

TERRESTRIAL VERTEBRATES IN MIS 6 TO MIS 5 DEPOSITS OF THE ZANNONA QUARRY (FAENZA, ITALY)

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ABSTRACT: We report few vertebrate remains from the Middle-Upper Pleistocene continental deposits of the Zannona quarry (Faenza, Italy), including two incomplete upper dental series of *Stephanorhinus hemitoechus*, a frontal with antlers of a cervid, and a fragmentary left scapula of an equid. This material provides additional information on the poorly known terrestrial faunal assemblages of the Quaternary deposits in the Romagna Apennine foothills. Data presented here are discussed within the framework of the well documented stratigraphic transition between the MIS (Marine Isotope Stage) 6 and 5 and support the role of vertebrate continental fauna in the correlation between marine and non-marine successions.

Keywords: Middle to Upper Pleistocene, Continental Stratigraphy, Mammals, Biochronology.

1. INTRODUCTION

The Zannona quarry site (Cava Zannona of local road signs) is located within the homonymous pit cave of pebbly and sandy material located a few kilometres south of the city of Faenza (Ravenna, Italy) in the Apennine foothills (Fig. 1). The active quarry, located at about 60 meters above sea level on a wide terrace of the Marzeno alluvial fan, is responsible for the exposure of deposits that are here referred to the *Palazzone Morphostratigraphic Unit* (Curzi et al., 1987) (Fig. 2). Exposed alluvial deposits reach a maximum thickness of 10-15 meters and rest unconformably on the uppermost deposits of the Pliocene to Pleistocene marine sequences of the Romagna Apennine (i.e. *Argille Azzurre* and *Sabbie Gialle* formations). Such alluvial deposits have been recently included in the *Subsintema di Bazzano* (Amorosi et al., 2009), which consist of coarse alluvial fan deposits interbedded with fine-grained alluvial plain beds. The Bazzano Subsynthem is dated to the uppermost Middle Pleistocene between 230 and 130 Ka (Amorosi et al., 2009). The Zannona quarry deposits have been the subject of periodic investigation for a decade before the discovery in 2012 of nicely preserved vertebrate remains. Specimens collected from the site allow to improve the chronostratigraphic and environmental resolution of the continental deposits of the area. Data presented here support the role that vertebrate faunal turnover play in our palaeoecological understanding of cyclic warm and cool stages in the Italian Pleistocene continental successions. In particular, based on a more accurate chronostratigraphic and palaeoclimatic zonation of the Middle to Late Pleistocene interval, this study attempts a correlation between terrestrial bio-events and the standard chronostratigraphical time

scale and in particular with the Marine Isotope Stages (MIS) 6 and 5 (Sanchez Goñi, 1999; Amorosi & Colalongo, 2005; Ferranti et al., 2006; Antonioli et al., 2009; Bertini et al., 2010).

2. SYNTHETIC STRATIGRAPHY OF THE CONTINENTAL DEPOSITS

The continental deposits exposed at the Zannona quarry rest unconformably on the Sabbie Gialle Formation, and are divided into two Unconformity-Bounded units showing increasing transgressive trend upwards (Fig. 3). The lower UB unit is bounded at its bottom by a basal unconformity having regional extension and marking a major depositional hiatus, and by a prominent palaeosol at its top. The upper UB unit is bounded by the same palaeosol at the bottom and by a thick vetusol at the top.

The basal deposits of the first interval are represented by a tabular and laterally continuous layer of coarse gravel (ϕ max \approx 50 cm) with an average thickness of 5-6 meters (lower gravel layer in Figs. 3 and 4). These braided-stream, channel deposits yielded an equine scapula as well as poorly preserved floated manufactures. Basal deposits fine upward into clay-dominated, tabular beds with minor silt and fine-grained sandy deposits showing planar parallel stratification: overall, such alluvial and colluvial strata reach a thickness of 8-10 meters. This interval is also topped by a dark-grey to brown-colored, 40-60 cm thick, clay-silty buried soil which represents an important marker in the study area, cropping out over several square kilometers near the Zannona quarry (Fig. 5). This distinctive palaeosol has been originally reported from the Spalancona locality by



Fig. 1 - Reference map the studied Middle to Late Pleistocene succession at the Cava Zannona quarry near Faenza, Italy (modified from ©Google Earth; coordinates 44°15'05.98" N, 11°53'15.11" E).

Curzi et al. (1987), located a few hundred meters south of the Zannona quarry; therefore, this marker bed is here referred to as *Spalancona Palaeosol*. It is moderately rich in organic matter, with well-developed pedostructures and minor carbonate concretions at its base. The palaeosol is traceable continuously within the Palazzone Morphostratigraphic Unit over a distance of approximately 5 km from the quarry, lying sub-horizontally at an average depth of 4-5 meters from the unit top.

The second sedimentary interval deposited above the *Spalancona Palaeosol* consists of silty, flood-plain beds up to 6 meter thick, punctuated by discontinuous erosive fine-gravely to sandy channelized bodies up to 1.5 m thick (ϕ max \approx 10 cm), suggesting an incoming meandering stream deposits (upper gravel layer in Figs. 3 and 4).

Pebbly and sandy deposits show significant pedogenetic alteration which is associated with the massive overlying *vetusol* that also bounds the upper surface of the ancient fluvial terrace. This distinctive represents a non-buried soil which underwent similar processes of soil formation over a period of time that include at least some part of the Pleistocene (Cremaschi, 1987), and therefore may provide important climatic and environmental information possibly related to the onset of the Last Interglacial transgression. Relevant to this study, the latter coarse and lenticular deposits preserved

the *in situ* deer frontal lobe with antlers and possibly the rhinoceros upper dental series.

The continental succession exposed at the Zannona quarry does not display major facies changes in the entire Palazzone Morphostratigraphic Unit, with the exception of local differences in the thickness of the dis-

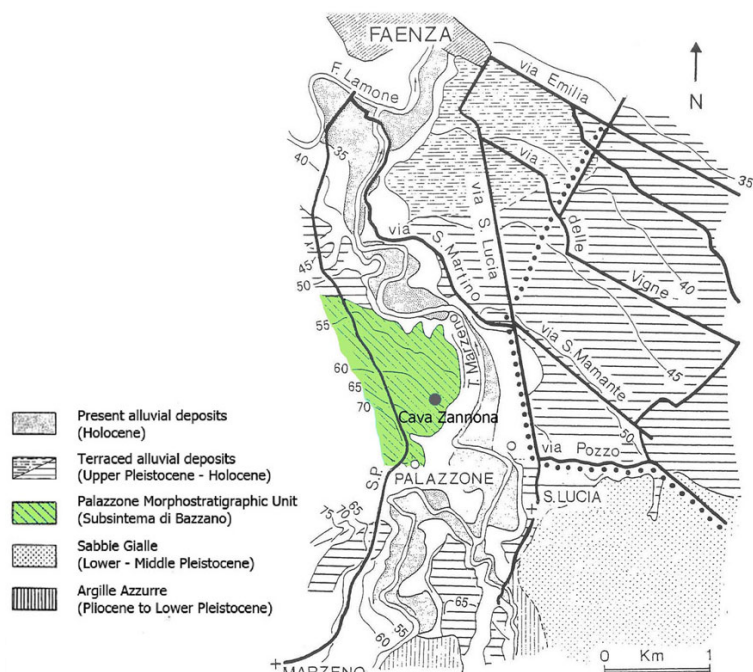


Fig. 2 - Geological map of the area surrounding the Cava Zannona quarry. The construction of a gas pipeline (dotted line) provided additional insights on stratigraphy of the Romagna Plain deposits (modified after Curzi et al., 1987).

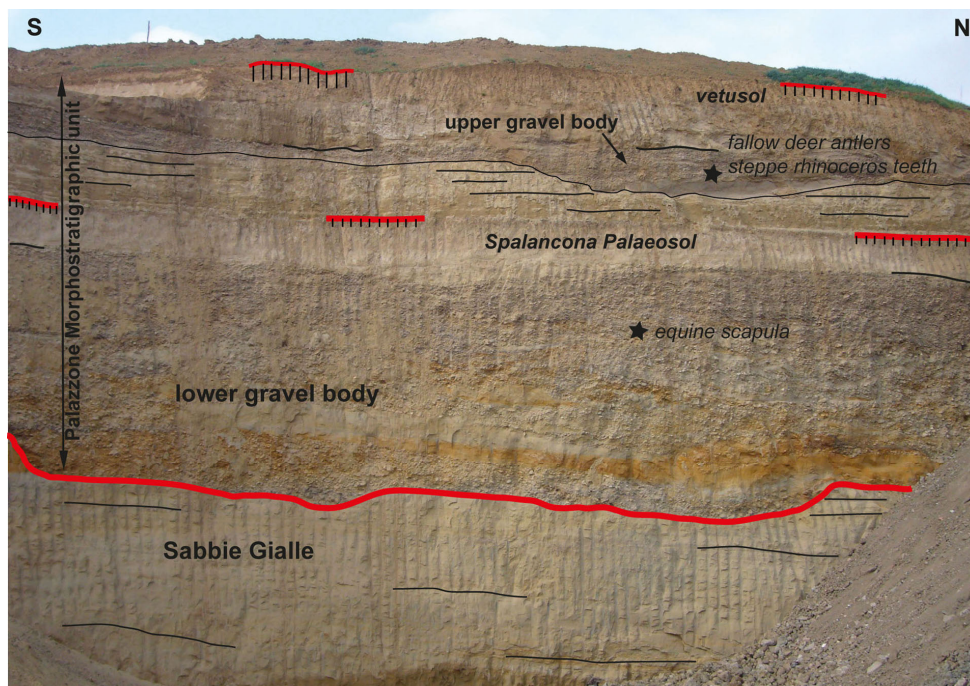


Fig. 3 - Field picture (frontal view) of the Cava Zannona quarry section running from S (left) to N (right). Two main depositional units, unconformably overlying the Sabbie Gialle Fm., are separated by the Splanconca Palaeosol.

cussed lithofacies. A stratigraphic analogy is represented by the succession exposed at the Ex Cava Crocetta locality, sited about 1 kilometre to the north-west of the Zannona quarry. In this locality it is possible to observe the Splanconca Palaeosol which is located a few meters below the ground level: a tooth of an undetermined bovine has been collected at the Ex Cava Crocetta locality just above this marker bed.

The chronological attribution of the continental deposits exposed at the Zannona quarry is primarily based on indirect evidences, in particular geometric relations with older and younger morphostratigraphic or UBS units that crop out extensively in the downstream section of a number of Apennine valleys in Emilia-Romagna between the Reno and the Montone rivers (see Carta Geologica d'Italia 1:50.000 scale, sheets 221 Bologna, 223 Ravenna, 239 Faenza, 256 Rimini). In these localities continental deposits are often bounded at their top by a reddish-brown *vetusol*, that locally reaches a few meter in thickness, that has been tentatively referred to the Upper Pleistocene (Martelli et al., 2009, p. 59-61). This age is supported by the lack in Zannona quarry deposits of Lower Palaeolithic manufactures that characterize the older Apennine foothills palaeo-surfaces up to the "Riss Cataglacial" (Peretto, 1996). To date, only isolated and poorly preserved prehistoric floated manufactures have been collected from the Pleistocene Palazzone Unit.

Specimens discussed in this study enrich the classical fauna of the Early and Middle Pleistocene large-bodied terrestrial vertebrates of the Imola region firstly reported by Giuseppe Scarabelli in the mid '800, known as "*Fauna di Imola*" (see also Azzaroli & Berzi, 1970; Masini et al., 1996 and Muttoni et al., 2011, although in the latter publication, the presented field stratigraphy is unreliable). Moreover, Scarabelli reported of a younger

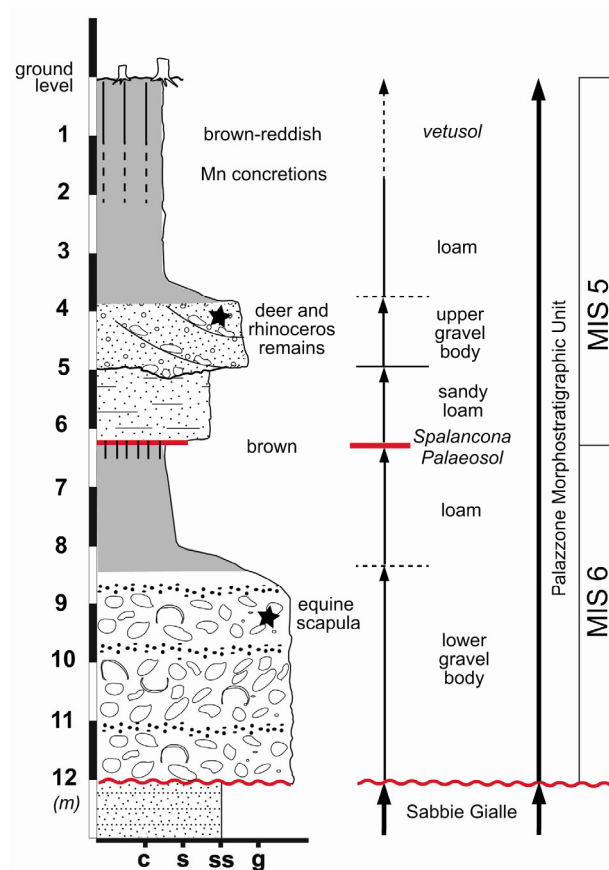


Fig. 4 - Stratigraphic log of the Cava Zannona quarry.



Fig. 5 - Field photograph of the Spalancona Palaeosol.

deposit "...which I named *fluviatile* [...] consisting primarily of rounded pebbles [...] three meters thick..." in which "...apparently no fossil has ever been collected with the exception of isolated horse or bovid teeth..." (Scarabelli, 1852). Such "*fluviatile*" deposits were identified by Scarabelli in the cover of the alluvial fan terraces of the Santerno river (Marabini, 2009). Such beds, located approximately 15 kilometers north-west of the study area, share important stratigraphic and geographic analogies with the Zannona quarry sequence. In fact, both continental successions have been referred to the Subsistema di Bazzano in the *Cartografia Geologica 1:50.000, Servizio Geologico d'Italia* (Amorosi et al., 2009).

3. PALAEOLOGICAL REMAINS

Vertebrate remains collected at the Zannona quarry include a proximal portion of a left scapula of *Equus* sp., a frontal with antlers of *Dama dama*, and the incomplete upper right and upper left dental series (from the third premolar to the last molar) of *Stephanorhinus hemitoechus*. All described specimens are deposited at the Museo Geologico Giovanni Capellini (MGGC) in Bologna (Italy), and catalogued under MGGC accession numbers.

The scapula (MGGC 21878), which has been collected *in situ* from the lower gravel layer (Figs. 3 and 4), preserves a partially eroded glenoid cavity, the neck and the beginning of the expanded part with the spine, the latter located in proximity of the cranial margin. The specimen collected at Cava Zannona has a low spine that runs out before the ventral angle and shows no evidence of acromion. The ventral angle shows deep muscular attachments insertions. Unfortunately, the scapula does not preserve the coracoid process and the glenoid

notch but only the beginning of the supraglenoid tubercle that seems to be extended and placed nearby the articular surface. Moreover, the neck of the scapula has an equid-like major length and appears more narrow than other perissodactyls or artiodactyls species (Barone, 2006). Lacking diagnostic specific traits, overall morphology and size allow to refer the scapula to *Equus* sp. (Fig. 6).

Fallow deer remains are represented by a nicely preserved frontal with antlers (MGGC 21871). This specimen was collected *in situ* in a thin lens of gravel and sand located between the *Spalancona Palaeosol* and the *vetusol* of the Zannona quarry terrace (upper gravel layer in figs. 3 and 4), at a depth of about 4 meters below surface. The left antler is the most complete having pedicle, rose, brow tine and beam that leads to the palmation (Lister 1990), well-defined and typical of the species *Dama dama* (Fig. 7). The distal termination of the palmation is missing; the right antler has only the rose implanted on the pedicle and the initial part of the antler with the brow tine preserved.

This specimen is still attached to the pedicle and part of the frontal, and shows all diagnostic features of fallow deer: a very high angle of departure of the beam (150° from the line of pedicle), and basal tines of circular section resting on the rose and making an obtuse angle (115°) with the beam. In addition, the large circumference of the basal tines (left ≈ 95 mm and right ≈ 93 mm) approaching that of the beam (133 mm) is comparable with the Middle Pleistocene *Dama dama* (Lister, 1990; Azzaoli, 1953).

Based on the size and the well-developed morphometric characters the specimen is attributed to an adult individual.

A direct comparison with the osteological collection materials at the University of Ferrara did not reveal diagnostic morphological differences to support an as

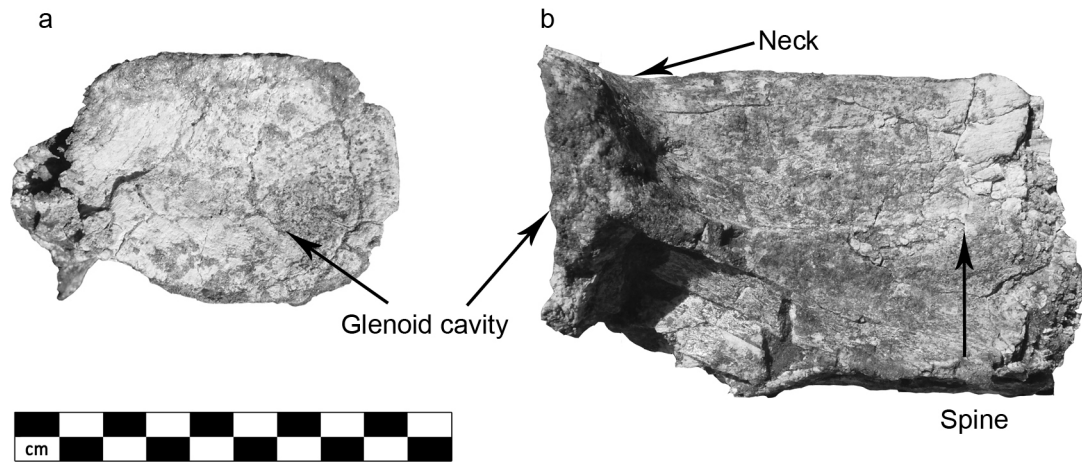


Fig. 6 - Left scapula of *Equus* sp. (MGGC 21878) in distal (a) and lateral (b) views.

signment of MGGC 21871 to the more primitive species *Dama clactoniana* (or *Dama dama clactoniana* for some authors), which is believed to have gone extinct during MIS 9 or MIS 8 (Di Stefano & Petronio, 1997). In addition, *D. clactoniana* is characterized by the presence of three tines on the anterior edge and one tine on the posterior edge, that lacks in the modern individual of *D. Dama* and in the specimen of Zannona quarry too (Leonardi & Petronio, 1976).

Rhinoceros remains consist of two upper dental series (MGGC21872 and 21874). Both specimens were not recovered *in situ*, but they were most likely originally preserved in the same stratigraphic horizon that produced the deer antler. The right maxillary series is complete, whereas the left one is missing the second premolar (Figs. 8 and 9).

The right P^2 has not distal and vestibular cingula. The mesial cingulum is well preserved, continuous and horizontal, whereas the lingual cingulum is well-

rendered, continuous but not horizontal; it forms a wedge-shaped constriction next to the median valley between the rear and the front lophe. The lingual cingulum displays the higher degree of variability: where preserved, it is either continuous and horizontal or showing variation in thickness and discontinuous.

The right P^3 has a well-developed crochet. The protocone constriction, considered as a discriminant character for extinct rhinoceros by Lacomat (2005), has not been identified. Ectolophe profile is inconstant. The paracone fold is prominent and the metacone fold may be visible. The tooth is similar to the specimen of *Stephanorhinus hemitoechus* from the Grotte du Mars (de Lumley, 1969; Lacomat 2005). The same premolar in *S. kirchbergensis* is characterized by a regular, smooth, slightly convex and without apparent reliefs vestibular wall.

The left P^3 is incomplete, missing the inner portion of the posterior lophe which includes the hypocone and

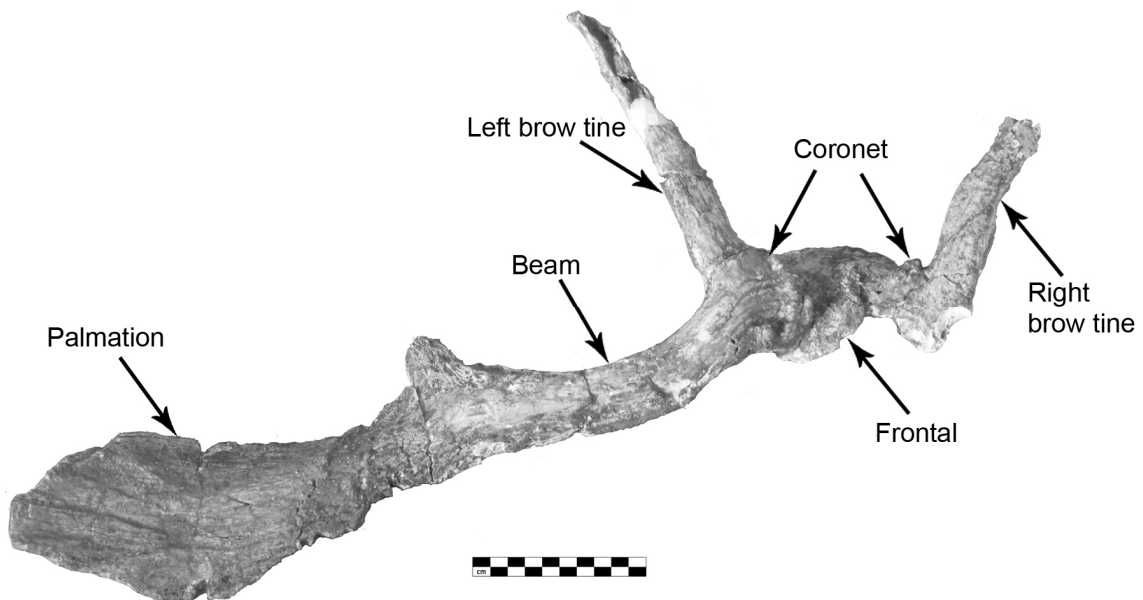


Fig. 7 - Antler of *Dama dama* (MGGC21871) in dorsal view with relative nomenclature.

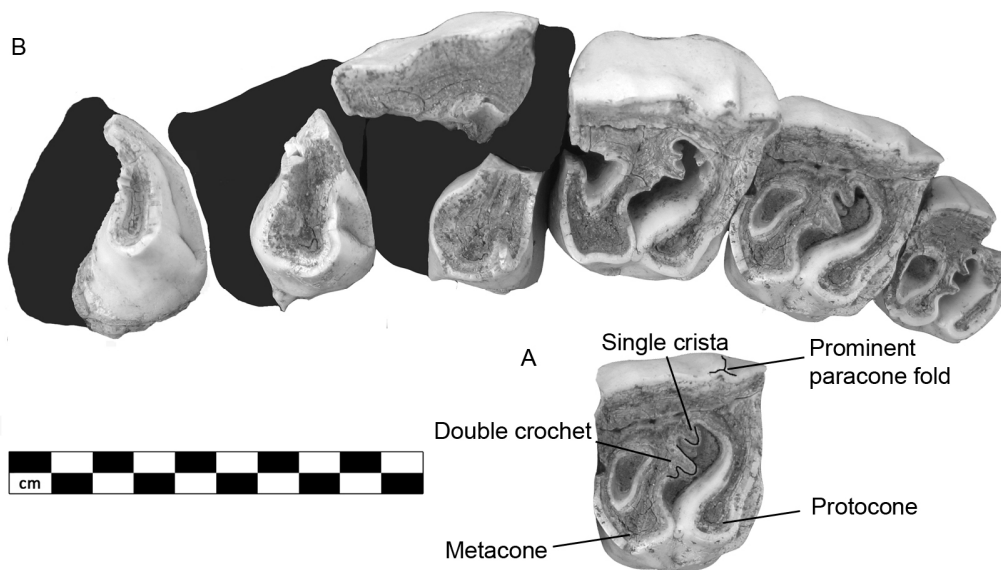


Fig. 8 - A: *Stephanorhinus hemitoechus* right maxillary series of teeth in occlusal view (MGGC 21874). B: Morphological features of the upper teeth in occlusal view.

the post-fossette; it is also not possible to distinguish the crochet nor the ante-crochet. The tooth appears symmetrical to the corresponding right one in overall characters, size and wear. It also displays a better preservation, having a prominent and well preserved mesial edge.

The right P⁴ has a preserved crochet, but the posterior and the vestibular cingula are missing. It has a double crochet, a character that has also been detected in specimens of *S. hemitoechus* from Caune de l'Arago as well as from Grotte du Mars (Lacombat, 2005). The lack of an ante-crochet, a character observed in this specimen, has been considered as diagnostic for *S. hemitoechus* by Lacombat (2005), with the exception of a specimen from Grotta del Principe (Balzi Rossi). The mesial cingulum in *S. hemitoechus* is well developed, prominent, continuous and horizontal, as in the specimens from the Zannona quarry: however, specimens collected from the Caune de l'Arago and Grotta del Principe localities lack this character. The lingual cingulum is not preserved but it cannot be excluded that it is a weathering-related artefact. In *S. hemitoechus* the ectolophe profile is sharply undulated with the paracone fold clearly visible, whereas the metacone fold is visible in some individuals. The vestibular edge profile of the right P⁴ is undulated with the paracone well-defined and a barely visible metacone.

Left P⁴ is significantly worn on the mesial edge of the anterior lophe when compared to the corresponding right tooth; the lingual wall and the median valley are also smoother. Overall, the tooth is specular to the its right counterpart. The vestibular wall is only preserved in the mesial section, is missing the metacone fold, and the paracone fold is clearly visible. Part of the paracone is also preserved, as well as the lingual and mesial walls of the tooth and the section surrounding the posterior lophe of the distal wall.

Right M¹ is only partially preserved, having a portion of the vestibular wall, a portion of the vestibular paracone fold and possibly the metacone crista. In addition,

it is possible to observe the protocone fold in a fragmentary section of the anterior lophe.

The left M¹ is represented by a portion of the anterior lophe (the paracone is missing) and the vestibular wall with the metacone fold, the metastyle and the metacone.

Similarly, diagnostic characters are not discernible in the right M² except for a prominent and continuous cingulum in the mesial wall.

The left M² is represented by the anterior lophe with preserved protocone constriction, a deep mesial cingulum, the complete vestibular wall (with a clear paracone fold and a shallow metacone fold), and a portion of the posterior lophe.

The right M³ has a prominent, continuous, and sub-horizontal cingulum in the anterior lophe; the left M³ has almost complete walls and is missing the inner section of the crochet and part of the mesial labial wall. The mesial cingulum is well-marked and slightly oblique, as observed in *S. hemitoechus*; the vestibular and lingual cingula are absent. The ectolophe line is very oblique and convex; the paracone line and the distal depression are very shallow. When compared with specimens referred to *S. kirchbergensis*, the ectolophe profile has a more regular trend; in fact, in Merck's rhinoceros it is commonly possible to identify solely the paracone fold.

The overall poor preservation as well as different degrees of molar vs premolar wearing do not allow to clearly identify a number of diagnostic characters in the Zannona quarry specimens. The sole observed qualitative character is represented by the ectolophe line, which is strongly undulated and characterized by a well-developed paracone line and a noticeable metacone fold. We do exclude an attribution of MGGC21872 and 21874 to *S. hundsheimensis* considering that the latter taxon the ectolophe profile is straight or slightly undulated with a clearly distinguishable paracone fold (the metacone fold is absent). Similarly, we refrain from assigning the specimens to *S. kirchbergensis*, which is charac-

terized by a slightly undulate profile of the ectolophe and the lack of reliefs.

Therefore, teeth collected at the Cava Zannona site are therefore conservatively assigned to *Stephanorhinus hemitoechus* and are believed to represent the palate elements of a single individual.

4. BIOSTRATIGRAPHIC DISCUSSION

Dama dama is a well-known member of the Asian immigrant fauna that spread across Europe in the late Middle Pleistocene: fossil remains have been reported from a number of localities and correlated with the isotopic stages MIS 7 and 5 (Palombo et al. 2004). Specimens recovered from the Grotta Romanelli (near Castro, Lecce, Italy) and referred to the Eemian interglacial by Blanc (1953) may represent the sole evidence of post-Galerian deer. However, such specimens may be assigned to the more primitive taxon *Dama clactoniana* and thus representative of a previous interglacial stage (Sala, 1980). More recent studies on the lithic industries (Mussi, 1992; Piperno pag. 165 in Guidi & Piperno, 1992) confirm this hypothesis, placing the lower layers of Grotta Romanelli before the final stages of the Middle Pleistocene. The more derived fallow deer *Dama dama* has been reported in several palaeontological sites – all dated to the MIS 7 (Palombo et al., 2002) – of Lazio, such as Torre in Pietra (Caloi & Palombo 1978), Vitinia (Caloi et al., 1983), Cerveteri (Capasso Barbato et al., 1983), Casal dei Pazzi (Anzidei et al., 1984), and is coeval with the primitive subspecies *Dama dama tiberina* (Di Stefano & Petronio, 1997). Similarly, the basal deposits of the Caverna degli Orsi (Trieste; Berto & Rubinato, 2013), San Sidero (Lecce; De Giulii, 1983), and Melpignano (Lecce; Bologna et al., 1994; Petronio & Pandolfi, 2008) have been referred to the MIS 5. The available palaeontological record suggest that fallow deer got extinct in north-eastern Italy, including the northern and central Adriatic regions, by the end of the isotopic stage 5 (Berto & Rubinato, 2011), whereas they survived up to the isotopic stage 3 in the more temperate climatic conditions of the Tyrrhenian coast and southern Italy (Sala, 1983), as supported by the finds of Grotta della Cala (Salerno) (Benini et al., 1997) and Grotta di Castelcivita (Salerno) (Masini & Abbazzi, 1997).

The rhinoceros *Stephanorhinus hemitoechus*, with all probability an Asian immigrant taxon, has been recovered in deposits encompassing the early Middle Pleistocene-latest Pleistocene interval (Kahlke & Kaiser, 2011). In Italy, the oldest record of *S. hemitoechus* is reported from the Faunal Unit of Silvia, which has been assigned an approximate age of 800.000 years (Ambrosetti et al., 1979; Gliozzi et al., 1997; Bertini et al., 2010): its youngest occurrence is represented by the remains collected at the Grotta della Cala (Salerno) in deposits with an estimated age of 29.850 ± 1700 BP (Belluomini & Bacchin, 1980; Benini et al., 1997), thus correlated with the latest MIS 3. It is also reported as a component of Middle Pleistocene faunal assemblages in a number of Italian locality such as Visogliano (Cattani et al., 1991; Rubinato, 2011; Patrizi, 2012). *S. hemitoechus* is a medium- to large-sized species characterized by a skull-bearing neutral position significantly lower than other congeneric species from the Middle Pleistocene, typical of a mixed, low vegetation, pasture behaviour. Available data suggest that temperature was not a primary factor in the distribution area of this taxon, although it is more adapted to cooler environments than other coeval congeneric rhinoceros (Lacombat, 2005). During relatively cold stages, *S. hundsheimensis* was replaced by *S. hemitoechus* in vast areas of the western Palaeoartic Region. *S. hemitoechus* survived the extinction of *S. hundsheimensis* (Middle Pleistocene) and *S. kirchbergensis* (early Late Pleistocene) representing the sole species of the genus in the fossil record. Its distribution in relatively dry stages extended over much of peninsular Italy, and fossil remains are known from Ligurian sites as Arma delle Manie (Savona; Fornasiero, 1989), and Tyrrhenian localities as Castelcivita (Salerno; Masini & Abbazzi, 1997), and Grotta della Cala (Salerno; Benini et al., 1997).

5. CONCLUSIONS

The discovery of fossil vertebrates at the Zannona quarry locality provides additional data for our comprehension of the environmental and chrono-stratigraphic framework of the continental succession near Faenza. Pending further radiometric and isotopic dating from the surrounding areas, data presented in this paper allow to

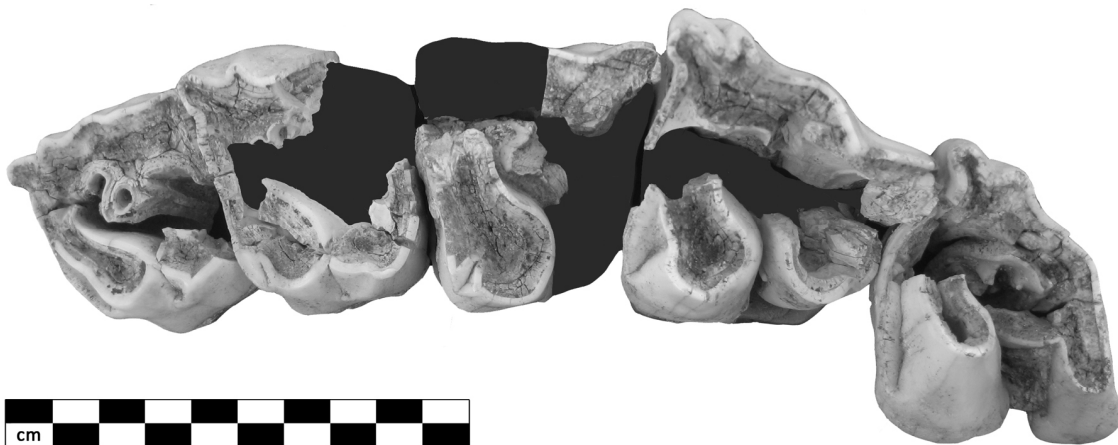


Fig. 9 - *Stephanorhinus hemitoechus* left maxillary series of teeth in occlusal view (MGGC 21872).

suggest an age for the Zannona quarry deposits and fauna. The discussed terrestrial deposits are dated near the Middle-Late Pleistocene boundary and consequently are coeval with the transition between the Marine Isotopic Stage 6 and 5. The fluvial beds bounded upwards by the *Spalancona Palaeosol* are here referred to the latest Middle Pleistocene (MIS 6; also in agreement with Amorosi et al., 2009). The continental beds above the *Spalancona Palaeosol* are interpreted to represent the inland expression of the major transgressive event that characterizes the MIS 5. Therefore, the equine scapula collected from the coarse, basal deposits can be tentatively referred to the late Middle Pleistocene. The occurrence of *Dama dama* in the upper interval support the assignment of such deposits to the MIS 5: this taxon, in fact, is reported in the Adriatic region exclusively from the isotopic stages 7 and 5, both characterized by temperate climatic conditions (Berto & Rubinato, 2013). Correlation with the Faenza borehole nearby and the recent proposed stratigraphy of the Eastern Po Plain (Amorosi & Colalongo, 2005; Amorosi et al., 2009), disfavor the presence of MIS 7 in the Zannona quarry terrestrial deposits.

The lack of the rhinoceros species *S. kirchbergensis*, well adapted to forest and warm environments and diagnostic for the Eemian (about MIS 5e) interval, does not allow to unequivocally identify the exact age of the studied fauna within a specific warm MIS 5 substage.

In conclusion, data presented here indicate that the continental deposits exposed at the Zannona quarry preserve the transition from the MIS 6 and 5. In particular, the *Spalancona Palaeosol* separates a lower, braided-stream, mainly coarse-grained interval from an upper, finer, meandering-stream, aggradational flood-plain interval where vertebrate remains support a warm, sub-arid steppe MIS 5 time-slice.

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