



## A REASSESSMENT OF THE INFILLS AND FAUNAL ASSEMBLAGES OF KARST CAVITIES KNOWN AS VENTAROLE IN SALENTO (APULIA, SOUTHERN ITALY): A MULTIDISCIPLINARY INVESTIGATION ON CAVA DONNO (CORIGLIANO D'OTRANTO, LECCE)

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**ABSTRACT:** The karstic areas of Apulia in SE Italy are characterized by fissures locally called *ventarole*, which are known to contain bones of Pleistocene mammals. These bone assemblages have been commonly associated to the Late Pleistocene, based on stratigraphic, geomorphological and biochronological observations. We undertook palaeontological, radiocarbon and isotope analyses to verify whether the animal remains from the quarry of Cava Donno, near Corigliano d'Otranto (Apulia), were all actually of Pleistocene age. Our study shows that the infills of the *ventarole* contain, along with Late Pleistocene bones attributable to the Melpignano Faunal Unit, Holocene vertebrate skeletal remains. The deeper red clay infill at Cava Donno contains fauna of Pleistocene age, whilst the upper dark-reddish clayey sands contain mainly the bones of domestic animals and of a modern human. The AMS radiocarbon date, obtained to establish the age of this human from the *ventarola*, coincides with the Neolithic period. Carbon and nitrogen isotope analyses on the same bone collagen suggest that the diet of this individual was similar to that of other Neolithic humans from Italy. The individual from Cava Donno had a balanced diet, centred upon terrestrial foods, with nutrients acquired both from vegetal and animal resources. The combined palaeontological, radiocarbon and isotopic data presented here suggest that crypto-solution processes occurred at Cava Donno both in the Last Interglacial and, to some extent, also around the Holocene Climatic Optimum. This implies that *ventarole* karst infills may contain vertebrate remains of Pleistocene and Holocene age and that, therefore, the assemblages from them probably need revising because they may not all date back to the early Late Pleistocene.

**Keywords:** Karst cavities; Pleistocene; early Holocene; Neolithic; carbon and nitrogen isotope analyses

### 1. INTRODUCTION

The Salento Peninsula (Apulia, Southern Italy) is well-known for the presence of karst cavities containing deposits that preserve rich paleontological and archaeological bone assemblages of Pleistocene and Holocene age (e.g., Mirigliano, 1941; Borzatti von Löwenstern, 1966; Palma di Cesnola, 1966; Spennato, 1981; De Giuli, 1983; Cremonesi et al., 1984; Corridi, 1987; Bologna et al., 1994; Rustioni, 1998; Vacca, 2006; Petronio & Pandolfi, 2008; Benazzi et al., 2011; Pandolfi & Petronio, 2011; Boscato & Crezzini, 2012; Pandolfi & Tagliacozzo, 2013). This area represents, therefore, an important repository of invaluable data for reconstructing the evolution of past environments during the Pleistocene and Holocene in Southern Europe. Abundant mammal remains have been recovered in different karstic features of the Salento Peninsula, such as in cave deposits (e.g., Blanc, 1920, 1928; Maviglia, 1955; Orlandi & Cigna, 1956; Cardini, 1958a; Borzatti von Löwenstern,

1966, 1971; Giusti, 1979; Dantoni & Nardi, 1980; Campetti, 1986; Boscato & Crezzini, 2012), in stratified sediments at the bottom of dolines (Corridi, 1987), and in sub-vertical or funnel-shaped fissures, locally known as *ventarole*, filled with reddish sediments (Mirigliano, 1941; Cardini, 1958b; De Giuli, 1983; Bologna et al., 1994; Rustioni et al., 1994).

The *ventarole* are located within the Pietra Leccese Formation and outcrop in several quarries located in the districts of Melpignano, Corigliano d'Otranto and Maglie (Lecce; Fig. 1). Most of the fossil mammal assemblages collected from the karstic fillings of the *ventarole* have been attributed to the early Late Pleistocene (Bologna et al., 1994; Bedetti et al. 2004; Cipullo et al., 2006; Petronio et al., 2007; Petronio & Pandolfi, 2008; Pandolfi & Petronio, 2011). These assemblages include skeletal remains of carnivores (*Panthera spelaea*, *Crocuta crocuta*, *Canis lupus*), elephants (*Palaeoloxodon antiquus*), rhinoceroses (*Stephanorhinus hemitoechus*), horses (*Equus hydruntinus*, *Equus ferus*), hippopotamuses

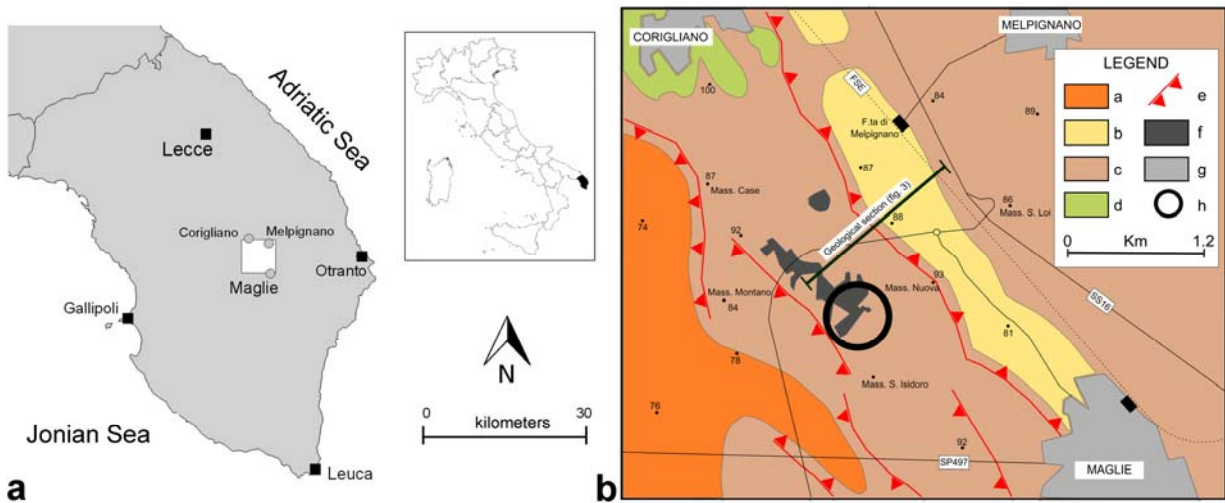


Fig. 1 - a: Location map of the investigated area; b: location map of the Cava Donno quarry and geological scheme of the S. Sidoro (Melpignano) area. Legend: a) Calcarenes (Lower Pleistocene); b) Leuca Formation and Sabbie di Uggiano (Pliocene); c) Pietra Leccese (Upper Miocene); d) Calcarei di Altamura (Upper Cretaceous); e) fault slope; f) quarry; h) urbanized area; i) investigated area.

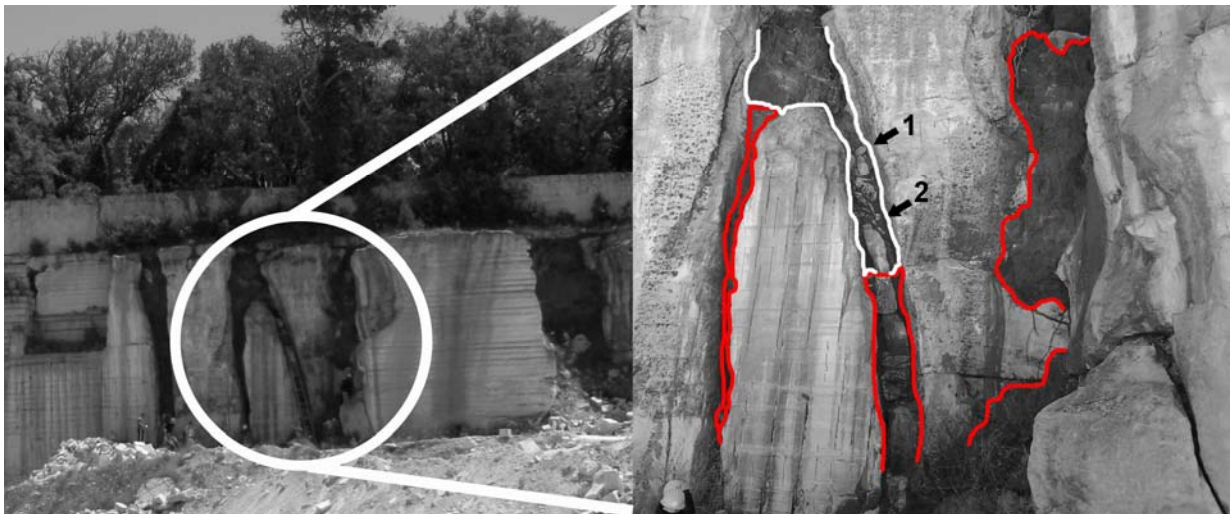


Fig. 2 - N-shaped karst cavities of Cava Donno (Melpignano, Lecce). The arrows indicate the position of the humerus (1) and coxal bone (2) of *Homo sapiens*. The white line indicates the dark reddish clayey sands that yielded the Holocene fauna whilst the red line indicates the red clay with Pleistocene fauna.

(*Hippopotamus amphibius*), bovids (*Bos primigenius*, *Bison priscus*), cervids (*Cervus elaphus*, *Dama dama*) and other taxa (Mirigliano, 1941; Cardini, 1958b; De Giuli, 1983; Bologna et al., 1994; Bedetti et al., 2004; Cipullo et al., 2006; Petronio & Pandolfi, 2008; Pandolfi & Petronio, 2011).

During a paleontological field survey, several fossil remains belonging to *Oryctolagus cuniculus*, *Lepus corsicanus*, *C. lupus*, *P. spelaea*, *C. crocuta*, *E. ferus*, *C. elaphus*, *D. dama* and *B. primigenius* were collected from several karst fillings exposed at Cava Donno, a quarry near the town of Corigliano d'Otranto. In addition to some of the above-mentioned taxa, remains of domestic mammals and of *Homo sapiens* were recovered from an N-shaped karst fissure. The Cava Donno *ventarola* investigated in this paper is characterized by red

clayey infills in its sub-vertical cavities and by red clayey and dark reddish clayey sands in its oblique cavity (Fig. 2). The Late Pleistocene and Holocene mammal remains recovered from this N-shaped fissure are the object of the present paper. The aims of this study were: 1. to study the bone assemblage from Cava Donno in an attempt to understand its formation and relative chronology; 2. to undertake AMS radiocarbon dating and isotope analyses on the bone collagen of the human individual whose remains were recovered from the *ventarola* to establish its absolute chronology and reconstruct its diet. Moreover, the diachrony of the karst fillings from Cava Donno and from the districts of Melpignano, Corigliano d'Otranto and Maglie is discussed.

## 2. GEOMORPHOLOGICAL AND GEOLOGICAL FRAMEWORK

The landscape of the area between the present-day villages of Corigliano d'Otranto, Melpignano and Maglie in Apulia is marked by a narrow morphostructural ridge stretching in a NW-SE direction and bordered by two low steep scarps (Fig. 1). This ridge characterizes the mean axis of southern Salento from the area to the south of the village of Botrugno to the NW of the village of Corigliano d'Otranto, where it reaches its maximum relief and acquires the local name of "Serra di Corigliano" (Palmentola, 1987).

Rocks belonging to the Pietra Leccese Formation (Upper Miocene) extensively crop out in correspondence to the morpho-structural ridge. They are biomicrites mainly constituted by calcareous plankton, generally yellowish in colour except in the uppermost levels which are greenish, because of the high glauconitic content. This lithostratigraphic unit is composed by indistinct thick strata and characterized by intense bioturbation, as well as by high macrofossil content, mainly of bivalves (above all pectinids) and echinoderms (spatangids). Fossils are both dispersed and concentrated in lenses or layers; shark teeth are very frequent (Largaiolli et al., 1969; Balenzano et al., 2003).

The unit is transgressive on the Mesozoic basement (Calcarei di Altamura Formation, Upper Cretaceous) by means of a conglomerate layer marked by phosphatized clasts and fossils, as well as apatite nod-

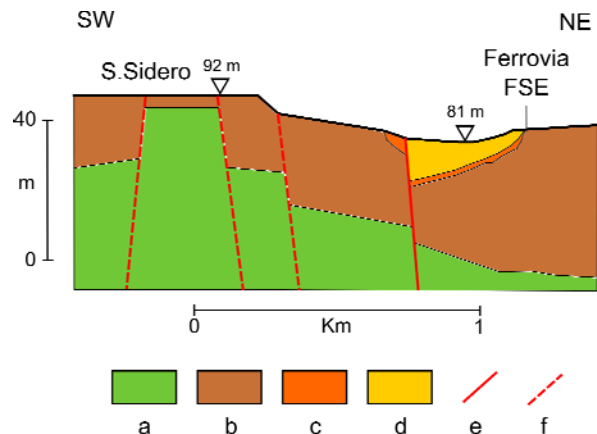


Fig. 3 - Schematic geological section of the investigated area. Legend: a) Calcarei di Altamura (Upper Cretaceous); b) Pietra Leccese (Upper Miocene); c) Leuca Formation (Lower Pliocene); d) Sabbie di Uggiano (Upper Pliocene); e) fault; f) supposed fault.

ules. The Mesozoic limestones crop out in the northernmost area of the ridge, roughly from the village of Corigliano d'Otranto to the NW. The contact between Mesozoic limestone and Miocene calcarenites is well exposed along the Salento Manufatti s.r.l. quarry cliffs.

The north-eastern border of the ridge, constituted by a degraded fault scarp, comprises at its foot a small outcrop of Upper Pliocene calcarenites belonging to the Uggiano La Chiesa Formation (Bossio et al., 1987). Smaller outcrops of Lower Pliocene rocks ("Formazione di Leuca"), uplifted by faulting, can be recognized at the lowermost part of the scarp (Fig. 3).

Above the ridge is a plain characterized by numerous quarries, given that Upper Miocene rocks are used for the production of blocks and slabs. Sub-vertical karst cavities (i.e. *ventarole*), are present along the cliff sections of the quarry, infilled with reddish sandy-clayey deposits that cover the plain above the ridge. The transverse section of these cavities is still not well defined.

The *ventarole* are spaced about ten meters from each other and reach depths of more than 10 m from soil surface. Their maximum width is generally less than 1 m, although locally, cavities of up to 5-6 meters can be recognized. Cavities become narrower downwards, terminating always in a joint plane (Fig. 4). The strong structural control in the development of these landforms is testified by the morpho-structural analysis performed

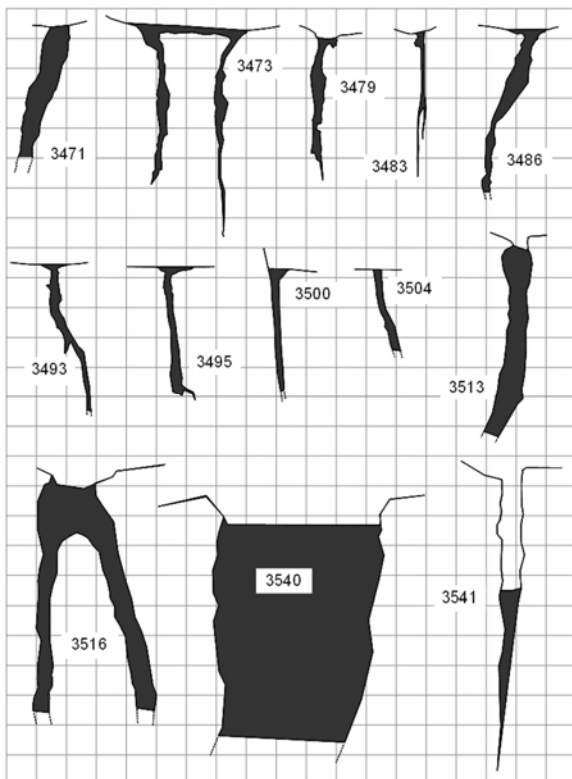


Fig. 4 - Longitudinal section of the karst cavities (*ventarole*) recorded at Cava Donno (S. Sidero, Melpignano, Lecce).

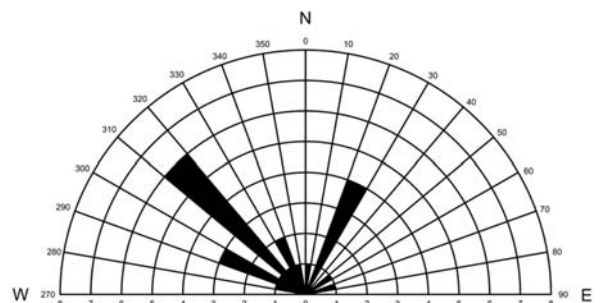


Fig. 5 - Azimuthal distribution of frequency of the *ventarole* outcropping at Cava Donno (S. Sidero, Melpignano).

on three adjacent quarry cliffs (the area is marked by a bold circle in Fig. 1). This analysis established that the *ventarole* developed mainly along NW-SE and NNE-SSW directions, following the main regional joint system (Di Bucci et al., 2011) (Fig. 5).

The karst cavities are completely filled by deeply-weathered dark-reddish clayey sands without definite sedimentary structures. In the wider cavities, reddish clayey sands are covered by less-weathered orange sands with a small clay content first and by greyish sands, about 1 m thick, further up the sequence.

### 3. MATERIALS AND METHODS

The human remains collected at Cava Donno (stored at the Department of Biology, University of Bari) include an incomplete left humerus and an incomplete right os coxae. The morphometric values of the humerus and pelvis are reported in Table 1. The methodology adopted follows Martin & Saller (1957-1962); additional measurements were obtained to estimate the length of the humerus and to evaluate the coxal bone proportions (see caption to Table 1 for references).

The faunal remains are currently housed at the Dipartimento di Scienze della Terra, Sapienza Università di Roma and are attributable to wild and domestic taxa. The remains were morphologically and morphometrically compared with several specimens from zoological and paleontological collections of the above-mentioned Department, in order to ascertain their taxonomic attribution. Wild and domestic taxa belonging to the same genera (i.e., *Canis*, *Equus* and *Bos*) were identified to species on morphological and morphometric basis, as well as on their conservation status. The specimens collected from the red clayey fillings are, in fact, well fossilized and encrusted with red-coloured soil, whereas the specimens collected from the dark-reddish clayey sands are not mineralized and are brown in colour.

Human and faunal remains from Cava Donno were sampled to establish the chronology and diet of the *Homo sapiens* recovered at this site. Bone collagen was extracted for this purpose using the pre-treatment method described by Talamo & Richards (2011), which includes an ultrafiltration step with Sartorius "Vivaspin 15" 30 KDa ultrafilters.

**Abbreviations:** **i**, lower incisor; **p**, lower premolar; **m**, lower molar; **La**, articular width; **DAPolb**, antero-posterior diameter of the oleocranon at the level of the beak; **DAPol**, antero-posterior diameter of the oleocranon over the beak; **DDT**, distal transverse diameter; **DDAP**, distal antero-posterior diameter; **DPT**, proximal transverse diameter; **L**, length; **N**, number of specimens.

### 4. PALAEOANTHROPOLOGICAL RESULTS AND LABORATORY ANALYSES

#### 4.1. Fossil remains from the red clay infill

##### *Erinaceus europaeus*

This species is represented by a complete hemimandible with i1, p3, m2 and m3.

M&S*	Humerus	M&S*	Coxal bone
1	296.6**	1	182.8
4	56.0	12	151.0
4a	54.8	14.1	36.0
5	17.8	15	65.5
6	13.7	15.1	49.1
6a	13.5	15a	75.1
6b	15.2	22	44.8
6c	18.1	ISM	89.2
7	52.0	ISM	94.7
7a	52.5	SS	68.6
11	19.4	SA	75.9
12	16.8	15.1/14.1^	136.4
12a	40.0	ISM	94.7
12b	20.1	SS	68.6
13	22.5	SA	75.9
14	23.7	15.1/14.1^	136.4
15	7.5		
6/5	77.0		
7/1	17.5		

Tab. 1 - Morphometric values of the human remains from Cava Donno (Melpignano, Lecce). \*Martin and Saller, 1957-1962; \*\*Estimate (Salles et al., 2009); ISM: Ischium length, modified (Novotny, 1986); ISMM: Ischium length, post-acetabular (Schulter-Ellis et al., 1983); SS, SA: Spino-sciatic and Spino-auricular lengths (Gaillard 1960); ^Cotylo-Sciatic Index (Sauter & Privat, 1955).

##### *Oryctolagus cuniculus*

This species is represented by several cranial and postcranial remains. The morphology and morphometry of these remains are in agreement with the general features of the species reported by Barone (1974, 1981), Iacoangeli (1996) and Angelci & Spagnesi (2008).

##### *Lepus corsicanus*

A fragmented femur, four ulnae, a fifth metatarsal and three fragmented mandibles can be referred to the hare. The anterior lower premolar (p3) does not display the crenulation on the posterior edge of the hypoflexid, which frequently occurs in *L. europaeus*. In addition, the crenulation on the internal side of the hypocond in the studied specimens is absent, whereas a deep and oblique entrance on the internal side of the hypocond can be present on p3 of *L. europaeus*. The paraflexid on the antero-lingual border is absent on the studied specimens as usually observed in *L. corsicanus*, whereas a deep paraflexid or parafosetid is usually present in *L. europaeus* (see Palacios, 1996). The postcranial remains can also be assigned to *L. corsicanus*.

##### *Microtus (Terricola) savii*

This small rodent is represented by five hemimandibles. The first lower molar on these specimens displays seven triangles, the fourth and the fifth of them are confluent to form the pitymyan rhombus (see Nappi & Contoli, 2008, and references therein).

***Canis lupus***

Two lumbar vertebrae, a proximal epiphysis of ulna, a first phalanx and an upper canine can be assigned to *C. lupus*. The remains are large in size, in particular the ulna (La = 22.4 mm; DAPolb = 31.3 mm; DAPol = 28.2 mm). The morphometry of the ulna and the presence of a strong muscular impression suggest that this specimen is slightly larger than the extant *C. lupus* from the Abruzzi region (Salari, unpublished data).

***Equus ferus***

The following remains are assigned to this taxon: a distal epiphysis of humerus (DDT = 82.1 mm; DDAP = 90.0 mm), a first posterior phalanx (La = 89.5 mm; DPT = 58.5 mm; DDT = 49 mm), two fragments of second and fourth vestigial metapodials and a lower deciduous tooth. The morphology and morphometry of these remains resemble those of the equid from Tana delle Iene (Brindisi, Southern Italy), which is Late Pleistocene in age (Conti et al., 2010).

***Bos primigenius***

A first upper molar (L = 32; La = 26), which displays a wide and developed entostyle (Sala, 1986), and a large first phalanx are referred to the aurochs.

***Cervidae indeterminate***

Cervidae is represented only by a thoracic vertebra of a young individual and an attribution to red deer rather than fallow deer is not possible.

**4.2. Fossil remains from the dark-reddish clayey sands*****Homo sapiens*: humerus**

This humerus lacks the proximal portion, including the articular head and the surgical neck. The metaphyse preserves part of the bicipital groove and the crests of the greater and lesser tubercles (Fig. 6). The residual length of the humerus is of approximately 246 mm. The bone has been reconstructed from two corresponding fragments broken distally to the middle of the shaft. The distal epiphysis is complete, yet slightly damaged on the distal articular surfaces.

The estimated length of the humerus (M1) was calculated from the regression, as proposed by Salles et al. (2009) on the basis of a recent sex-aggregated sample of adult individuals belonging to various populations. An estimated value of 296.6 mm ( $\pm 13.5$  mm) was obtained from the average values of three different regressions (Fig. 7). The method proposed by Steele (1970)



Fig. 6 - *Homo sapiens* from Cava Donno (Melpignano, Lecce), humerus in anterior (a), posterior (b), lateral (c) and medial (d) views.

allowed us to obtain estimated values of between 295.7 and 298.2 mm. A mean value of 282.6 mm was reported by Formicola & Franceschi (1996) for a Neolithic European sample of 27 females (Fig. 7). These values do not differ significantly (T-test,  $p = 0.200$ ) from the mean values obtained for a recent Apulian female sample ( $287 \text{ mm} \pm 16.4 \text{ mm}$ ,  $N = 40$ ; Introna et al., 1994).

Three sexually dimorphic features of the posterior distal humerus were evaluated (Rogers, 1999). The trochlear constriction is intermediate, but the shape of the trochlea tends to be symmetrical with the margin of the capitulum. The shape of the olecranon fossa is oval and the medial epicondyle is angled. Taking these features into account, the Cava Donno humerus could be assigned to a category of "probable female" (Falys et al., 2005). Considering morphometric values, the last circumference of the shaft ( $M7 = 52.0 \text{ mm}$ ) falls within the dimensional range of female individuals from Neolithic Apulia (Fabbri & Lonoce, 2011). A discriminant function, calibrated on a recent Apulian population (f.n. 10; 90% correctly classified), places the specimen from Cava Donno within the area occupied by female individuals, thus classifying the humerus as female (Introna et al., 1994). Two female humeri from Malerba (Mlt2A, Mlt2B, Scattarella et al., 1997, 2001) and a male humerus from Cala Colombo (CC17, Pesce Delfino et al., 1977) are correctly assigned to gender, based on the discriminant function analysis performed for the specimens from Cava Donno, in agreement with their morphological features.

It is well-known that comparisons between modern and ancient human remains, of which little is known on sexual dimorphism, may be inadequate; such comparisons, hence, represent mere evaluations relative to the modern variability.

The stature was estimated based on the method proposed by Formicola & Franceschi (1996). The values obtained are 154.7 cm for the least squares and 155.8 cm for the major axis formulae respectively. Similar values (156 cm) are obtained using the methods of Sjøvold (1990) and Trotter & Gleser (1952, 1977; 156 cm, black females). Figure 7 shows the estimated heights for some female individuals from Neolithic Apulia compared with those of Cava Donno (humerus least square equation; Formicola and Franceschi, 1996).

According to Formicola (1983, 1989), the estimated stature for the Neolithic Italian sample spans between 148 and 156 cm, whereas the estimated stat-

ure for Ligurian female samples (8 individuals) has an average value of 150.6 cm. An average value of 151.4 cm ( $\pm 2.94 \text{ cm}$ ) was reported for a sample of 11 female individuals from the central Apulian area (Barbieri et al., in press). The estimated stature for the Cava Donno specimen is relatively low compared with recent populations (Martin & Saller, 1957-1962), but relatively high compared with the Neolithic sample.

The age at death, referable to approximately the fourth decade, is derived from the absence of any residual epiphyseal fusion line, as well as from the presence of moderate signs of lipping on the articular surfaces.

The proximal third appears laterally curved in the anterior view, the convexity being accentuated by the attachment of the pectoralis major. The midshaft section of the diaphysis is flattened mediolaterally. According to the robusticity index ( $M7/1 = 17.2$ ), the bone is relatively gracile, but the attachment of the pectoralis major is hypertrophic, robust and bounded by light, but well defined, radiating lines (Mariotti et al., 2007); furthermore, the insertion for the brachioradialis muscle is well expressed. The attachment for the deltoid is, instead, less well-defined, with the surface wrinkled and uneven. This profile may indicate activities requiring considerable involvement of the shoulder joint or intense manipulation.

The cross-section index of the shaft demonstrates eurybrachia near the platybrachia ( $M6/5=77.0$ ). For two female individuals from Serra Cicora (T6B, T10A) a eurybrachic index is reported (Fabbri & Lonoce, 2011); eurybrachia is also recorded for Passo di Corvo (Facchini, 1983) and for four female humeri from central Apulia (Barbieri et al., in press).

Differences in lifestyles and nutritional deficiencies, especially in early childhood, affect the bone mass and cortical bone thickness. For these reasons, in the long bones, the development of the cortex of the shaft is a reliable indicator of nutritional status (Larsen, 1999).

In Cava Donno, the percentage of the cortical area ( $CA = 79.7\%$ ) is higher than the mean values reported for 11 Neolithic females from central Apulia ( $69.5 \pm 7.9$ ) (Barbieri et al., in press). The cross-sectional moments of inertia, proportional to the bending rigidity of the bone in the sagittal and medio-lateral planes, are instead among the lowest ( $I_{max}=4316$ ;  $I_{min}=1754$ ). In the Cava Donno humerus, therefore, a relatively low degree of biomechanical stress is associ-

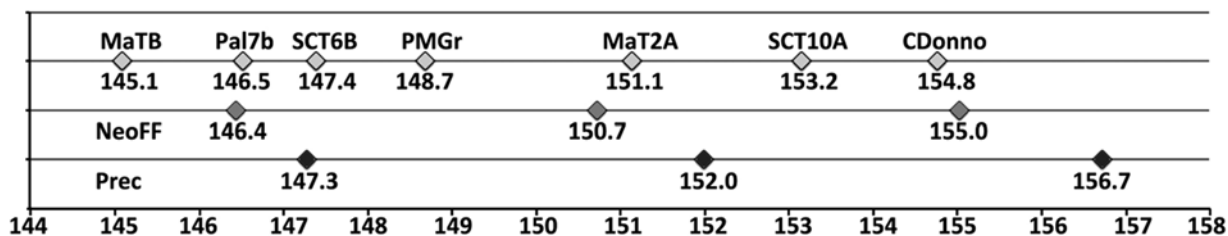


Fig. 7 - Stature (in cm) obtained from the length of the humerus from Cava Donno (CDonno) and comparison with several Neolithic females from central and southern Apulia (Serra Cicora (SCT6B, SCT10A; Fabbri & Lonoce 2011); Malerba (Mat2A, Mat2B); Polignano - Madonna di Grottole (PMGr; Scattarella & De Lucia, 1988); Palagianò (Pal7b, Barbieri et al., in press), with a sample of European Neolithic females (NeoFF, Formicola & Franceschi 1996; mean  $\pm 1SD$ ) and with a recent Apulian sample (Prec, Introna et al. 1994; mean  $\pm 1SD$ ).



Fig. 8 - *Homo sapiens* from Cava Donno (Melpignano, Lecce), coxal bone in lateral (a) and medial (b) views.

ated with a balanced nutrition (as discussed below).

#### ***Homo sapiens*: coxal bone**

The hipbone lacks the pubis, from the ramus superior to the anterior border of the acetabulum, and from the ramus inferior to the ischial tuberosity (Fig. 8). The bone has been reconstructed from two large fragments which include the ilium and part of the ischium with a relatively complete acetabular cavity. Two small fragments, one of the ischial tuberosity and one of the iliac spine, also belong to the same specimen. As with the humerus, the hipbone is also reddish-brown and partially covered by soil residues.

The bone is relatively short, the maximal height (182.8 mm) falls within the range of the modern Apulian female sample, but is considerably smaller than the mean value of the same sample ( $193.2 \pm 8.6$ ,  $N = 63$ ) (Vacca & Di Vella, 2012). The iliac width (151.0 mm) is comparable, instead, with the average value of the same population ( $152.4 \pm 6.5$ ,  $N = 57$ ).

The sigmoid curvature of the iliac crest is rather weak, the iliac fossa is moderately concave and the gluteal lines poorly marked. The muscle attachments on the ischial tuberosity are well defined, the bone surface appears finely wrinkled in relation to the flexion of the leg on the thigh. The iliac tuberosity is well devel-

oped and elevated with respect to the auricular facet, a marked post-auricular sulcus separates the two features; on the margin of the facet, moderate lippings of osteophytes can be observed. Interosseous groove and iliac tuberosity play an important role in maintaining the stability of the pelvic girdle (Andersen, 1986), it is therefore possible that these structures relate to sacroiliac ligament stress and strain.

The coxal bone displays at least three morphological characteristics that suggest attribution to a female individual: preauricular sulcus, a composite arch and the form of the sciatic notch. The notch is wide, the anterior and posterior part diverging with a certain degree of asymmetry, yet without recursivity of the posterior ramus. The posterior ramus, normally shorter than the anterior, is instead longer. It is possible that this configuration is due to the same biomechanical stresses discussed in relation to iliac tuberosity and interosseous groove.

The cotylo-sciatic index ( $M15.1/14.1 = 136.4$ ) is comparable with the average values obtained from the recent Apulian sample cited above ( $134.5 \pm 11.2$ ,  $N = 82$ ).

Two discriminant functions calibrated on the same sample (f.n. 7 and 8; Vacca & Di Vella, 2012), suggest that the specimen from Cava Donno is a female. By

using the same functions, two coxal bones from Malerba (Mt1, male; Mt2B, female) are correctly assigned to gender, in agreement with their morphological characteristics. The equations defined by Murail et al. (2005) for a worldwide hipbone metrical database also classify Cava Donno as female ( $PF \geq 0.95$ ).

The age at death was estimated from auricular surface morphology: the transverse organization is almost absent, the bone surface has micro and macroporosity and slight retroauricular and apical activity is present. This configuration leads to an estimate of age at death at least in the fourth decade of life (Lovejoy et al., 1985).

The stature was estimated based on the height of the coxal bones and the diameter of the articular head of the femur (36.8 mm). The latter was obtained from the diameter of the acetabulum and considering the linear regression, as reported by Giroux & Wescott (2008) and Holliday (2000). The values obtained, 153.2 cm (white female) and 153.9 cm (black female), are comparable with those estimated for the humerus of Cava Donno.

Based on the femoral head diameter, a body mass of 48.7 kg is estimated for Cava Donno (Ruff et al., 1991). An average value of 55.7 Kg ( $\pm 5.1$ ) (Barbieri et al., in press) was obtained for 6 Neolithic female individuals from central Apulia.

#### *Microtus (T.) savii*

This taxon is represented by a hemimandible and a few cranial remains with the third upper molar in *simplex* morphology (see Nappi & Contoli, 2008 and references therein).

#### *Canis sp.*

A cervical vertebra of a young individual and a fragmented thoracic vertebra can be assigned to this genus. Unfortunately, the morphology and morphometry of these specimens are not useful to distinguish between a medium-sized wolf and a domestic dog.

#### *Bos taurus*

The morphometric values of an almost complete calcaneum (L = ca. 140 mm) fall within the dimensional range of the Neolithic domestic cattle from central and southern Italy (Wilkins, 1987, 2003). A fragment of horn probably belonging to a female individual, a fragment of skull with the tympanic region, a cervical vertebra, a cuneiform, a sesamoid and a proximal fragment of rib can also be attributed to *B. taurus*.

#### *Ovis aries vel Capra hircus*

A few cranial and postcranial remains can be generally referred to *Ovis vel Capra*. Based on Boessnek (1969), Barone (1978, 1981) and Gudea & Stan (2012), a relatively hypsodont third upper molar, a fragmented pelvis and a distal epiphysis of tibia can be attributed to *Ovis aries* (sheep), whereas an almost complete humerus can be referred to *Capra hircus* (goat).

#### 4.3. Isotope analyses and radiocarbon dating on bone collagen

The human coxal bone sampled for this study yielded an extract that, based on the quality criteria proposed by van Klinken (1999), is well-preserved collagen (Tab. 2). This extract was AMS radiocarbon dated to  $6216 \pm 23$   $^{14}\text{C}$  BP (at 95.4% of confidence: 7250-7010

Laboratory number (S-EVA)	Species	Element	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	% C	% N	C:N	% collagen yield
29039	<i>Homo sapiens</i>	pelvis	-19.28	9.69	39.03	13.68	3.33	2.15
29040	<i>Canis lupus</i>	canine fr.	-	-	-	-	-	0
29041	<i>Bos taurus</i>	sesamoid	-20.41	5.32	39.18	13.96	3.27	3.04
29042	<i>Equus ferus</i>	vertebra	-	-	-	-	-	0.25
29043	<i>Equus ferus</i>	metapodial	-20.42	6.60	39.45	13.89	3.31	2.91
29044	<i>Lepus corsicanus</i>	femur	-	-	-	-	-	-
29045	<i>Equus ferus</i>	phalanx I	-20.37	6.12	42.43	14.83	3.34	1.94
29046	<i>Lepus corsicanus</i>	femur	-	-	-	-	-	-
29047	<i>Canis lupus</i>	ulna	-	-	-	-	-	-
29048	<i>Bos taurus</i>	cuneiform	-20.32	7.47	37.43	13.34	3.27	1.73
29049	<i>Microtus (Terricola) savii</i>	cranium	-20.75	8.68	24.06	9.25	3.03	2.68
29050	<i>Bos primigenius</i>	phalanx I	-	-	-	-	-	-

Tab. 2 - Carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) isotope values of bone collagen extracted from human and faunal samples recovered at Cava Donno.

Laboratory number (S-EVA)	Radiocarbon laboratory number	$^{14}\text{C}$ date (BP)	calendar age cal. BC (95.4%)	calendar age cal. BP (95.4%)	% collagen
29050	MAMS-21214	$6216 \pm 23$	5300-5060	7250-7010	2.15

Tab. 3 - AMS radiocarbon date on bone collagen of the human from Cava Donno, pretreated at the Max Planck Institute for Evolutionary Anthropology (Leipzig). The date was performed at the Klaus Tschira Laboratory of the Curt-Engelhorn-Zentrum Archaeometrie in Mannheim (MAMS) and calibrated with the OxCal 4.2 software (Bronk, Ramsey & Lee, 2013), using the IntCal13 curve (Reimer et al., 2013).



calibrated years BP or 5300-5060 calibrated years BC; Tab. 3), a time coinciding with the Middle Neolithic in Apulia (Malone, 2003; Quarta et al., 2005). Of the 11 animal bones sampled, 6 did not yield extracts due to poor preservation. The latter samples are from Late Pleistocene fauna (i.e. the wolf *Canis lupus* and the auroch *Bos primigenius*), as well as equids and lagomorphs that may also be of similar age. The remaining 5 samples have %C, %N, C:N ratio and % yields (Tab. 2) falling within the range for good quality collagen (van Klinken, 1999).

The  $\delta^{13}\text{C}$  values of the fauna from the site are typical of animals living in terrestrial habitats dominated by  $\text{C}_3$  plants (mean =  $-20.4 \pm 0.1\text{‰}$ ), such as those of the northern Mediterranean before the introduction of agriculture (e.g. Mannino et al., 2012, 2015). The  $\delta^{15}\text{N}$  values of the large herbivores (i.e. *Bos taurus* and *Equus ferus*) are compatible with those of animals living in temperate environments and of the majority of analyzed domestic fauna from Neolithic sites in Apulia (e.g. Lelli et al., 2012; Tafuri et al., 2014). The *Microtus* specimen, on the other hand, lived at a time when the  $\delta^{15}\text{N}$  baseline was relatively high, which likely indicates that this animal was contemporary to a more arid phase than the early-to-mid Holocene.

The  $\delta^{13}\text{C}$  value of the human bone collagen indicates that the diet of this individual was based on the consumption of terrestrial dietary protein from  $\text{C}_3$  plant dominated environments. The  $\delta^{15}\text{N}$  ratio falls within the range of such values obtained for Neolithic humans from Apulia and the Italian Peninsula. Had the bovids and equids for which we have isotopic data been contemporary to the human specimen analyzed (which is likely given their overlap with values from similar animals from Neolithic Apulian sites), it could be suggested that this individual had a mixed diet with regular consumption of meat, because its  $\delta^{15}\text{N}$  ratio is  $\sim 3.3\text{‰}$  higher than the mean of the herbivores ( $= 6.4 \pm 0.9\text{‰}$ ). However, given the mixed nature of the context of recovery, without dating of each bone we cannot be sure of their exact chronology.

For this reason, we compared the isotope values of the human from Cava Donno with Neolithic humans and fauna from Apulia (Lelli et al., 2012; Tafuri et al., 2014). The herbivores from Grotta della Mura ( $\delta^{13}\text{C} = -20.2\text{‰}$ ;  $\delta^{15}\text{N} = 5.9\text{‰}$ ), Masseria Candelaro ( $\delta^{13}\text{C} = -21.1\text{‰}$ ;  $\delta^{15}\text{N} = 6.3\text{‰}$ ) and Grotta Scaloria ( $\delta^{13}\text{C} = -19.9\text{‰}$ ;  $\delta^{15}\text{N} = 6.0\text{‰}$ ), as well as from areas of Apulia such as the Tavoliere ( $\delta^{13}\text{C} = -20.6\text{‰}$ ;  $\delta^{15}\text{N} = 7.5\text{‰}$ ) and the Murge ( $\delta^{13}\text{C} = -19.9\text{‰}$ ;  $\delta^{15}\text{N} = 6.9\text{‰}$ ), have isotopic compositions similar to those from Cava Donno ( $\delta^{13}\text{C} = -20.4\text{‰}$ ;  $\delta^{15}\text{N} = 6.4\text{‰}$ ).

The only Neolithic fauna from Apulia with a different isotope composition to that of the animals from Cava Donno and other contemporary sites is that from Passo di Corvo (Tafuri et al., 2014). Domestic fauna from this ditched village have mean  $\delta^{13}\text{C}$  ratios of  $-19.7\text{‰}$  and mean  $\delta^{15}\text{N}$  ratios of  $10.2\text{‰}$ . The nitrogen isotope values of the domesticates from Passo di Corvo are far higher than those from any other site in SE Italy and likely a consequence of feeding on plants from manured fields. Manuring produces enrichments in the nitrogen isotope composition of intensively-manured plants and, in turn,

animals that feed on these will have higher  $\delta^{15}\text{N}$  values than those grazing in nearby unmanured fields (Bogaard et al., 2013). The humans from Passo di Corvo also have high  $\delta^{15}\text{N}$  values ( $= 13.3\text{‰}$ ), confirming that they fed on plants and/or meat affected by manuring, in the context of a densely populated village the occupants of which were intensively exploiting the landscape around the settlement. This does not appear to have been the case of the human from Cava Donno, who has an isotopic composition more in line with that of most other Neolithic sites in Apulia, as well as further afield in the Italian Peninsula (e.g. Giorgi et al., 2005; Lelli et al., 2012; Goude et al., 2014).

## 5. DISCUSSION

### 5.1. Geomorphological evolution of the karst cavities

*Ventarole* are karst landforms that developed along main joints affecting the carbonatic bedrock, because of intense karst processes that occurred below soil cover (crypto-solution processes). These cavities formed mainly in the Upper Miocene calcarenites of the Pietra Leccese Formation during the Late Pleistocene, as clearly indicated by fossil fauna. Karst landforms due to crypto-solution sharing the same age of *ventarole* have been recognized in other areas of the Salento Peninsula (Marsico et al., 2003; Leucci et al., 2005). In these last cases, solution pipes of cylindrical shape formed because of the isotropy of carbonatic bedrock; pipes are up to 2 m deep and have a diameter length between 0.5 and 1 m.

The development of *ventarole* has been strongly influenced by jointing of Miocene carbonatic rocks, so that crypto-solution processes produced the widening of joints forming narrow cavities lengthened downwards.

In the scientific literature crypto-solution cavities developed along joints are defined cutters (Howard, 1963; Palmer, 2009); they have been well studied in Indiana (USA), where they are exposed along the quarry cliffs cut into the Salem Limestone (Early Carboniferous).

The widening of the *ventarole* causes slow sinking of loose superficial soils, along with fossil remains present inside; these processes turn *ventarole* into sedimentary traps.

### 5.2. Anthropological and archaeological considerations

The biological profile of the human remains from Cava Donno, represented by a fragmented left humerus and a fragmented right coxal bone, suggest that these two specimens probably belonged to the same individual. This individual was a relatively gracile adult female, of medium stature for the Neolithic period, yet with a good level of muscular activity.

On the basis of the general features of these human remains and of the comparative data, the bones from Cava Donno fall within the variability of the Neolithic populations of Southern Italy, similarly to other Apulian samples. The lack of artifacts in the infill does not allow us to say more about the cultural attribution and archaeology of the adult female from Cava Donno.

Nevertheless, the radiocarbon date, obtained as part of this study, suggests that the area of Cava Donno was occupied at least during the Middle Neolithic, in line with contemporary evidence for intense human occupation in the Salento area at sites such as Serra Cicora, Samari, Grotta Parabita and Grotta della Trinità (Cremonesi, 1978, 1985-86; Ingravallo, 1997; Quarta et al., 2005; Tiberi, 2011; Dolfini, 2015).

### 5.3. Palaeontological considerations

The mammal assemblages from the *ventarole* of the study area are known since the nineteenth century (Mirigliano, 1941; Cardini, 1958b). The vertebrate remains are generally in a good state of preservation and are located at the base and at the top of these karstic infills, without signs of long-distance transport (Bologna et al., 1994). In addition, remains are chaotically scattered within these features, lacking specific taphonomic signatures or traces of human activity, and sometimes parts of the same skeletal element occur at different depths (De Giuli, 1983; Bologna et al., 1994). *Ventarole* karst infills probably accumulated rapidly and the mammalian bone assemblages within them usually appear as coeval in age (Bologna et al., 1994).

In the first half of the 20<sup>th</sup> century, several mammalian bone assemblages from different karst cavities in the Melpignano area were collected and described by Mirigliano (1941) (Tab. 4). The presence of several fossiliferous karst infills in the Pietra Leccese quarries was later also reported by Cardini (1958b). However, some of the species reported by Cardini (1958b; Tab. 4) were recorded in one or a few cavities (e.g., *Hippopotamus* was only recorded at Cava Motta). De Giuli (1983) later described a rich mammalian bone assemblage recovered from a single cavity near Maglie at the quarry 'Cava L', known as San Sidero 3 (Tab. 4). Bologna et al. (1994) described several vertebrate remains, including a tooth of *Homo cf. neanderthalensis*, collected in different *ventarole* from Cava Nuzzo near Melpignano (Tab. 4). The mammal assemblage from Cava Nuzzo was stratigraphically correlated by Bologna et al. (1994) with the fossiliferous levels above the Euthyrrenian deposits of several caves along the Salento coast (e.g., Grotta Romanelli, Grotta del Cavallo, Grotta delle Striare) and chronologically attributed to the MIS 5c-5a, based on stratigraphic, geomorphological and biochronological evidence. In addition, other mammalian assemblages such as those recovered from the districts of Melpignano, Corigliano d'Otranto and Maglie, reported by De Giuli (1983) and Corridi (1987), and those from ossiferous breccias cropping out between 0 and 10 m a.s.l. along the southeastern coast of Salento Peninsula, from Castro Marina to Otranto (Di Stefano et al., 1992), were chronologically correlated with MIS 5c-5a by Bologna et al. (1994).

More recently, Petronio et al. (2007) established the Faunal Unit (FU) of Melpignano as a new Italian biochronological unit for the Late Pleistocene and proposed the mammal assemblage from Cava Nuzzo as a local faunal type. The new FU included the classic Late Pleistocene warm-adapted mammal fauna *Auctorum*, and likely dated back to between ca. 100 and 70 ka (then from 120 to 80 ka; see Petronio et al., 2011; Pan-

dolfi et al., 2013). The Melpignano FU was characterized by the first occurrence of *Cervus elaphus* and *Dama dama* with "evolved" antler morphology, the persistence of large-sized mammals, such as *P. antiquus*, *S. hemitoechus* and *H. amphibius*, and the absence of *Mammuthus primigenius*, *Coelodonta antiquitatis* and other typical cold-adapted mammals *Auctorum*, which defined a new subsequent Late Pleistocene Faunal Unit, the Ingarano FU (Petronio et al., 2007, 2011).

In addition, based on the considerations by Bologna et al. (1994) and Petronio et al. (2007), some authors have also attributed to the early Late Pleistocene several bird and mammal assemblages from different *ventarole* at 'Cava L' near Maglie (Bedetti et al., 2004) and several fossil remains of carnivores (Cipullo et al., 2006), horses (Conti et al., 2010) and rhinoceroses (Petronio & Pandolfi, 2008; Pandolfi & Petronio, 2011) collected in *ventarole* from the Pietra Leccese quarries of the Melpignano, Corigliano d'Otranto and Maglie area.

In the N-shaped cavity at Cava Donno, however, the presence of two different faunal associations referable to two distinct epochs (i.e. Late Pleistocene and Holocene) suggest that the mammal assemblages from different karst cavities may not be coeval. In the case of the cavity at Cava Donno, taxa collected from the red clay deposits (i.e., *Erinaceus europaeus*, *Oryctolagus cuniculus*, *Lepus corsicanus*, *Microtus (T.) savii*, *Canis lupus*, *Equus ferus*, *Bos primigenius*) are in all likelihood older than those collected with the human specimens. A Late Pleistocene age is suggested for the former taxa, although there is no data to propose a more detailed chronological attribution. The presence of Holocene fauna, however, is documented by the occurrence of domestic mammals and, importantly, by the AMS radiocarbon date obtained from the human coxal bone (7250-7010 calibrated years BP). The carbon and nitrogen isotope data from this human specimen fall within the variability recorded for Neolithic humans from Apulia and Italy, suggesting (as discussed above) that the individual in question obtained most of her dietary protein from terrestrial sources that included both vegetal and animal foodstuffs. In addition, the isotopic composition of the well-preserved bone collagen from the fauna, analyzed as part of the present study, is very similar to that of specimens analyzed to date from Apulia. This is a further clue that a significant proportion of the vertebrate assemblage from Cava Donno dates to the Holocene.

Nevertheless, if most of the karst fissures in question were generated and filled with sediments rapidly between the last interglacial (MIS 5e) and the early phases of the subsequent climatic deterioration (MIS 5c-5a, or perhaps up to the beginning of MIS 4), we cannot exclude that other cavities in the Salento area were also filled during different stages of the Late Pleistocene. This is probably the case, for instance, of a *ventarola* at the Pietra Leccese quarry near Sternatia (Tab. 4), a locality a few kilometers North of Cava Donno, the mammal bone assemblage from which was attributed by Rustioni et al. (1994) to the second part of MIS 4 or to MIS 3.

Taxon	Mirigliano (1941) various quarries	Cardini (1958b) Cava Motta	Cardini (1958b) Cava C1 di San Isidoro	Cardini (1958b) Cava E di San Isidoro	De Giuli (1983) San Sidero 3	Bologna et al. (1994) Cava Nuzzo	Rustioni et al. (1994) Sternatia	Bedetti et al. (2004) Cava L	Cava Donno N-fissure
<i>Homo cf. neanderthalensis</i>						X			
<i>Erinaceus europeus</i>						X	X	X	X
<i>Oryctolagus cuniculus</i>			X	X	X	X	X	X	X
<i>Lepus corsicanus</i>		X	X	X		X		X	X
<i>Glis glis</i>				X					
<i>Eliomys quercinus</i>					X			X	
<i>Microtus sp.</i>					X				
<i>Microtus savii</i>					X	X	X	X	X
<i>Apodemus sylvaticus</i>					X		X	X	
<i>Canis lupus</i>		X	X	X	X	X	X	X	X
<i>Vulpes vulpes</i>	X	X	X	X	X	X	X	X	
<i>Ursus sp.</i>					X				
<i>Mustela nivalis</i>							X		
<i>Martes sp.</i>							X		
<i>Meles meles</i>				X		X		X	
<i>Felis silvestris</i>								X	
<i>Lynx lynx</i>						X		X	
<i>Panthera cf. spelaea</i>					X				
<i>Panthera pardus</i>			X	X				X	
<i>Crocota crocuta</i>		X		X	X	X	X	X	
<i>Palaeoloxodon antiquus</i>	X	X	X		X	X			
<i>Stephanorhinus hemitoechus</i>	X		X			X		X	
<i>Stephanorhinus sp.</i>					X				
<i>Equus ferus</i>	X	X	X	X	X	X	X	X	X
<i>Equus hydruntinus</i>	X			X	X	X	X	X	
<i>Hippopotamus amphibius</i>	X	X				X			
<i>Sus scrofa</i>	X		X	X	X	X		X	
<i>Capreolus capreolus</i>						X		X	
<i>Cervus elaphus</i>		X	X	X	X	X	X	X	
<i>Dama dama</i>		X	X	X	X	X	X	X	
<i>Bison priscus</i>						X		X	
<i>Bos primigenius</i>	X	X	X	X	X	X	X	X	X
<i>Capra ibex</i>							X		

Tab. 4 - Late Pleistocene mammalian taxa recorded from the *ventarole* karst infill discussed in the text. The taxonomy of the recorded species is updated according to several published papers (among others: Trocchi & Riga, 2005; Petronio & Pandolfi, 2008; Conti et al., 2010; Pandolfi & Petronio, 2011; Petronio et al., 2011; Marra et al., 2014; Sardella et al., 2014; Pandolfi & Tagliacozzo, 2015; Pandolfi & Marra, 2015).

## 6. CONCLUSIONS

The occurrence of fossil remains belonging to Late Pleistocene vertebrates suggests that crypto-solution processes at Cava Donno and in the surrounding area were probably promoted by humid-warm climatic conditions that affected the Salento peninsula during the last interglacial period.

Moreover, the presence of Neolithic fauna (attested by this study) could indicate a weak reactivation of crypto-solution processes during the Holocene Climatic Optimum. This likely caused the sinking of the soil cover, constituted by greyish continental deposits that were present at the top of larger *ventarole*.

The presence of Holocene and Pleistocene mammals in the N-shaped karst fissure from the Pietra Lecce quarry of Cava Donno suggests that a critical revision of the chronology of the different bone assemblages recovered within the sediments filling the *ventarole* scattered throughout the districts of Melpignano, Corigliano d'Otranto and Maglie should be undertaken. Some fossiliferous deposits could be referred to the early Late Pleistocene, however, some others could indeed be younger in age. We, therefore, suggest to attribute to the Melpignano FU, proposed by Petronio et al. (2007), only those deposits that yielded a well-defined association which are analogous in faunal composition and, ideally, abundances with the mammal assemblage of Cava Nuzzo (e.g., San Sidero 3, Cava Motta). All faunal associations that are not based on mammals useful for establishing biochronological constraints should, therefore, be revised and supported by the application of radiometric dating. An additional outcome of the present study was to obtain carbon and nitrogen isotope data on bone collagen, useful to reconstruct the diet of the Neolithic human whose remains were recovered at Cava Donno. In the absence of information on the settlement and local subsistence economy of the group to whom the individual from Cava Donno belonged, we can only reach broad conclusions with the data at hand. Firstly, we can conclude that Neolithic people either intentionally, or not, left traces of their presence at sites such as Cava Donno. Secondly, interpreting the isotope data obtained as part of our study in the context of the database currently available from Italian sites, we suggest that the individual from Cava Donno had a similar diet to that of most of her contemporaries from across Italy. The dietary protein consumed by this individual originated overwhelmingly, if not exclusively, from terrestrial sources and both from animals and plants. With the data presented here, we cannot say much more about the proportion of plant to meat consumed. However, given the relatively high  $\delta^{15}\text{N}$  value, it is possible that animal protein acquired by consuming meat and/or dairy products were an important component of the diet of the Neolithic human from Cava Donno.

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