Anthracological studies on the early Holocene sediments of the Grotta di Corbeddu (Nuoro, Sardinia)

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Zusammenfassung – Die Grotta di Corbeddu ist ein Höhlensystem im zentralen Nordosten Sardiniens. Es ist als archäologische Fundstelle für seine Knochen enthaltenden Schichten bekannt, die vom Menschen während des Paläolithikums eingebracht wurden. Die Höhle wurde nicht nur während des Pleistozäns besucht, auch in holozänen Sedimenten sind Reste menschlicher Anwesenheit vorhanden. 8 m² dieser früh- und mittelholozänen Schichten gruben Mitarbeiter des Seminars für Vor- und Frühgeschichte der Goethe-Universität Frankfurt am Main aus. Es konnte gezeigt werden, dass Menschen die Höhle im Mesolithikum regelmäßig besucht haben. Eine intensive Nutzung ist dann für die Zeit der frühneolithischen Cardial-Impressa Kultur und der Filiestru-Gruppe sowie für die mittelneolithische Bonu Ighinu-Gruppe belegt.

In diesem Beitrag werden die Ergebnisse der archäobotanischen Untersuchungen, insbesondere der Holzkohlenanalysen, vorgestellt. Alle untersuchten Schichten enthielten Holzkohle – in einer geringen Konzentration in den mesolithischen und in (sehr) hoher Konzentration in den neolithischen Ablagerungen. Nahezu alle nachgewiesenen Holzarten können von Pflanzenarten stammen, die auch aktuell in der Umgebung der Höhle wachsen. Es gibt jedoch zwei Ausnahmen: *Pinus nigra* und *Paliurus spina-christa* gehören nicht zur heutigen Flora Sardiniens, obwohl *Pinus nigra* in fast allen mesolithischen und frühneolithischen Proben vorkommt. Das Holzkohlenspektrum des Mesolithikums spiegelt eine ungestörte Vegetation in der Nähe der Höhle wider, die des Frühneolithikums jedoch eine vom Menschen verursachte Macchia, die mehr oder weniger die gleiche Artenzusammensetzung aufweist wie heute.

Schlüsselwörter – Sardinien, Höhlensedimente, Anthrakologie, Mesolithikum, Frühneolithikum

Abstract – Grotta di Corbeddu is a cave system in the central North East of Sardinia. It is known as an archaeological site for its bone bearing layers, deposited by humans during the Palaeolithic. The cave was not only visited during the Pleistocene, sediments from the Holocene show many traces of human presence too. Members of the Institute of Prehistoric Archaeology of the Goethe-University Frankfurt am Main (Germany) excavated 8 m² of these early and middle Holocene layers. It was shown that the cave was regularly visited by Mesolithic people and intensively used by the Early Neolithic Cardial Impressed Ware and Filiestru groups, and subsequent by the Middle Neolithic Bonu Ighinu group.

In this contribution the results of the archaeobotanical studies are presented, especially of the charcoal analyses. All investigated strata contained charcoal, in a low concentration in the Mesolithic layers, and in (very) high concentration in the Neolithic. Almost all wood types could derive from plant species currently present around the cave. There are, however, two exceptions: *Pinus nigra* and *Paliurus spina-christa*, which both do not belong to the present-day flora of Sardinia, although Corsican pine was present in almost all Mesolithic and Early Neolithic samples. The charcoal spectrum of the Mesolithic reflects undisturbed vegetation near the cave, that of the Early Neolithic, however, a man-induced maquis, of more or less the same species composition as today[1].

Keywords – Sardinia, cave sediments, anthracology, Mesolithic, Early Neolithic

Introduction

The Grotta di Corbeddu[2] is located in northeastern Sardinia, in the province of Nuoro, in the Lanaittu Valley east of the town of Oliena (40°15´07´´ N, 02°57´59´´ E). The Lanaittu Valley is a NNE–SSW orientated tectonic depression between two steep limestone mountain ridges of the Supramonte d'Oliena. The Supramonte represents the northern part of the Gennargentu Massif, the highest mountain range of Sardinia. The bottom of the deep Lanaittu Valley has an altitude of around 130 m, the surrounding mountain ridges reach up to about 950 m in the west and about 700 m in the east. Corbeddu Cave is situated at 185 m a. s. l. on an east-facing slope of the 950 m high mount Uscradu. During the Quaternary karstic processes created many caves, tunnels, wells, sink holes, underground lakes, etc. in the Jurassic limestone. Corbeddu Cave belongs to the Sa Oche-Su Bentu system, which is, with its length of 14 km, one of the largest of the many cave systems of the Supramonte d'Oliena (Ulzega 1988).

Since 1982 the sediments of the Corbeddu Cave were excavated by members of the Department of Palaeontology of the Institute of Earth Sciences, University of Utrecht (Netherlands), and the Soprintendenza Archeologica per le province di Sassari e Nuoro. Originally the excavations were focused on the fossil remains of the extinct deer *Megaloceros cazioti*, but very soon also signs of human presence were found in the cave sediments, not only from Bronze Age and Neolithic, but to the great surprise of the Sardinian archaeologists also from much older, pre-Neolithic periods (Sondaar et al. 1984); until then Sardinia was thought to be uninhabited before the Early Neolithic. As soon as the archaeological importance of the site was discovered, a wide range of archaeological and paleo-environmental studies of the cave sediments were carried out: sedimentology, human artefacts, palynology, studies on carbonized plant remains,

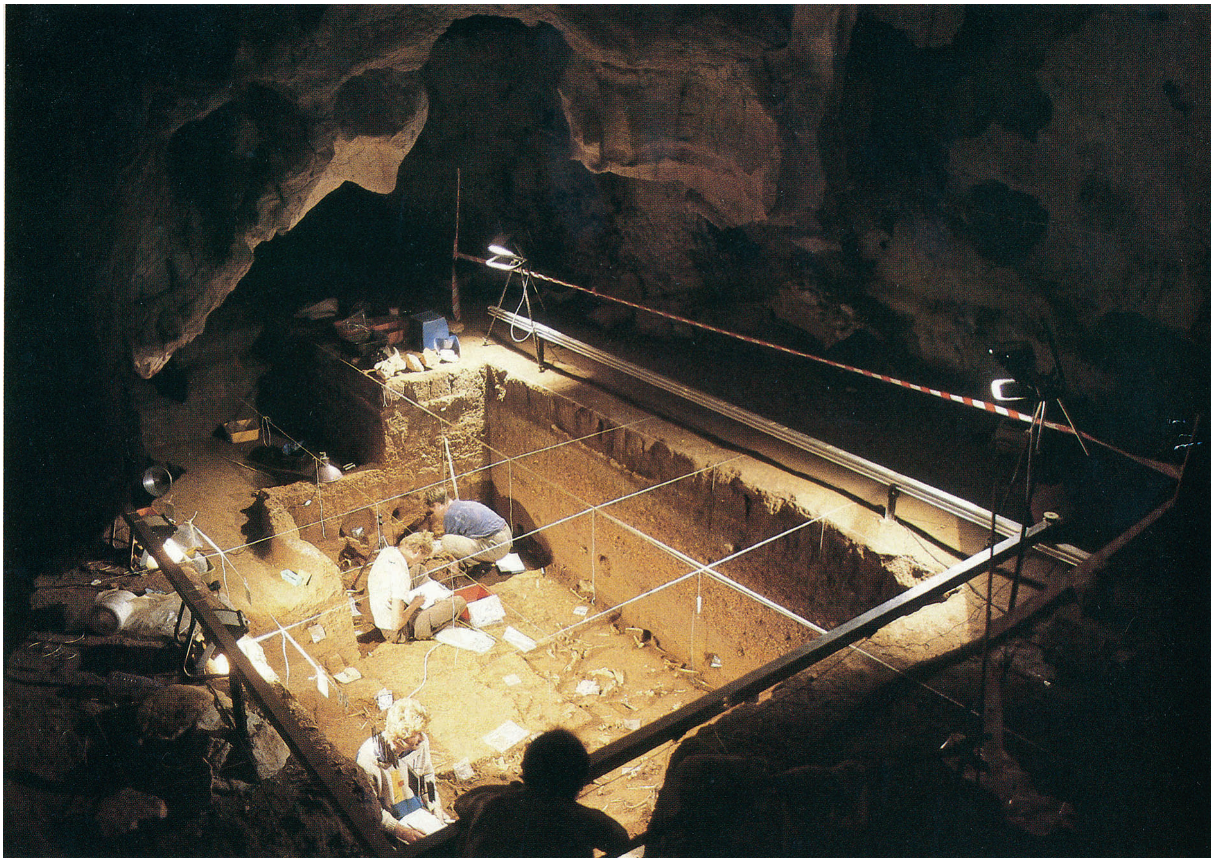

Fig. 1 View in Hall 2 of Corbeddu Cave during the archaeological excavations.

etc. The many studies showed that at least since the Last Glacial maximum, the cave was known and visited by early human inhabitants (Sondaar et al. 1986; Sondaar et al. 1991; Martini 1992; Sondaar et al. 1995). Corbeddu Cave has, with the thesis of G. Klein Hofmeijer, become the best documented site of the Late Palaeolithic in Sardinia (Klein Hofmeijer 1997). Nevertheless, the younger sediments of the cave also have a high archaeological significance, since they contain abundant remains of Early and Middle Neolithic as well as Bronze Age human presence in the cave (Sanges 1986).

Caves with prehistoric remains are not rare in Sardinia; several caves with Neolithic occupation layers have been discovered and already excavated (e. g. Grotta Verde [Lo Schiavo 1987], Grotta Filiestru [Trump et al. 1983]). But the Neolithic layers in Corbeddu Cave are in such clear stratigraphic order, and botanical and faunal remains in such good preservation, that a detailed study seemed worthwhile. J. Lüning, head of the Institute of Prehistoric Archaeology of the Goethe-University Frankfurt am Main, was invited to excavate a representative part of the Neolithic layers (**fig. 1**). The German Science Foundation (DFG) awarded him a grant and under the local supervision of U. Eisenhauer and A. J. Kalis, a group of students from the Frankfurt Institute excavated eight quadrants in Hall 2 of Corbeddu Cave during the summers of 1987–1989 (Eisenhauer/Kalis 1999). Due to organizational difficulties and the sudden death of the initiator and inspiring leader of the research group, P. Y. Sondaar, no final publication was possible. In the present contribution – dedicated to the estimated colleague and anthracologist Ursula Tegtmeier – the results concerning the charcoal remains from the early Holocene will be presented.

The present vegetation near the cave

From a biogeographic point of view the Lanaittu Valley is situated in the thermo-mediterranean area. The landscape within a 1 km range around the cave is diverse. East and below the cave, there is a more or less flat pediment at 140–150 m altitude, composed of clastic quaternary deposits and with a recent vegetation of maquis and garrigue. West and above the cave entrance are steep slopes of Jurassic limestone, which are covered with maquis up to an altitude of 400 m. Above this level, the steep slopes almost become vertical, showing only bare limestone rock. The cave is situated exactly at the transition between the two lithologically and morphologically distinct landscapes.

The entrance of Corbeddu Cave lies on a steep northeast facing slope of almost bare limestone rock on which plants only find place to grow in cracks and fissures. Among them *Phillyrea latifolia* is the most common species, accompanied by *Juniperus phoenicea*, *Pistacia lentiscus* and *Arisarum vulgare* as undergrowth. *Juniperus oxycedrus* is more common higher up. On the pediment at the foot of this slope a dense maquis of *Quercus ilex* and *Juniperus phoenicea* trees above shrubs of *Phillyrea angustifolia*, *Phillyrea latifolia, Pistacia lentiscus* and *Arbutus unedo*, and a herb layer of a. o. *Asphodelus fistulosus*, *Cyclamen repandrum* is present. The natural potential vegetation of the Lanaittu Valley is, according to the Carta delle serie di vegetazione della Sardegna scala 1 : 350 000 (Bacchetta et al. 2009b), a *Quercus ilex*-woodland, which, from the point of view of phytosociology belongs to the Prasio majoris-Quercetum ilicis. This woodland community is (Bacchetta et al. 2009a, 43 f.) characterized by a tree layer of *Quercus ilex, Juniperus oxycedrus* ssp. *oxycedrus, J. phoenicea* ssp. *turbinata*, *Olea europaea* var. *sylvestris* and a shrub layer of *Pistacia lentiscus, Rhamnus alaternus, Erica arborea* and *Arbutus unedo. Phillyrea angustifolia, Myrtus communis* and *Quercus suber* characterize the more acidophilus stands. Lianas may be present regularly, as for instance *Clematis cirrhosa, Smilax aspera, Rubia peregrina, Lonicera implexa* and *Tamus communis.* The herb layer may consist of *Arisarum vulgare, Cyclamen repandrum, Ruscus aculeatus*. All those species are present in the existing woodland on the pediment below the cave. Above, on the slope with the entrance of the cave, the potentially natural vegetation is that of the calcareous mountains of the Supramonte d'Oliena, Orgosolo and Urzulei, according to the Carta delle serie di vegetazione della Sardegna scala 1 : 350 000 (Bacchetta et al. 2009b), also a *Quercus ilex*-woodland. This, however, belongs from the point of view of phytosociology to the Acer monspessulani-Quercetum ilicis. This woodland community is characterized (Bacchetta et al. 2009a, 46) by a tree layer of *Quercus ilex* and *Phillyrea latifolia*, accompanied by *Ilex aquifolium* and *Acer monspessulanum*. Nearby, at a distance of 670 m and 250 m, are two deep E–W orientated gorges with their characteristic vegetation. At their bottom arises the Rio de sa Oche, a temporary rivulet, bordered by thickets of *Nerium oleander*.

The valley bottom of Lanaittu Valley is heavily grazed by sheep and goats and there is a garrigue with *Genista* species, *Cistus incana, Rosmarinus officinalis, Teucrium marum* and others present. No phytosociological research has been published on the vegetational pattern of the Lanaittu Valley, but the area is very similar to the nearby Monte Albo, described by I. Camarda (Camarda 1988).

Description of the cave sediments

The four chambers of the ca. 100 m long Corbeddu Cave were at least 50 000 years ago separated from the main Sa Oche-Su Bentu cave system. Since then they have undergone their own particular infill history: three of them show the "normal" pattern of cave infilling, coarse and heterogeneous sediments broken down from the roof and/or brought in by fluvial processes and deposited during short and rare events. These chambers were not part of our investigations. The sediments of Hall 2 represent an exception: the lower 4.2 m of sediment is composed of fine clay and silt in a semi-continuous deposition, starting about 50 000 years ago. An evenly grown cave sediment of such volume is seldom found in west Mediterranean lowland. The overlying layers from the past 10 000 years consist of course and heterogeneous material.

In the sedimentological description of the more than 5 m thick sediment of Hall 2, three layers were defined (de Visser/van den Bergh 1999):

Layer 3: Consisting of red clay, sometimes silty or sandy. This is the above mentioned clay layer, deposited since about 50 000 BP. Intercalated in these clays are the many bone-bearing Palaeolithic occupation layers which were described by G. Klein Hofmeijer (Klein Hofmeijer 1997). Layer 3 of Corbeddu Cave is, until now, the only archaeological site known of the last glacial Palaeolithic of Sardinia. Pollen analyses of the sediments show a pollen spectrum of wind-pollinated plants (Spaan 1990), indicating that during the deposition of the clay air turbulence had free access to Hall 2. This implies that Hall 2 had its own naturally lit entrance during the glacial period[3] which also explains the abundance of traces of human presence.

Layer 2: The lower boundary is characterized by both limestone, and quartz and schist granules, all mixed with the red clay in minor amounts. From here on upwards, an increasing amount of breccias of angular limestone fragments defines the sediment. This gravel seems to originate from outside the cave, because it is unevenly distributed, with a maximal height of 1.15 m in the south-eastern corner of Hall 2 and thinning out rapidly towards the west. This locates the former entrance in the southeast, where an east-facing opening to the outside must have existed.

Unfortunately, nowadays this section is covered by a voluminous stalactite formation, named "the organ" by the excavators, which precludes further fact checking. What caused the disintegration of limestone rock at or near the former entrance is not known. It is not even clear when this event could have happened, because the sediments below and above the first breccia layer contain hardly any datable material. The upper reliable date of Layer 3 was 11350 ± 350 BP[4], the lowest date from Layer 2.2 is 9790 ± 160 BP[5]. The disintegration of rock happened in between those times, possibly during the Younger-Dryas cold phase of the Lateglacial as a consequence of frosts; a ^{14}C-date from the base of Layer 2.2 breccia of 11040 ± 130 BP[6] points to this conclusion.

Layer 2 was subdivided in
Layer 2.2: This is a complex of yellow-brown clay deposits with intercalated thin breccias, which was neither part of the present study.
Layer 2.1: This is the bottom layer of the present study, which consists of three trampling horizons alternating with two breccias. It contains abundant evidence of human presence. Most obvious were several fire places surrounded by bones of the extinct hare-like mammal *Prolagus sardus* (Sardinian pika), often partly burned and in almost complete skeletons, and terrestrial molluscs. Also seven limestone artefacts could be identified (Klein Hofmeijer et al. 1987; Sondaar et al. 1991; Martini 1992) as well as two human skull bones (Spoor/Sondaar 1986; Spoor 1999). This was the first archaeological site known from the Mesolithic[7] in Sardinia. Since then, another two sites have been found and excavated on the island (Skeates 2012, 3).

The base of Layer 2.1 is formed as a trampling horizon (2.1.e,f,g) with at least one fire place. Pollen analysis of 2.1.e showed that during its deposition, pollen from wind-pollinated species had free access to Hall 2, which means that the entrance still existed (see below).

The basal layer was overlain by a limestone breccia with animal bones and molluscs in a matrix of dark brown silty clay (2.1.d). Its deposition must be related to the final collapse of the entrance of Hall 2, because the silty clay with bone fragments and mollusks of the occupation layer that covers the breccia (2.1.c) contains no pollen from wind-pollinated plants (see below). It is difficult to get an accurate age for the collapse, because the ^{14}C-dates obtained from below and above the breccia are rather imprecise. But interpolated with other dates above[8] and below[9], it seems that an age of around 8000 calBC could be a good guess. Another two dates from the occupation layer 2.1.c[10] show that this subsequently was formed within the time interval between ca. 8000 and ca. 6600 calBC.

Above another limestone breccia with numerous bone fragments and molluscs in a matrix of rather silty reddish-brown clay (2.1.b) lies a reddish-brown sandy silt to silty clay, also with abundant bone fragments and molluscs. It is an anthropogenic trampling horizon, which increases in thickness towards the inner cave (2.1.a). The layer is perforated by numerous worm tubes filled with grey-brown silt, indicating strong bioturbation by worms during the following occupation phases. This was the soil surface of Hall 2 at the time that Early Neolithic people first entered the cave at ca. 5600 calBC.

Layer 1 consists of grey-brown silty clay with angular limestone pebbles, abundant charcoal and bones of both domesticated and wild animals. However, most important are the finds of ceramics, a grinding stone, artefacts from obsidian and flint, ornaments made from marine shells[11], bones from the domestic animals sheep/goat and pig (Eisenhauer/Kalis 1999, 499 f.). They show that from now on the cave was used by Neolithic people. On Sardinia it was not uncommon that caves were used in Neolithic times. According to R. Skeates some 21 caves are already known, against only two open air Early Neolithic sites (Skeates 2012, 4).
Layer 1 was subdivided into 1.2 and 1.1. Only layer 1.2, with its Neolithic content, will be discussed here. It is subdivided according to its connection with archaeological groups.

The first Neolithic activities are reflected in 1.2.p,q,r. The boundary between Layer 2 and Layer 1 is sharp and can be clearly distinguished by a change in colour from reddish-brown to brown-grey, due to the increased content of charcoal in the upper sediment. Especially 1.2.q contributes to the dark colour, because it consists of almost pure charcoal dust, due to the presence of numerous fire places. At least seven individual fires could be identified within 5 m², among the many more that were present but could not be separated. Charcoal from one of the fire places was dated to 5670–5540 calBC[12]. This is contemporaneous with the Sardinian Cardial Impressed Ware Phase. Cardial ceramics have indeed been found in Hall 2 (Sanges 1986), but unfortunately not in our excavation pit, where the sherds were undecorated. Archaeological finds include, apart from the potsherds, obsidian artefacts, bones of domesticated ovicaprids and of a young pig (not native on Sardinia), and ornaments from the shells of the marine gastropods *Columbella rustica* and *Gibbula* spec. A radiocarbon date of 5530–5365 calBC[13], measured on one of the many bones in 1.2.p, corroborates the above mentioned Cardial age of 1.2.p,q,r.

Ceramics of the second Phase of the Sardinian Early Neolithic, called Filiestru Phase *sensu* Trump et al. (1983, 331), was present in the layers 1.2.k,l,m,n,o. They are an irregular complex of thin layers of breccias of bones, mollusc shells, rounded limestone pebbles and much charcoal, separated by brownish grey silt. Human presence is obvious: artefacts include obsidian, some flint and many potsherds, among them several decorated pieces of Filiestru ceramics. In addition, a grinding stone was also found and among the bones of ovicaprids, one fragment of which could be identified as *Ovis aries* (sheep).

The overlying complex 1.2.f,g,h is characterized by many fire places, surrounded by a thick debris layer of bones and shells (1.2.g), apparently rests of meals. Among the bones of ovicaprids, one piece could be identified as *Capra hircus* (goat). The fireplaces yielded material for three radiocarbon dates, who all gave approximately the same age[14]. If all three fire places belonged to the same occupation period, this must have been between 5225 and 5055 calBC[15], which again would be during the Filiestru Phase. Unfortunately, no decorated potsherds have been found among the many pieces of ceramic, which these human activities could attribute to a specific archaeological context.

The layer 1.2.c is of silty clay with fragments of shells, bones, obsidian, flint and the highest concentration of pottery found in this excavation, among them three sherds of Bonu Ighinu ceramic. It is covered by a breccia layer of limestone clasts and coarse limestone sand with bones and mollusks (1.2.b). The Bonu Ighinu ceramic phase characterizes the Sardinian Middle Neolithic, which covers the time between 4700 and 4000 calBC (Skeates 2012, 7).

Higher up in the profile, the number of fragments from molluscs, bones and charcoal fragments was much lower as in the underlying layers. Also it was increasingly calcified. Among the few fragments of pottery, none could be attributed to a specific archaeological period. A ^{14}C-date from an (unidentified) charcoal fragment gave an age of 3970–3800 calBC[16], which is still a Neolithic date but indicates a long hiatus in time.

In the northeastern part of the excavated area a pit could be identified, which was dug out and refilled during the (early?) Bronze Age (Layer 1.1.g).

The overlying layers of 1.1 were not investigated.

Sampling of the charcoal

The high concentration of charcoal is one of the most obvious characteristics of the Holocene sediments in Hall 2 of Corbeddu Cave, especially those from the Neolithic. Layer 1.2.q consists almost entirely of pure charcoal and the majority of the other layers, including those from the Mesolithic, have many – more or less circular – concentrations of charcoal: the remains of former fire places.

During the excavation, three methods of sampling were used:

1. All pieces of charcoal larger than 0.5 cm were carefully picked out of the sediment by hand, individually registered and packed.
2. The individual layers were carefully removed in segments of 0.25 m². Outside the cave, the sediment was spread out on a table and sorted – for the smaller artefacts and bone fragments as well as for charcoal. This procedure was followed to avoid "excavation damage" to the tiny pieces of bone and charcoal. The samples were packed and registered per layer, quadrant and segment.
3. Afterwards the remaining sediment was wet sieved over meshes of 1 and 0.25 mm and the charred remains of fruits, seeds and wood were dried, packed and registered per layer, quadrant and segment[17].

For this contribution only the charcoal from sampling methods 1 and 2 was analysed because all pieces were hand-picked without secondary frag-

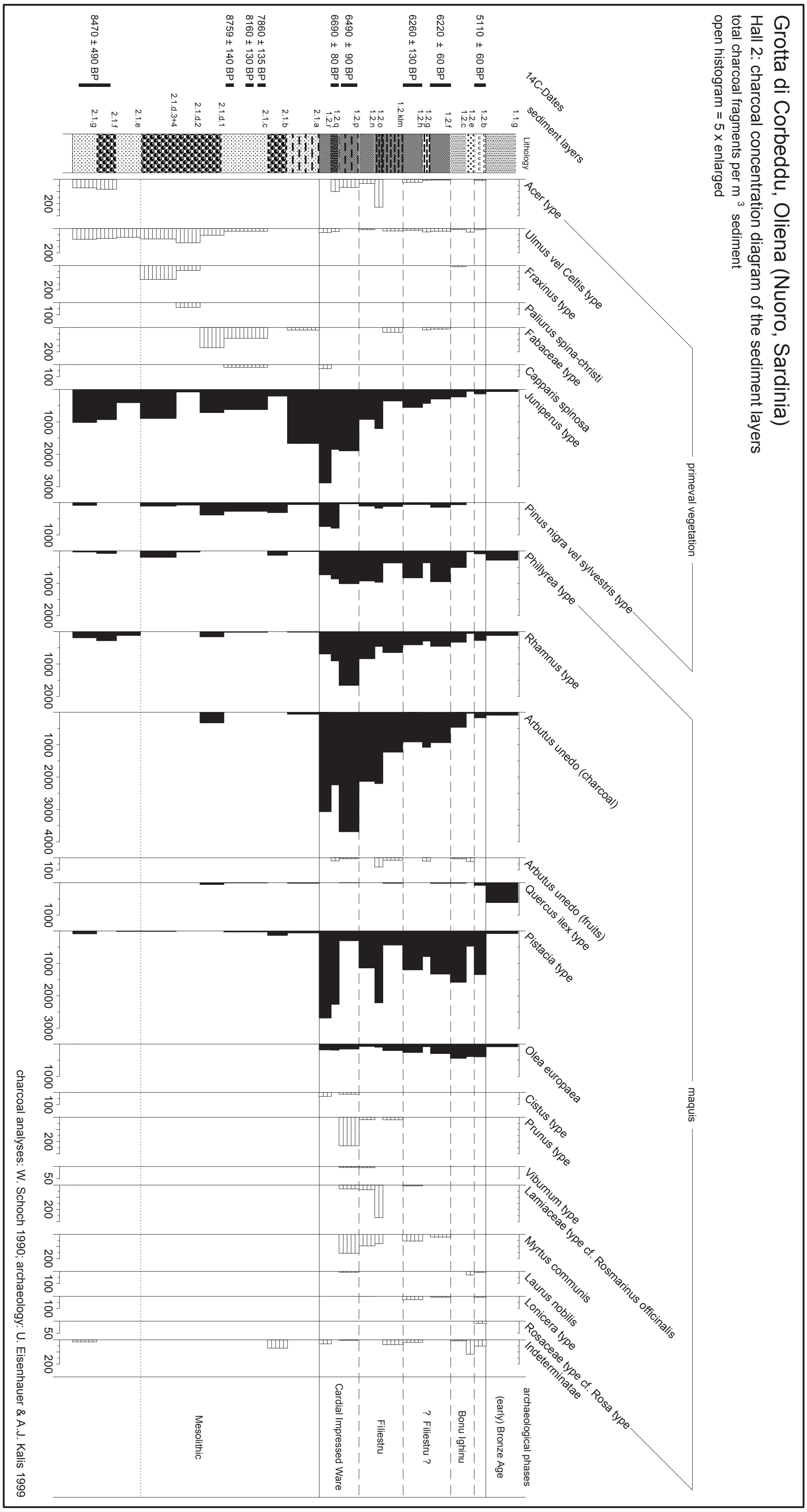

Fig. 2 Diagram of the charcoal concentration per m³ in the Holocene sediments of Hall 2 in Corbeddu Cave.

mentation. The number of fragments represents their number and distribution in the sediment layers. This is certainly not the case after sieving, because hydrating the samples and the power of the water jet caused much arteficial fragmentation. However, the reason for the sieving was not in the first place for charcoal but to find charred fruits and seeds; their analysis is not complete yet. By using only material from sampling approaches 1 and 2, inevitably only the larger charcoal fragments have been analysed. This, however, is methodologically acceptable because the number of the charcoal fragments seems not to affect the image of the charcoal spectrum, as long as the sample is statistically reliable (Badal Garcia 1990, 170).

Because of the small size of this excavation (only 8 m²) and the low concentration of charcoal in the Mesolithic layers, it was not always possible to collect sufficient pieces for a statistically reliable sample. Therefore, all collected pieces of charcoal were analysed. L. Chabal recommends 250–400 pieces per layer or per sample (Chabal 1992). This number could indeed be reached in most of the Neolithic layers (layer 1.2), but not in those from the Mesolithic (layer 2.1). In the latter only few fire places were present and their charcoal was already collected by the paleontologists and used for ^{14}C-dates before we began our studies. As a consequence of the low number of fire places, also dispersed charcoal pieces were few.

Results

The charcoal was in a rather good state of preservation and only a minor proportion of fragments was unidentifiable. 6 168 fragments were identified and attributed to 22 wood types. The high variability of features as it can be found in Mediterranean arboreal species is also shown by the Corbeddu material. This made it often difficult to attribute certain specimens to a definite type, as will be discussed later. The results are presented in a diagram showing for each layer the charcoal concentration in numbers of pieces per m³ (**fig. 2**).

The diagram shows a clear distinction in the charcoal spectra:

Layer 2.1 (Mesolithic): low charcoal concentrations, dominated by *Juniperus* spec.

Layer 1.2 (Neolithic): high charcoal concentrations, especially from *Arbutus unedo*, *Pistacia* spec., *Rhamnus* spec., *Phillyrea* spec. and again *Juniperus* spec.

Each wood type will be discussed in alphabetical order.

***Acer* type:** Because of the very small size of analysed fragments, a species attribution was not possible. *A. monspessulanum* is native and *A. campestre* is supposed to be indigenous (Pignatti 1982 [Vol. 2], 70), but are presently not growing near the cave. *Acer* charcoal is present – in low concentrations – throughout the profile, meaning that maple grew nearby during the early and middle Holocene. As *A. monspessulanum* (**fig. 3**) is characteristic for the natural woodland on the slopes near and above the cave entrance, the presence of maple charcoal means that the slope was forested.

Arbutus unedo (**fig. 4**): In spite of the high variability of the anatomical features within this species, the charred wood was easy identifiable based on the spiral thickenings in almost all vessels and vessel tracheids. *Arbutus unedo* is a major component of the present maquis on the pediment below the cave. Under natural conditions, *Arbutus unedo* is part of the understory vegetation of holm oak forests, but when the trees are cut or the woodland is burnt, this species tends to spread (Badal et al. 1994). The charcoal diagram shows that from the Early Neolithic on high amounts of *Arbutus* are present in the charcoal spectrum; during the Early Neolithic it even was the dominant charcoal type. The presence of charred fruit stones in the cave sediments shows that not only the wood was used as fuel, but the fruits also were collected and eaten.

Capparis spinosa (**fig. 5**): Three pieces of charcoal showed the characteristics of *Capparis spinosa*, a species growing on the steep bare limestone rocks (Pignatti 1982 [Vol. 1], 367), as for instance the rocky slope around the cave entrance.

***Cistus* type:** A species attribution based on wood anatomical criteria within the genus *Cistus* is not possible. Three species are indigenous on Sardinia (Pignatti 1982 [Vol. 2], 121 f.): *C. incanus* (**fig. 6**), *C. monspeliensis* and *C. salvifolius*. They grow in maquis and garrigue. *Cistus* charcoal has only been found in the Early Neolithic. The low presence of *Cistus*-charcoal should rather be a consequence of the thin heavily branched twigs, being bad quality fire wood, than of its presence or absence in the surrounding vegetation.

***Fraxinus* type:** The charcoal was too tiny to enable further identification as to the genus. Two species grow on Sardinia (Pignatti 1982 [Vol. 2], 322): *F. ornus* (**fig. 7**) in the mountains and *F. oxycarpa* in hygrophilous forests. The few charcoal

Fig. 3 *Acer monspessulanum*. Deciduous, medium-sized tree with a height of 3–10 m. The leaves in opposite pairs are three-lobed with smooth margins.

Fig. 4 *Arbutus unedo*. Apart from its use as firewood, the decorative fruits of the strawberry tree were eaten.

Fig. 5 *Capparis spinosa.* The caper bush with its beautiful flowers could have grown on the rocks nearby the cave.

Fig. 6 *Cistus incanus*. The delicate crumpled petals are typical for the flowers of this plant.

fragments were found – together with those from Ulmaceae – in Mesolithic layers. Their provenance from riverine elm forests seems possible.

***Juniperus* type:** It is impossible to identify to the species level based on wood anatomical criteria alone. Indigenous on Sardinia are according to S. Pignatti (Pignatti 1982 [Vol. 2], 84 ff.): *J. nana*, *J. oxycedrus* ssp. *oxycedrus*, *J. oxycedrus* ssp. *macrocarpa* and *J. phoenicea* (**fig. 8**). *Juniperus nana* is distributed at the subalpine tree line (Bacchetta 2009a, 25) and *J. oxycedrus* ssp. *macrocarpa* on sand dunes along the coast (Mossa et al. 1988), their Holocene presence in the Lanaittu Valley may therefore be excluded. The other two species grow nowadays in large amounts near the cave, especially on the steep limestone slope surrounding the entrance. Charcoal of *Juniperus* is the only type which shows an almost constant concentration throughout the profile, with a slight maximum at the beginning of the Early Neolithic. This may indicate that juniper species always have grown near the cave entrance and were always at hand as easy accessible fire wood.

Lamiaceae type: From a wood anatomical point of view all woody members of this plant family have more or less the same cell structure, so that species identification is very difficult. Some specimens, however, show a structure identical to *Rosmarinus officinalis* (**fig. 9**). This plant species is abundant in the garrigue of the Lanaittu Valley. Charred Lamiaceae wood has been found in the Early and Middle Neolithic layers.

Laurus nobilis: A riverine plant species, growing in the river bed of the nearby Rio de sa Oche (**fig. 10**). A few pieces of charcoal are found in the Neolithic layers.

Fig. 7 *Fraxinus ornus.* In late spring the flowers of the manna ash are spreading a pleasant sweetish scent.

Fig. 8 *Juniperus phoenicea.* The berry-like cones are mature in the second year, then having a shining red to red-brown colour.

Fig. 9 *Rosmarinus officinalis.* Flowers of the dense, very aromatic evergreen shrub, which is abundant in the present vegetation of the Lanaittu Valley.

Fig. 10 *Laurus nobilis*. Laurel is still present in ever-green ravine forests and on river beds of Sardinia.

Fig. 11 *Lonicera etrusca.* In the maquis this climber is conspicuous for the scent of its flowers.

Fig. 12 *Myrtus communis.* The blue-black berries of myrtle are used in Sardinia to produce the sweet aromatic liqueur called “Mirto Rosso”.

Fabaceae type: The wood anatomical variability of this wood type is so large that as a rule it is not possible to identify single pieces of charcoal on a species level. The few pieces of this type are found throughout the profile and could originate from broom species like *Calycotome villosa* or *Genista corsica*, growing in the maquis near the cave.
Lonicera **type:** The species of this genus can hardly be differentiated on wood anatomical criteria alone. On Sardinia grow the woodland species *L. etrusca* (syn. *L. cyrenaica*) (**fig. 11**) and the maquis species *L. implexa* (Pignatti 1982 [Vol. 2], 643 f.), growing actually on the pediment. The few pieces of charcoal from the Neolithic layers could originate from both species.
Myrtus communis**:** This is a characteristic species of the maquis, especially the more arid and thermophilous types (Pignatti 1982 [Vol. 2], 149). It is abundant in the shrub layer of the maquis in the Lanaittu Valley (**fig. 12**). The charcoal is found in the Neolithic layers.
Olea europaea**:** There is no wood anatomical difference between the wild and domesticated olives (**fig. 13**). Wild olive (*Olea europaea* var. *sylvestris*, syn. *Olea oleaster*) is a rare but characteristic species of the Sardinian thermophilous maquis (Bacchetta et al. 2009a, 34; 40) – often in combination with *Pistacia lentiscus*. Its charcoal is present from the earliest Neolithic layer on in low amounts.
Paliurus spina-christi**:** One tiny fragment of charcoal has the wood anatomical characteristics of this plant species (**fig. 14**). The plant is a species from thermophilous and arid slopes like there are plenty near the cave, but according to S. Pignatti Christ´s thorn is at present not growing on Sardinia (Pignatti 1982 [Vol. 2], 76). The fragment of charcoal from a Mesolithic layer indicates, however, its presence in the early Holocene.
Phillyrea **type:** This plant genus includes several taxonomically rather variable plant species (Pignatti 1982 [Vol. 2], 325 f.). This variability is also reflected in the wood anatomy. Even within one single branch a high variability in features can be found; the year rings not seldom show an annually differing pattern in the distribution of the pores. In some extreme examples it is even impossible to differentiate the wood from that of the genus *Rhamnus*. This should be considered in the interpretation. It will be clear that a species attribution of charcoal within the genus *Phillyrea* is not possible. Two species grow in the maquis and holm oak woodland of Lanaittu Valley: *P. angustifolia* (**fig. 15**) as a common species from maquis and garrigue on the pediment and *P. latifolia* in maquis and holm oak woodland on the limestone slopes. Both species could have attributed to the charcoal which is present throughout the profile.
Pinus nigra/sylvestris **type:** A further differentiation between the two species is not possible, but this wood type excludes all other Mediterranean pine species. However, neither *P. nigra* nor *P. sylvestris* are native in the present-day vegetation of Sardinia (Pignatti 1982 [Vol. 1], 78). *P. nigra* ssp. *laricio* though grows on the neighboring island of Corsica in the mountains above 700 m. As Corsica and Sardinia were during the last Glacial and early Holocene connected by a land bridge, an immigration of pine was possible and probable. Indeed, the early Holocene pollen spectra of Corbeddu Cave show the presence of pine on Sardinia during Late Glacial and early Holocene. Pine charcoal is present throughout the profile until the Middle Neolithic. Contamination by charcoal from much older layers, as could be established in the Early Neolithic layers of the Cova de les Cendres (Alicante, Spain) (Bernabeu et al. 1999) can in this case be ruled out, because the 40 cm thick breccia layer 2.1.d. prevented the worms to dig into the late-glacial layers. Thus we have to conclude that *Pinus nigra* was a native species on Sardinia during the early Holocene and grew in the Lanaittu Valley.
Pistacia **type:** On wood anatomical criteria it is not possible to differentiate between the two native species, *P. lentiscus* and *P. terebinthus* (**fig. 16**). Both species grow in the Lanaittu Valley, the former in the evergreen maquis – often in combination with *Olea europaea* –, the latter in thermophilous oak woods and on arid limestone slopes. The charcoal which is present throughout the profile, but especially in the Neolithic layers, may originate from both species. During the Middle Neolithic it was with 30–40 % the dominant type in the charcoal spectrum. Because it is found there in combination with charcoal from *Olea europaea*, *P. lentiscus* seems to be the most probable species.
Prunus **type:** Some charcoal fragments of *Prunus* spec. are present. Several species are native on Sardinia: *P. avium* a rare but indigenous tree of riverine woodland in the mountains, *P. prostata* ssp. *humilis* a Sardinian endemic species from the high mountains, and *P. spinosa* (**fig. 17**) a species from forest fringes. The wood anatomical criteria show strong resemblance to *Prunus spinosa*, which grows in the Lanaittu Valley. Some specimens, however, show in cross section structures which resemble those of *P. dulcis* and *P. persica.* This charcoal type has only been found in the Early Neolithic layers for which the presence of those two species is improbable.

Fig. 13 *Olea europaea.* Archaeological finds point to the cultivation of the olive tree already around 4000 BC (Zohary et al. 2012, 116–121).

Fig. 14 *Paliurus spina-christi.* The 5–6 m tall spiny shrub grows on sunny to light shady locations. Remarkable is the fruit with its circular wing.

Fig. 15 *Phillyrea angustifolia.* A branch with leaves in opposite pairs is bearing the ripening drupes in autumn.

Fig. 16 *Pistacia terebinthus.* The male inflorescences of the turpentine tree often show a bright-reddish colour.

Fig. 17 *Prunus spinosa.* A branch with ripening drupes. Blackthorn prefers sunny sites on rocky slopes or in woodland fringes on calcareous soils.

Fig. 18 *Quercus ilex.* Young shoots with aphids, which are being milked by ants.

Fig. 19 *Rhamnus alaternus.* An evergreen shrub that is flowering during winter and early spring, bearing fleshless drupes that turn black at full maturity.

Fig. 20 *Celtis australis.* Sunlight shining through the leaves and ripe, edible fruits of the European nettle tree.

Fig. 21 *Viburnum tinus.* The ripe drupes of the evergreen shrub are metallic-blue.

***Quercus ilex* type:** Apart from *Q. ilex* (**fig. 18**), also *Q. coccifera* and *Q. suber* belong to this wood type. The charcoal fragments were too small for a more precise identification. However, *Q. coccifera* grows in Sardinia only on the dunes along the west coast (Nudda 1986; Mossa et al. 1988) and *Q. suber* avoids limestone areas (Nudda 1986). Therefore, all specimens of this type originate from *Quercus ilex*. Apart from the sample from the Bronze Age pit, charcoal of this type is only present in very low numbers throughout the profile.

***Rhamnus* type:** The small pieces of charcoal do not allow a further identification on the species level, although *R. alpinus* ssp. *alpinus* can be excluded because of its different wood anatomy. In some cases even confusion with *Phillyrea* cannot be excluded (see above). Apart from *R. alpinus* three more species are native on Sardinia (Pignatti 1982 [Vol. 2], 78): *R. alaternus*, *R. oleoides* and *R. persicifolius*. *Rhamnus alaternus* (**fig. 19**) is characteristic for the maquis near the cave. Charcoal of *Rhamnus* is present throughout the profile, with maximum values in the Early Neolithic layers.

Rosaceae type: One specimen from a Late Neolithic sample shows the structure of *Rosa* spec., although it is too small for a definite identification. Other wood types like that of the Maloideae could be considered, but their presence during the Neolithic seems improbable. On Sardinia several *Rosa* species are present (Arrigoni/Camarda 2014): *R. canina* and *R. elliptica* along woodland fringes, *R. serafinii* and *R. pouzinii* in the mountains, *R. sempervirens* in the understory of holm oak woodland.

Ulmaceae/Cannabaceae type: Although the wood anatomical characteristics of the Ulmaceae/Cannabaceae exclude confusion with other wood types, identification onto the species level is not possible. Two species are native on Sardinia: *Ulmus minor* and *Celtis australis* (**fig. 20**) (Pignatti 1982 [Vol. 1], 121 f.; Nudda 1986). The former is a tree from riverine forests and forests on moist and base rich slopes; the latter, however, prefers dry forests on limestone soils. Ulmaceae/Cannabaceae charcoal is present throughout the profile, although in somewhat higher concentrations during the Mesolithic.

***Viburnum* type:** A species attribution based on wood anatomical criteria is not possible, but on Sardinia only one species is native: *Viburnum tinus* (**fig. 21**), which grows in the *Quercus ilex*-woodlands (Bacchetta et al. 2009b, 44). This charcoal type has only been found in the Early Neolithic layers.

Reconstruction of the wooded vegetation near Corbeddu Cave

For a better understanding of the early Holocene vegetation history, the results of the unpublished palynological analyses of the cave sediments by A. Spaan (Spaan 1990) will be included. **Figure 22** shows the Holocene sequence of the much longer pollen diagram.

Vegetation during the Mesolithic (Layer 2.1)

For a reconstruction of the vegetation near Corbeddu Cave the pollen spectrum of the layers 2.1.e and 2.1g is conclusive. The pollen spectrum is dominated by non-arboreal pollen, especially Asteroideae (10–20 %), Poaceae (6–12 %) and Chenopodiaceae (1–2 %). Important are also fern spores, reaching values from 20 to 30 %. The arboreal pollen content varies between 45 and 50 % of the pollen sum. It is mainly composed of *Pinus* (20–35 %), *Olea* (5–12 %) and *Quercus* (6–12 %) with single finds of *Betula*, *Corylus*, *Salix* and *Alnus*. This pollen spectrum reflects a vegetation pattern in which the arboreal vegetation played a subordinate role; the Lanaittu Valley was covered by steppe vegetation with patches of pine and oak woodland. This was probably caused by the aridity of the valley bottom, which even nowadays belongs to the driest parts of Sardinia. The arboreal vegetation must therefore be found in the mountains, because of their higher precipitation, and along rivers.

The charcoal spectrum of the layers 2.1.e,f,g is dominated by the species group of the limestone slopes (*Juniperus* and *Pinus*). The bad pollen preservation in the archaeological layers did unfortunately not allow us the recognition of *Juniperus* pollen and therefore its presence could not be verified in the pollen diagram. Nevertheless, the charcoal spectrum indicates its presence on the slopes around the cave entrance. Some kind of xero-thermophilous woodland must have existed nearby, because charcoal of *Phillyrea*, *Rhamnus* (probably *R. alaternus*) and *Pistacia* (probably *P. terebinthus*) has been found. The rather low pollen percentages of *Quercus* spec. and *Quercus ilex* and the almost complete absence of their charcoal make it improbable that those xero-thermophilous arboreal vegetations were evergreen oak woods. Could they have been pine woodlands?

About 200 m from the cave entrance flows the currently temporary stream Rio de sa Oche. Its temporality is regulated by thresholds in the underground lakes of the Sa Oche-Su Bentu cave system (Ulzega 1988). It is not unthinkable that in earlier times the water regulation was different and the outflow more evenly spread over the year. In that case riverine forests could have existed along the Rio de sa Oche. The charcoal spectrum from Corbeddu Cave points very much to that conclusion, because charcoal of three wood types (*Acer*, *Fraxinus* and Ulmaceae) – especially in the lower part of the profile – indicate the nearby presence of riverine forests.

In conclusion, it can be stated that the pollen and charcoal spectrum from the early Holocene show that around Corbeddu Cave an arboreal vegetation of Corsican pine and juniper was present, with a mixed forest of ash, elm and maple along the rivulets and in the canyons near the cave. Large areas of the Lanaittu Valley, however, were not forested and covered with steppe vegetation.

With the collapse of the entrance of Hall 2, the pollen diagram can no longer inform us about the vegetation in the Lanaittu Valley. The pollen spectrum is now dominated by pollen and spores of the plants that were brought in by people, especially ferns and grasses. The purpose of this action is not known, but the plants could have been used as isolation on the cold (around 8°C) cave floor.

However, the charcoal assemblage remains almost the same after closure of the entrance, dominated by juniper and pine. Only the amount of Ulmaceae decreases and that of pine increases somewhat. The cave was used further on by people, and the same wood species were used for fire as before.

Vegetation during the Early Neolithic

From the early begin of the Neolithic, however, the charcoal assemblage changes radically, while the pollen spectrum, on the other hand, remains the same.

The charcoal assemblage from the Early Neolithic on shows a spectrum in which *Pinus* and *Juniperus* are no longer the main constituents. From now on *Arbutus unedo* is the main species. The almost 40 % *Arbutus* in the Early Neolithic charcoal spectrum contrast sharply with the Mesolithic, were it was hardly present. This is corroborated by the absence of (easy recognizable) Ericaceae pollen in Mesolithic layers. *Arbutus unedo* normally tends to spread when *Quercus ilex*-woodland is cut or burned, for it benefits to a certain degree from its destruction (Badal et al., 1994). Its sudden appear-

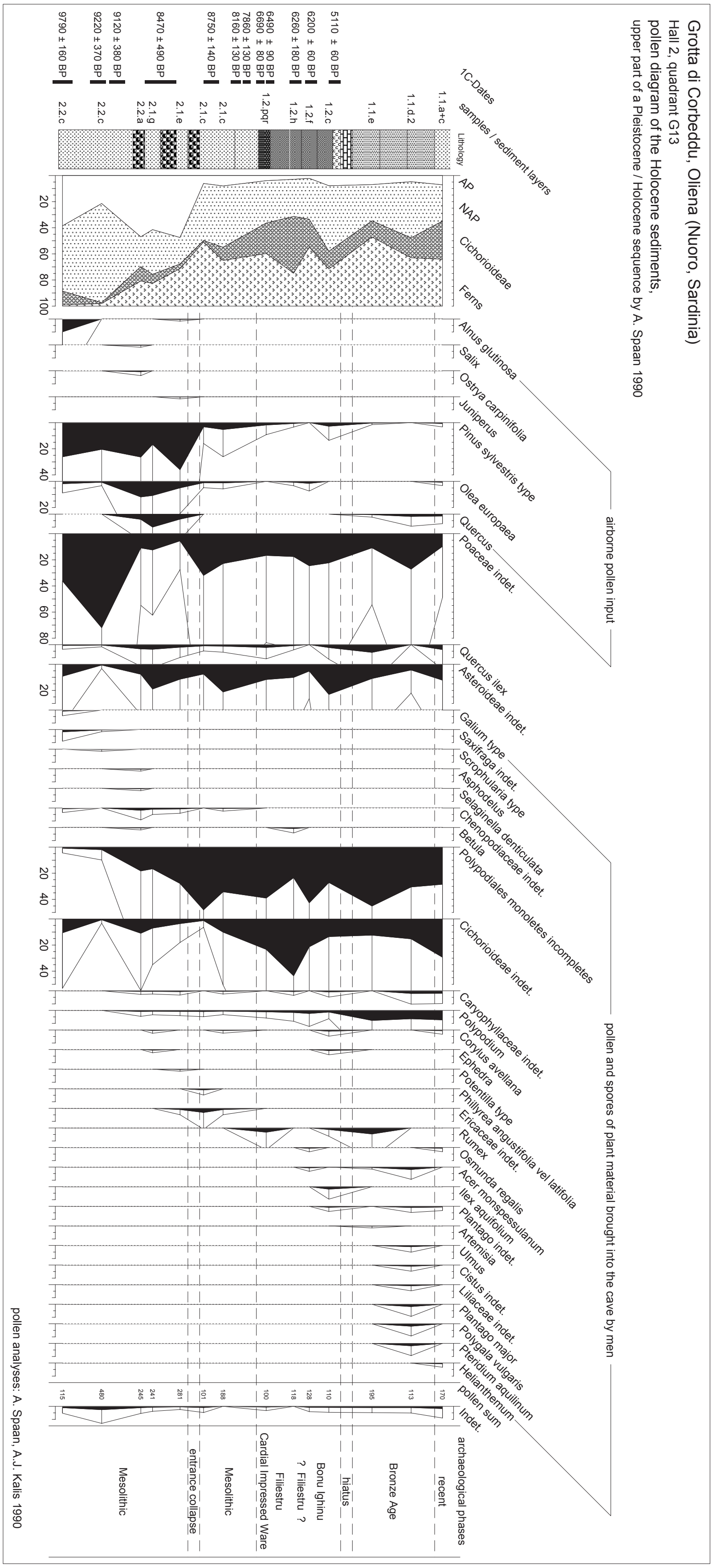

Fig. 22 Pollen diagram of the Holocene sediments of Hall 2 in Corbeddu Cave.

ance and dominance in the Early Neolithic layers therefore indicate a strong human impact on natural holm oak woodland. Charcoal of the *Viburnum* type, *Lonicera* type, *Prunus* type, *Phillyrea* type and *Rhamnus* type which are part of the Early Neolithic charcoal spectrum could also have originated from the *Quercus ilex*-woodland – considering that *Viburnum tinus*, *Lonicera etrusca*, *Prunus spinosa*, *Phillyrea latifolia* and *Rhamnus alaternus* are all components of the potential natural vegetation, see above. However, holm oak itself is hardly present in the charcoal spectrum, neither in the Mesolithic nor in the Neolithic layers. So the question arises what kind of woodland was burned by Neolithic people. Pine woods seem a probable candidate. Nevertheless, the high *Arbutus unedo* values indicate that already from the beginning of Neolithic occupation on, a maquis-like vegetation existed on the pediment below the cave entrance. A kind of *Arbutus* dominated shrub vegetation with so many woodland species, that a dense and dark maquis could have existed.

The concentrations of *Juniperus* and *Pinus* increased much less than those of the other wood types, meaning that they were collected in about the same degree as before. In conclusion the charcoal spectrum from the Early Neolithic period shows arboreal vegetation near Corbeddu Cave of juniper and pine on the limestone slopes and a dense *Arbutus* maquis on the pediment below. The presence of riverine forest along the Rio de sa Oche could be stated further on.

The vegetation during the Middle Neolithic

A decrease of charcoal from *Arbutus* and *Rhamnus*, and an increase in those from *Pistacia* and *Olea europaea* mark the vegetation to the second phase of the Early Neolithic (probable the Filiestru phase). The number of wood types also decreases. This is the natural reaction of the vegetation on an even more intensive exploitation of the thermo-mediterranean environment: the *Arbutus*-shrubland is also cut or burned and a garrigue of *Olea*/*Pistacia*-shrubland develops. During this phase *Pistacia* became with 30–40 % the dominant type in the charcoal spectrum; because it appeared now in combination with charcoal from *Olea europaea*, it seems from a phytosociological point of view likely that *P. lentiscus* was the plant species in question. The Filiestru people collected their fire wood in a vegetation type comparable to the recent Oleo-Lentiscetum.

Discussion

The combination of the results from archaeology and archaeobotany enhances our understanding concerning the function of Corbeddu Cave in successive prehistoric societies. The sedimentological analyses of the layers in Hall 2 show that originally there was no input of clastic material from outside into the cave (de Visser/van den Bergh 1999). The abundant bones and plant remains could therefore not have entered the cave by natural causes, like for instance water transport. The presence can only be explained as waste which was left behind inside the cave by prehistoric people. The charcoal content of the early and middle Holocene sediments proves that bonfires were laid and indeed many fire places were identified in both Mesolithic and Neolithic layers. The composition of the charcoal assemblage seems to be a good reflection of the arboreal vegetation in the vicinity of the cave. The fire wood was apparently not biased by selection. This corroborates the results of other Palaeolithic and Mesolithic sites.

During the early Holocene the fire places were made to prepare food, especially to grill pikas (*Prolagus sardus*). The cave was used as shelter illuminated by daylight, and was used only temporarily probably during hot summer days or cold winter nights.

After the collapse of the entrance it became very difficult to reach Hall 2 and from now on it was impossible to go into the cave without artefical light; fire in form of torches or lamps was essential. Nevertheless, the concentration of charcoal per m^3 sediment remained the same throughout the Mesolithic, which means that Mesolithic people used to visit the cave further on in the same way as before. *Juniperus* was the wood that was most frequently used, most likely because these shrubs grew around the cave and can easily be lit.

This behaviour drastically changed with the beginning of the Early Neolithic. The colour of the cave sediments turns abruptly from reddish brown to dark grey at the transition from Mesolithic to Early Neolithic. This reflects the rising concentration of charcoal which jumps from several hundreds of identifiable fragments (at least 5 mm long) to over 10 000 per m^3; one of the layers (1.2.q) consists even of almost pure charcoal dust (see above). The excavation showed that the Early Neolithic surface was scattered with numerous fire places demonstrating an intensive use of Hall 2. The many bone fragments (450 per m^3) (Eisenhauer/Kalis 1999, Abb. 5) suggest that the fire places were mainly used for the preparation of meals, especially meat. The decomposing remains of meals offered ideal nutrition for earthworms – in the Holocene part of the profile worm tubes especially occur in Early Neolithic layers and penetrate into the underlying layers.

Not only the amount of charcoal but also the composition of the fire wood changed radically with the beginning of the Neolithic. *Arbutus unedo*, hardly present in Mesolithic layers, became the dominant fire wood. Also *Phillyrea* spec., *Rhamnus* spec. and *Pistacia* spec. were found in high concentrations. Only charcoal of *Juniperus* was already important before reaching its highest concentration in the Early Neolithic. Two explanations for this change are possible but can hardly be separated. A change of vegetation could be the first explanation. The second reason could be the growing need for fuel that urged the Early Neolithic people to enlarge their collective range for fire wood and consequently they entered other ecotypes with different vegetation types.

The pediment at around 50 m below the cave entrance is nowadays covered with a dense maquis in which all the in Neolithic times as fire wood used shrub species grow. Maquis, however, is not natural vegetation. According to most ecologists it is a man-made vegetation type, which only can develop and be maintained under a regime of regular cutting, burning and/or grazing. This would plead for the first explanation: the original vegetation near Corbeddu Cave was turned into a maquis by the activities of Early Neolithic people and their domestic animals (sheep, goat and pig, according to the bones from Corbeddu Cave). This explanation would imply that within decades after the arrival of Neolithic people on the island the maquis developed, and in the almost eight thousand years after since hardly changed. The results of the charcoal analysis do allow hardly another choice.

What role did the cave play during the Early Neolithic? During the excavation no traces of household activities other than preparing meals was found. The cave as a permanent residence may therefore be excluded from further consideration. The charcoal spectra, however, show near the cave an environment that was so intensively altered by people and their livestock that the settlements of those people must have been in the direct vicinity, although no traces have been found yet; but one has to bear in mind that the morphology of this arid landscape was heavily changed since the Early Neolithic and special archaeological prospection techniques are needed to find those settlements. Within this (unknown) settlement pattern the cave certainly played a role, because it was frequently visited. Those periods were long enough for the urge to prepare and digest meals. Again the function of a shelter, against winterly colds or possibly against enemies, comes to mind as a possible function.

During the Middle Neolithic the use of Hall 2 hardly changes. The fire places are fewer in number, but are from a more permanent character with stone circles surrounding shallow pits. Potsherds reach with 25 per m^3 the highest density of all layers. The charcoal spectrum shows an even more intensive exploitation of the environment near the cave.

Notes

[1] We like to thank Prof Dr Amy Bogaard (Oxford) for her linguistic improvements of the text.

[2] At the opening for the public in 2010 renamed to Grotta Corbeddu–Sondaar, in honour to Dr Paul Y. Sondaar, initiator and project leader of the excavations.

[3] Otherwise than Skeates (2012, 3) stated.

[4] UtC-sine numero.

[5] UtC-999.

[6] UtC-250.

[7] Formerly this archaeological phase was named Epipalaeolithic.

[8] 8470 ± 90 BP, UtC-15001.

[9] 8750 ± 140 BP, UtC-300.

[10] 7860 ± 135 BP, UtC-301 and 8160 ± 130 BP, UtC-235.

[11] All archaeological finds are archived in the Museo nazionale archeologico di Nuoro.

[12] 6690 ± 80 BP, UtC-1251.

[13] 6490 ± 90 BP, UtC-15/233N.

[14] 6200 ± 60 BP, UtC-1253, 6200 ± 140 BP, GrN-11406, 6260 ± 180 BP, GrN-11433.

[15] The Filiestru ceramic phase of the Early Neolithic dates according to Skeates (2012) from 5300 to 4700 calBC.

[16] 5110 ± 60 BP, UtC-1252

[17] They were unfortunately no subject of further analyses.

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