good HHV properties, make this genus particularly suitable for firesetting. The use of *Erica* as fuelwood in mining, ore processing, and other artisanal activities seems to be specific of the Mediterranean region. A wide range of wood taxa is attested in Europe for firesetting but the anthracological characterisation of the use of *Erica* in Spaccasasso is unprecedented. Since this prehistoric period, and for the next *c.* 6500 years, Erica has been a preferred fuelwood for mining-related activities in southern Tuscany.

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