



REVISED BISON SKULL FROM THE SALITA DI ORIOLO QUARRY NEAR FAENZA, “SABBIE GIALLE”, PLEISTOCENE, NORTHERN APENNINES

Giulia Toniato¹, Stefano Marabini², Benedetto Sala¹, Gian Battista Vai²

¹ Museo di Paleontologia e Preistoria, Università di Ferrara, Italy

² Museo Geologico Giovanni Capellini, Dip BiGeA, Alma Mater Studiorum, Università di Bologna, Italy

Corresponding author: S. Marabini <stemarabini@libero.it>

ABSTRACT: Improvements in the knowledge of Middle to Late Pleistocene terrestrial stratigraphy in the Romagna and Emilia Apennine foothills and new studies on the underlying marine yellow sand deposits have led to reconsider the taxonomy of a fossil bison neurocranium found in the “Sabbie gialle” layers of the Salita di Oriolo quarry, near Faenza in the late 1980s. The skull fragment, erroneously associated in the past with a southern mammoth (*Mammuthus meridionalis*) skull found in the same large quarry some distance away from it, was identified as *Bison* aff. *schoetensacki*. Reanalysis of morphometric traits and comparison with other fossil material questions this interpretation and suggests a re-positioning of the Oriolo bison among the primitive *Bison* (*Eobison*) forms of the Late Villafranchian, before the end of the Early Pleistocene.

To test the consistency of the new assignment, an updated review of all available regional and local stratigraphic data is here presented. Original and new field data are focused in view of a more precise dating of the top layers of the marine Blue Clay (Argille Azzurre) Fm underlying the “Sabbie gialle” (Yellow sand) and of a closer correlation of the different cyclic sand bodies. The outcome is that the bison skull was dug about 25 m below the *Mammuthus meridionalis*, and both mammals were buried into different depositional cycles separated by unconformities. While the mammoth remain was emplaced sometimes after the Matuyama/Brunhes reversal and may therefore be assigned to the Middle Pleistocene, the bison is definitely older, and might actually be correlated with a late Early Pleistocene Sicilian age not far from the Jaramillo subchron, which is the present target of field research.

Keywords: late Lower and Middle Pleistocene, marine biostratigraphy, large mammals, cyclostratigraphy, magnetostratigraphy.

1. INTRODUCTION

The classic *lithostratigraphy* of the Plio-Pleistocene foothills of the Northern Apennines, dating back to Leonardo da Vinci (1452-1519), Jacopo Bartolomeo Beccari (1682-1766), Giambattista Brocchi (1772-1826), and Giuseppe Scarabelli (1820-1905) to whom we owe the traditional marine formation names of Argille Azzurre (Blue Clay), “Sabbie gialle” (Yellow sand), and the recognition of terraced alluvial deposits (see also Selli, 1949a, 1949b, 1962; Ruggieri, 1944; Ruggieri & Selli, 1949-1950, Azzaroli & Berzi, 1970, Vai, 1988), has been articulated and improved in the last century with the addition of a *sequential approach*, which resulted crucial in understanding the marginal environment (“Sabbie gialle”) and even more the continental (terraced) deposits. In spite of this, some problems remain unresolved.

This paper proposes an updated taxonomic and chronological position of the bison skull from the “Sabbie gialle” of the Salita di Oriolo quarry (Masini et al., 1995), and contributes to improving the stratigraphic framework of the Imola Sands (Amorosi et al., 1998a, 1998b), as well as discussing some results recently published in a paper by Muttoni et al. (2011).

2. PREVIOUS STUDIES AND STRATIGRAPHY OF “SABBIE GIALLE” IN THE IMOLA-FAENZA FOOTHILLS

An increasing use of a sequential approach (Ricci Lucchi, 1982; Vai 1984, 1988; Marabini et al., 1987a, 1987b; Farabegoli, 1985; Farabegoli & Onorevoli, 1991;

Farabegoli et al., 1999; Marabini & Vai, 1995; Marabini et al., 1996; Amorosi et al., 1998a, 1998b; Capozzi & Picotti, 2003) was postulated also by the tectonic pulses (both compressional and extensional) which have affected at different times the various parts of the foothills due to the outward migration of the Apennine chain (Castellarin & Vai, 1986, Vai & Castellarin, 1992, Picotti & Pazzaglia, 2008, Picotti et al., 2009). In this frame, Ricci Lucchi (1982) first introduced a sequential framework separating marine (Qm) from mainly continental (Qc) sequences (Fig. 1).

Later on, Vai (1984, 1988) and Marabini et al. (1987a, 1987b) emphasized the basic difference between regressive yellow sand (conformably closing the gradual shallowing of the blue clay depositional environment) and transgressive yellow sand bodies (unconformably representing deposits of mono- or polycyclic climatically-driven temporary marine incursions over the uplifting foothill area as already stated by Selli, 1949a, 1949b and Ruggieri, 1944). An additional distinction was made between yellow sand bodies, marked by cold biotas alternating within the upper Blue Clay (AA) Fm, and yellow sand bodies with warm subtropical biotas characteristic of the transgressive yellow sand cluster (Marabini et al. 1996). Two different types of mid-rank cyclicity were singled out in the Plio-Pleistocene deposits of the Apennine foothills separating thrust-top and foreland basins.

The shallower thrust-top front-Apennine basins, characterized by three main recurrent *Arctica islandica* horizons (Fig. 1), are bio-climatically controlled and punctuated by cold peaks within the Santerian, Emilian,

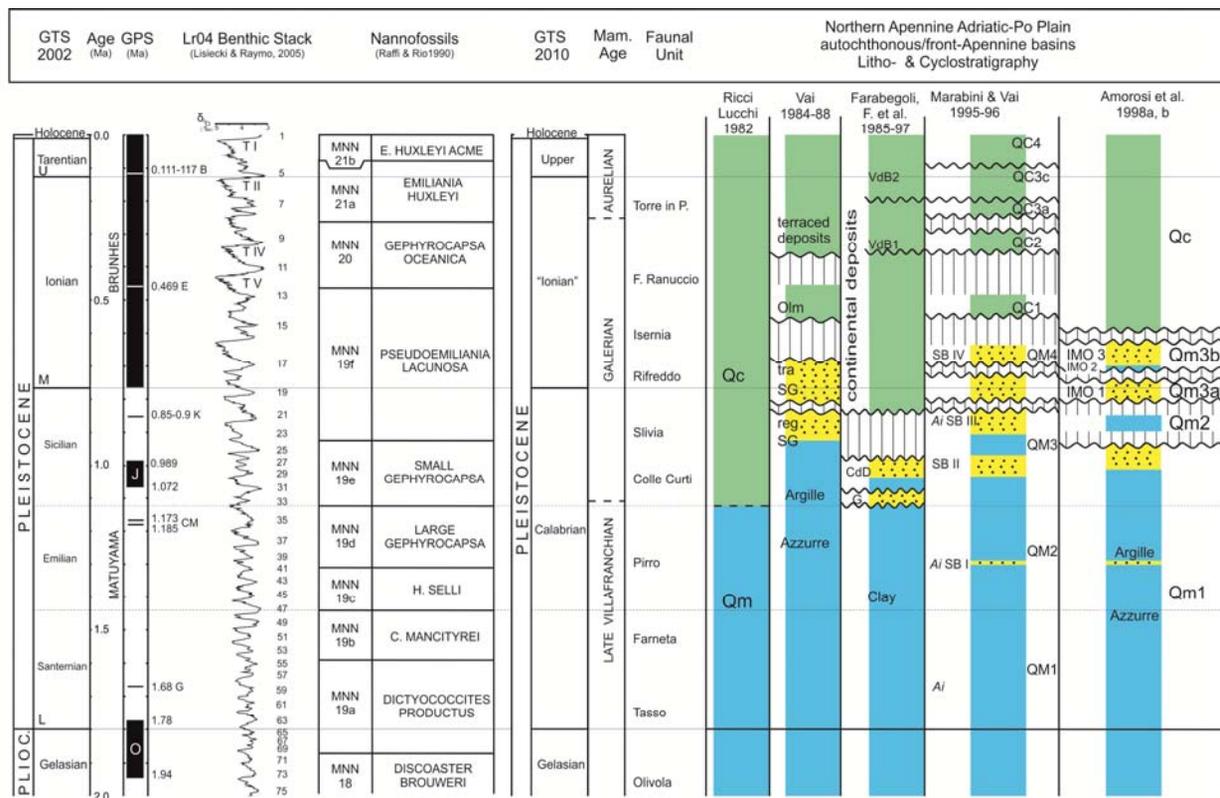


Fig. 1 - Lithostratigraphic correlation on a sequential frame tied to geological time, Romagna Apennine foothills.

and Sicilian Mediterranean regional substages (with apparent 400 ka eccentricity forcing at about MIS 64, 38-36, 22). The first *Arctica* horizon is developed in clayey facies, part of the second and the third in sandy facies, indicating gradual basin shallowing and infill (Blue Clay regression). Another type of cyclicity is suggested by four main marine sandy bodies intercalated into and topping the Blue Clay (AA) Fm (Fig. 1). They are roughly dated around 1.3-1.2 (MIS 38-36), 1.05 (MIS 30), 0.88 (MIS 22), and 0.75 (MIS 19-17) (Vai 1995, p. 173; Marabini et al. 1996, p. 272). The first and third overlap with *Arctica islandica* horizons, consistently with climatically-induced marginal sea-level dropping in a frame of dominating 40 ka obliquity forcing (Fig. 1). The fourth instead is provided with warm flora and fauna, suggesting deposition during one or two high sea-level stands of 100 ka eccentricity forcing. The sand bodies appear roughly punctuated by c. 200 and 100 ka recurrence time and were involved in terminal outer Apennine folding phases (Vai, 1995, p. 173; Marabini et al., 1996, p. 272) (Fig. 1). Both types of lithologic and faunal cyclicity are much better developed in the coeval marginal Sicily basins (Catalano et al. 1997).

The deeper foreland basin presents less or no sand bodies inside the Blue Clay (AA) Fm.

A lithostratigraphic formalization (Imola Sands) and subdivision, required for official geological mapping purposes and suitable for the Castel S. Pietro to Imola area and the related southern Po Plain core 239-S1,

was established by the Emilia-Romagna geological survey (Amorosi et al., 1998a, 1998b; Benini et al., 2009). This lithostratigraphy is intimately tied in to a simplified sequence frame. However, both litho- and sequence-stratigraphic frames are not straightforwardly correlated outside the Imola type area, even in the close well-studied Faenza area, and increasing correlation uncertainty is found outside the foredeep-foreland basin in the nearby thrust-top basins (see also Amorosi et al. 1998b, fig. 6).

Basic tools for dating the "Sabbie gialle" have relied upon large mammals and leaves, foraminifera and nannoflora, and palaeomagnetic inversions. Continental faunas and leaves that flooded into the coastal sands prompted a Villafranchian (equivalent to Calabrian) age (Scarabelli 1849, 1881) which basically continues into the present age assignment (Azzaroli & Berzi, 1970, Masini et al., 1995, 2013; Masini & Sala, 2007, Ferretti, 1999). In spite of warnings about uncertainty in collecting sites and strata and repeated suggestions that fossils at hand from both past centuries could derive from quite different horizons and rock bodies (Vai, 1984, 1988; Marabini et al., 1996; Torre et al., 1996), vertebrate palaeontologists have steadily assumed the occurrence of a unique yellow sand Oriolo fauna of dubious and quite debated late Villafranchian - or possibly early Galerian age (Masini et al., 1995) (Fig. 1).

Foraminifera and nannoflora are useful in dating the top of the Blue Clay (AA) Fm and clayey marine

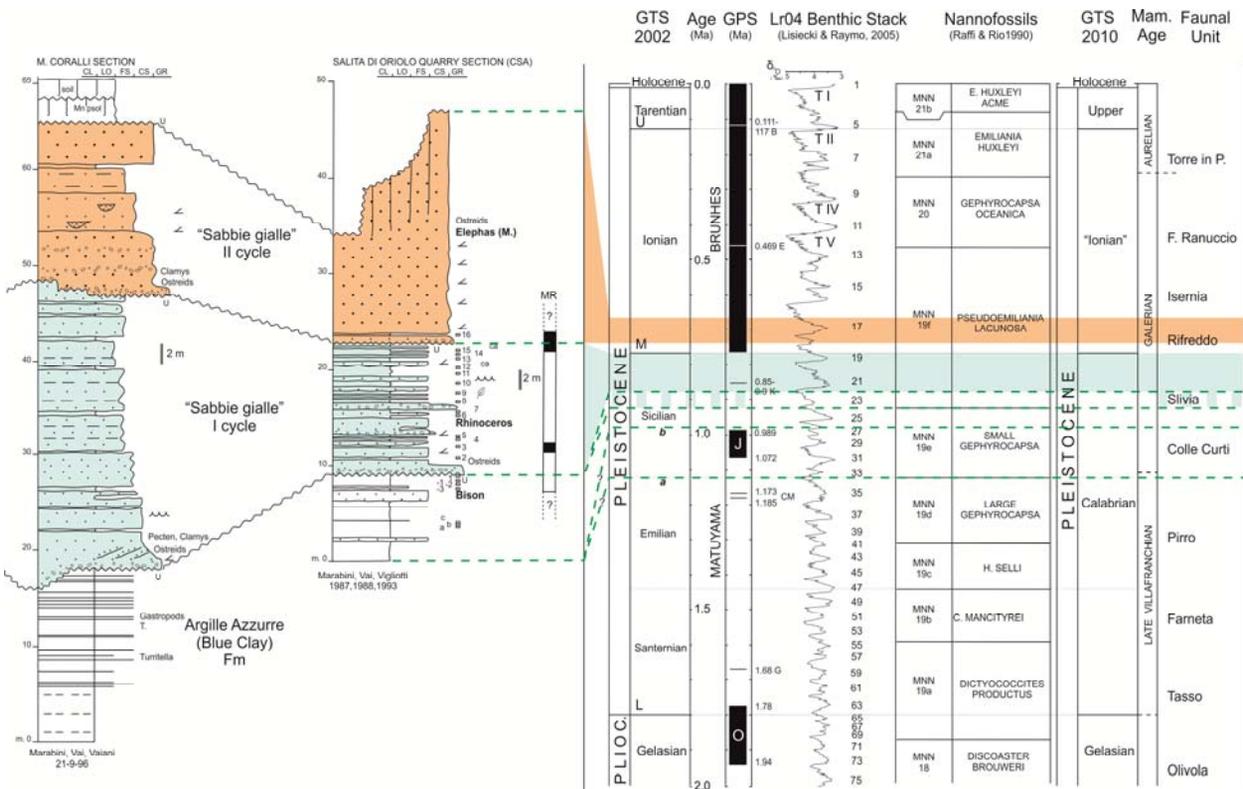


Fig. 2 - Chronological correlation of the Salita di Oriolo and M. Coralli sections in the Faenza area.

intercalations within the overlying transitional sand bodies. Unlike biostratigraphic dating of the 1980s, at the end of the century it became clear that, as in the Marche area, also in the Po Plain-Adriatic foreland basin continuous Blue Clay sedimentation reached the late Sicilian, above the Jaramillo chron, thus placing the Imola Sands (and other “Sabbie gialle”) already within the Middle Pleistocene (Marabini et al., 1996, p. 272; Amorosi et al., 1998b, Figs 1, 17).

Reliable magnetostratigraphic sections of reasonable length have been published only by Marabini et al., (1996), Muttoni et al., (2011) - both for the Imola-Faenza foreland basin - and by Gunderson et al. (2014) for the front-Appennine thrust-top basin in the western part of the Northern Appennine foothills, beyond the Po Plain deep core 239-S1 also studied by Muttoni et al. (2011). This is mirrored by the lesser thickness and shallower facies of the Blue Clay Fm (AA) in the thrust-top basins and by earlier regression and basin infill, when compared with the Imola-Faenza basin. An older (~ 100 ka) magnetostratigraphic age of the Sabbie di Imola in Gunderson et al. (2014, fig. 12) vs Muttoni et al. (2011, fig. 2) was expected based on the same earlier regression in the western foothills. However, this raises a problem for both lithostratigraphic and chronological correlations.

The last two paragraphs above may suggest that the Imola Sands can be diachronous, as can be expected for any lithostratigraphic unit. But also that not all marine yellow sand bodies nearby must have the same age (and pertain to the same sequence/cycle of the

Imola Sands). Only independent and integrated dating tools along with complete and articulated sections can provide reliable answers as to the age of individual sand bodies. Within this approach, we try to investigate the stratigraphic significance of the bison skull from Salita di Oriolo quarry, which was found detached from the remaining skeletal bones and transported by a flood into the marine littoral environment.

3. NEW FIELD DATA ON SOME “SABBIE GIALLE” SECTIONS S OF FAENZA

We examined three quite long “Sabbie gialle” sections S of the city of Faenza, the two best exposed and well-studied in the past decades, Salita di Oriolo quarry (Marabini et al., 1987a, 1987b; Vai, 1988, Marabini et al., 1996) and Monte Coralli trench (not yet published except for some information in Amorosi et al. (1998a, 1998b) and Vaiani (2000) and unfortunately too superficial to provide magnetostratigraphic response) (Fig. 2), and a new unstudied section from the Falcona quarry, a presently abandoned quarry with well-preserved walls that could be preserved as geosite with good potential also for further studies.

All three sections are strictly part of the same structural-stratigraphic domain, the Imola- Faenza foreland basin. All are composed by two dominantly sandy marine cycles bounded in outcrop by unconformity surfaces. Notice that “Two thick sandy layers separated by a muddy interval” were emphasized as the “Milazzian” basinward equivalents of the “Sabbie gialle” in the Po

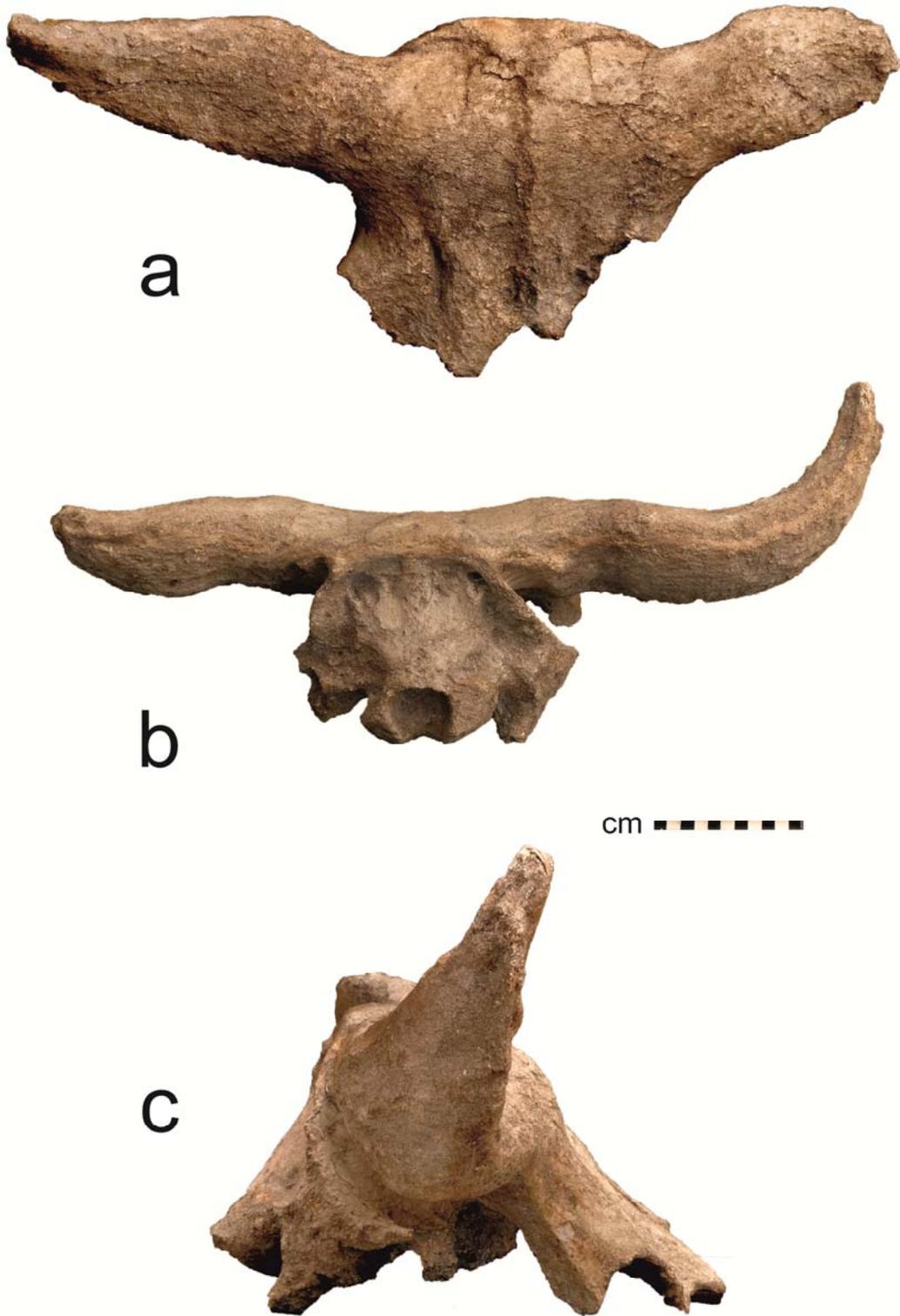


Fig. 3 - The skull of the Salita di Oriolo bison in dorsal (a), nuchal (b) and lateral (c) views (maximum width 63 cm).

Plain subsurface studied by Selli (1949) in many boreholes. Taken together, the two cycles unconformably overlay regressive sandy pelites and mud at the top of the more tectonically deformed Blue Clay (AA) Fm, and are in turn overlain by Middle Pleistocene mainly pelitic partly pedogenic terrestrial deposits.

The two cycles, though more or less yellow and sandy, exhibit common differences in the three sections that are related to lithology, and both litho- and biofacies. The *lower (I) cycle* (Fig. 2) contains some lenticular gravel lags and many thin muddy beds intercalated inside the sand, suggesting alternation of littoral and lagoonal/bay environment with relevant fluvial activity, as indicated also by some layers rich in well-preserved diverse floated leaves accumulation (Martinetto & Sami, 2001). Large mammal fragments are present with juvenile rhinoceros jawbones. The *upper (II) cycle* (Fig. 2) is more monotonously dominated by medium to coarse well-sorted littoral sand, suggesting a more stable and wider foreshore environment and a dryer climate. If we assume that the two “Sabbie gialle” cycles have, at least partly, an orbital climatic forcing (Farabegoli & Onorevoli, 1991), their individual duration might overlap with one or two obliquity 40 ka intervals (especially the lower) or an eccentricity 100 ka interval (especially the upper cycle) including the erosional-depositional time gap.

The Salita di Oriolo section (Fig. 2) is the only out of the three that has provided reliable magnetostratigraphic results (all samples of the other two proved to be remagnetized). As a result, the I cycle is dominantly magnetically reversed and the II cycle is magnetically normal. According to Marabini et al. (1996) top samples of the Blue Clay (AA) Fm and the lower one of the first “Sabbie gialle” cycle are reversed. One single normal sample follows (CSA 3), which in turn is overlain by a reversed interval up to near the top of the first “Sabbie gialle” cycle (CSA 4 to 13). The last sample of the lower (I) cycle and the first of the upper (II) cycle instead are normal. These data have been discussed in detail by Marabini et al. (1996, p. 267-270). The normal polarity interval at the top of the cycle (nos. 15, 16) should represent the beginning of the Brunhes Chron (0.781 Ma). In this case, the tiny wiggle (no. 3) could reflect the closest normal event recognized in the Matuyama Chron, cryptochron Kamitsura (0.85, Champion et al., 1988; 0.90, Coe et al., 2004). Worthy to notice, two different magnetostratigraphic campaigns (1987 and 1993) have shown a reverse to normal polarity pattern in the same stratigraphic position of sample no. 3, about half a metre beneath the unconformity surface separating the two cycles. Alternatively, the no. 3 normal polarity interval is too short to be taken as an evidence for the Jaramillo Subchron (1.072 - 0.989). The Jaramillo Subchron has been detected in the Qm1 member of the AA Fm in Section A by Muttoni et al. (2011, Fig. 2) not far from Salita di Oriolo quarry. It consistently contains nannofossils of “the late Early Pleistocene part of Zone NN 19 (~ 1.02 - 0.61 Ma). However, this small muddy - sandy section is interrupted before reaching the “Sabbie gialle”.

The Monte Coralli section (Fig. 2), some 10 km W of the Salita di Oriolo section and no longer exposed, is

divided into four units by three main unconformity surfaces, all marking minor upward decrease in dip, especially the first and the third ones. The first unit exhibits a transition from massive silty clay (Blue Clay Fm) to finely bedded silty-sandy clay rich in gastropods (mainly *Turritella* layers) and bivalves. The “Sabbie gialle” lower (I) cycle contains medium to fine grained foreshore sand with thin clayey to pelitic alternations. The few basal gravel lags are characterized by black-chert pebbles. About 5° dip decrease occurs at the transition to the overlying coastal, coarse-grained “Sabbie gialle” upper (II) cycle, whose basal gravel lags contain common red-chert pebbles. The “Sabbie gialle” cycle I is much thicker in this section than in the Salita di Oriolo section, but cycle II is correspondingly less, giving to the “Sabbie gialle” a total thickness of about 48 m. The terrestrial sandy loam topping the “Sabbie gialle” is distinctly pedogenic with black Mn nodules pervasively developed beneath the present-day land soil (Fig. 2).

The Falcona quarry section, quite close to the M. Coralli one, has the great advantage of duplicating most of the features of the Monte Coralli section, and also represents a well-exposed potential “Sabbie gialle” geosite. Above the two “Sabbie gialle” cycles, the following units were preliminarily observed: fluvial deposits of the Omatello Fm; heavily pedogenic alluvial plain deposits rich in gilgai periglacial calcic palaeosols (Marabini et al. 1987); and possibly Late Pleistocene alluvial plain deposits with reddish palaeosols (Rubinato et al., 2013). These units can be traced physically down to the terrestrial deposits of the alluvial fan belt in the Faenza sector of the eastern Po Plain extensively excavated by pipelines, quarries and wells in the last decades.

More generally, the different yellow sand bodies are variously involved in regional tectonics as shown in relevant changes in both thickness and facies sequence (Castellarin & Vai, 1986, Vai, 1989, Vai & Castellarin, 1993). Both “Sabbie gialle” cycles in the Imola-Faenza foreland basin show modest angular unconformity at the base, consistent with vertical uplift tectonics and likely faster uplift rate after the second sandy cycle (Fig. 2). Earlier sand bodies within the upper part of the AA Fm have been hit by the latest Early Pleistocene (*sensu* GTS 2002) tectonic phase (Fig. 1), as shown for the Faenza foothills (by the Tombe-Persolino minor anticline in the Rio Janna and Monte Piano area (Marabini et al., 1996), and more prominently in the S. Mamante section with bed dips over 45° (Farabegoli & Onorevoli, 1991, Farabegoli et al., 1997) not far away from the Montone-Forlì fault zone. Accurate dating of the sand bodies and encasing mudstones is critical to unravel the age of transition from folding (usually occurring still in subaqueous conditions) to uplift (leading to stable emersion) for the different Pleistocene basins of the Emilia-Romagna foothills, and the related yellow sand bodies.

4. THE SALITA DI ORIOLO BISON SKULL

The neurocranium, preserved at the Civic Natural History Museum of Faenza, was recovered in 1989 by M. Diversi and M. Sami at the Salita di Oriolo quarry, near Faenza (Marabini et al., 1987), one year after the discovery of the mammoth I at the same site.

	<i>Bison (Eobison) sp. Oriolo</i>		<i>Bison sp. Taman (Vereshchagin, 1957)</i>		<i>Bison (Eobison) degiulii Pirro Nord</i>			<i>Bison cf. aff. schoetensacki Freud. (Vereshchagin, 1957)</i>			<i>Bison schoetensacki Isernia la Pineta (Sala, 1987)</i>			<i>Bison voigtstedtensis (Fischer, 1965)</i>		<i>Bison (Eobison) palaeosinensis Nihowan (Masini, 1989)</i>
			26010	253		Zimbal 26009	Tiraspol 1935	Eastern Transcaucasia	Is 27A 3	Is 4663	I1 98 3A 004					
1	703	-	-	-	-	-	-	770	699	-	610	520				
2	662	-	-	-	-	-	-	785	735	840	620	-				
3	240-250	-	-	-	-	-	-	235	265	-	230d	240s	-			
4	310	-	-	-	-	-	-	310	350	-	261d	265s	-			
5	200-210	-	-	-	-	-	-	215	235	-	230d	240s	200			
6	265d	255s	285	-	24-26	260	305	≈225	-	-	255d	255s	-			
7	68d	64s	75	86	63-68	77	72-89	≈65	-	-	78d	77s	-			
8	93d	90s	95	113	>88	84	79-100	≈78	-	-	87d	88s	-			
9	73d	71s	79	76	>71	91,5	78-91,1	≈83,6	-	-	89d	87s	-			
10	112,5	-	-	-	-	-	-	129	133	128,5	123	100,5				
11	41,25	-	-	-	-	-	-	34,5	42	57	32	42,5				

Table 1 - (1) Least distance between the horn core tips, (2) Greatest tangential distance between the outer curves of the horn cores, (3) Length of the horn core upper side, (4) Length of horn core lower side, (5) Taut length (chord) of the horn core, (6) Horn core basal circumference, (7) Least (dorso-basal) diameter of the horn core base, (8) Least (oro-aboral) diameter of the horn core base, (9) Narrowness index of the horn core base, $7 \div 8 \times 100$, (10) Greatest breadth of the occipital condyles, (11) Height of the foramen magnum.

The fossil land mammals of Oriolo all flooded into marine waters were studied in the 1990's, when the museum's paleontological collection was completely revised. Back then the neurocranium was identified as *Bison aff. schoetensacki* with more primitive features than *Bison schoetensacki* from Isernia La Pineta (Masini et al., 1995). However, recent geological researches on Quaternary yellow sands have brought about the need of reconsidering this interpretation by re-examining the fossil bison (Fig. 3).

4.1. DESCRIPTION AND MEASUREMENTS (Tab. 1)

The bison find from Salita di Oriolo consists only of the neurocranium. The skull fragment is partially preserved; the left side is slightly more damaged than the right. The horn cores are rather short with a somewhat dorso-ventrally compressed cross section and are lightly furrowed longitudinally. Directed laterally and posteriorly at the base, they then bend slightly downwards in ventral direction and curve finally upwards, only to terminate with a rounded tip. This detail can be clearly observed from the right horn core, as the left horn core tip is missing. The frontal bone is quite flat and broken in the orbital region. Only the upper margin of the right orbit is preserved revealing rather tubular shaped orbits. The frontal suture is partially fused and extends from the parietal roof down to the level of the supraorbital sulcus. The partial fusion of the frontal suture along with the well-developed horn cores indicate that the specimen was most likely a young-adult.

In aboral view, the parietal roof shows a triangular protrusion which culminates in a highly prominent infra-

temporal bridge. The parietal and temporal crests form a strongly acute angle. The occiput has a trapezoidal, though incomplete, profile. The left condyle is slightly damaged and the left mastoid process as well as both paroccipital processes are missing.

4.2. MAMMAL TAXONOMY, BIOSTRATIGRAPHY, EVOLUTION AND DISPERSAL INTO THE ITALIAN PENINSULA

Given that the Oriolo specimen likely belonged to a young-adult, the relatively small size of the neurocranium sets it apart from *Bison menneri*, which, according to Sher (1997), is characterized by a very large body size. Though the discovery of a complete skull of *B. menneri* has been reported from the site of Untermassfeld (Kahlke, 2009), no measurements are yet available for comparison; however, the picture of the cranium published by Kahlke (2009) seems to display evolved features commonly found in the subgenus *Bison*. Likewise, comparison with the cranial cast of the Taubach *Bison priscus* and others fragmented Is from Settepolesini di Bondeno, housed at the 'Piero Leonardi' Palaeontological Museum of the University of Ferrara, confirms the more primitive origin of the Oriolo bison. In fact, the *B. priscus* skull appears much larger and heavier built and differs from the Oriolo specimen in that the horn cores are sub-circular and curve readily upwards and the occiput has a rounded arch-like profile as well as a more drawn-back position of the frontal bone.

Unfortunately, biometric measurements had to be taken principally on horn cores, as most of the com-

parative material was poorly preserved and lacked of substantial cranial portions. Though biometry proved difficult and the results were meagre, it seems evident that the size range of the Oriolo neurocranium does not overlap with that of any other species. This is consistent with the results of morphological comparison. Considerable differences separate the Oriolo bison from *Bison voigtstedtensis* and *Bison schoetensacki*. These principally concern the occipital region, which is wider and more compressed, almost sub-circular, in both *B. voigtstedtensis* and *B. schoetensacki*, and the horn cores, which are shorter and directed obliquely backwards in *B. voigtstedtensis* displaying an array of different morphological characters, being more swollen at the base, less curved and tapering quickly upwards. By contrast, the horn cores of the Oriolo bison form an angle of approximately 90 degrees with the frontal plane and curve outwards and slightly downwards before pointing upwards, resembling quite closely those of *Bison (Eobison) tamanensis*, especially in the marked dorso-ventral flatness of the base.

Other striking similarities are to be noted with the subgenus *Bison (Eobison)*, in particular the deep infratemporal fossae and high occiput. These two features are present in *Bison (Eobison) palaeosinensis* (Teilhard de Chardin & Piveteau, 1930) and in the younger *Bison (Eobison) degiulii* Masini 1989. Though, in the latter the constriction between the occipital region and the parieto-frontals is narrower and the occipital region is smaller (Masini et al., 2013). Direct comparison with the holotype of *Bison (Eobison) degiulii* Masini 1989, temporarily preserved at the Natural Science department of the University of Firenze, enabled these observations. As opposed to *B. (Eobison) degiulii*, the Oriolo specimen also shows a less swollen forehead and a broader occipital region. Moreover, in *B. (Eobison) degiulii* the infratemporal fossae are narrower and more elliptical. Thus, these features of the Oriolo bison seem to indicate a younger age than that of *B. (Eobison) degiulii* of the Pirro FU, which is ascribable to the late Villafranchian, before the end of the Early Pleistocene (Fig. 1).

The genus *Bison* makes its appearance in the Italian peninsula during the late Early Pleistocene, late Villafranchian, with *Bison (Eobison) degiulii*, first recorded in the karstic fissure fillings of Pirro Nord, at the western border of the Gargano peninsula (De Giuli et al., 1986). This species occurs also in the Italian fossil record of the late Villafranchian (*sensu* Gliozzi et al., 1997, Masini & Sala, 2007) in various areas, such as the Mugello and Upper Valdarno basins and at Capena, near Rome (Masini, 1989).

The use of the subgenus *Eobison* was proposed by Flerov (1975, 1979), who decided to group together, on the basis of fossil evidence, all the small lightly built primitive bison forms of the Early Pleistocene. These include several species, like *Bison tamanensis* Vereshchagin, 1957 (Taman peninsula, Russia), *Bison palaeosinensis* Teilhard & Piveteau, 1930 (Nihowan, China), *Bison sivalensis* Lydekker, 1876 (Siwalik, Pakistan), *Bison degiulii* Masini 1989 (Pirro Nord, Italy) and the *Bison* sp. of Venta Micena (Spain). According to Bukhsianidze (2005), the remains of *Dmanisibos georgicus* Vekua 1995, renamed *Bison (Eobison)*

georgicus, represent the oldest known bison record in Europe, suggesting that the genus originated from *Leptobos* as far back as the middle to late Villafranchian transition, but Masini et al. (2013) prefer to take this classification cautiously.

Other bison remains, assigned to the subgenus *Bison (Eobison)* (Moyà-Solà, 1987), were unearthed in the Iberian peninsula, at the site of Venta Micena, which, according to recent comparative studies based on the faunal assemblage (Martínez-Navarro et al., 2011), could be slightly younger than Dmanisi with an estimated age around 1.5-1.6 Ma. However, the scantiness and poor preservation of these remains do not allow a secure classification.

The earliest representative of the true bison in Europe (the subgenus *Bison*) is *Bison menneri*, which is well-attested in the fossil-rich epi-Villafranchian (early Galerian for the Italian biochronology) fluvial sediments of Untermassfeld. Its large and long-legged structure, probably an adaptation to woodland habitats (Sher, 1997), makes it the biggest known European fossil bison.

During the Middle Pleistocene, new bison forms enter the Italian fossil record. *Bison schoetensacki*, is attested in the fossiliferous breccia of Slivia (Ambrosetti et al., 1979) and is believed to belong to the same lineage of *Bison schoetensacki voigtstedtensis* (Fischer, 1965), though Flerov (1975) considers it a distinct species. The progressive climatic decline and the arrival of the steppe bison, *Bison prisca*, during the Late Galerian, determined the extinction of *B. schoetensacki* from the Italian peninsula.

In this framework, the peculiar mixture of bisontine characters of the Oriolo neurocranium makes it a unique find within the Italian Early Pleistocene fossil record. Indeed, biometrical and morphological comparison with other cranial remains of Early and Middle Pleistocene bison species does not allow definitive species identification, but accounts for important evolutionary changes in morphology. The trapezoidal profile of the occiput and the narrow constriction between the occipital bone and the parietal roof recall primitive features, similar to those of *Bison (Eobison) degiulii*, while the marked flatness of the horn cores, regarded as a distinctive character among early bison forms, resembles that of *Bison tamanensis*. The latter is believed to be the oldest European bison, that appeared in Eastern Europe at the end of the Villafranchian (Flerov, 1979). Yet, in her recent work, Vislobokova (2008) correlates the Tamaian faunal assemblage with the early Galerian of Western Europe, specifically with the Colle Curti and Untermassfeld local faunal assemblages, assigning the Tamaian bison to the subgenus *Bison*. Whatever the opinion of the various authors on the subgenus of the Tamaian bison, the morphological features of the Oriolo specimen are comparable to those exhibited by the *Bison (Eobison)* fossil species of the late Villafranchian. Yet, the high occipital region and in particular the broader infra-temporal bridge of the Oriolo neurocranium are probably advanced characters that indicate a younger age than that of *B. (Eobison) degiulii*.

In conclusion, revision of the taxonomic classifica-



Fig. 4 - The westernmost part of Salita di Oriolo quarry in 1988 (photo by M. Sami). White star (top right) indicates the projected stratigraphic position of the *Elephas (Mammuthus) meridionalis* skull found in the eastern part of the quarry; geologists are extracting remains of a juvenile *Rhinoceros* from the sand; the digging place of the *Bison* skull is the whitish outcrop just behind the red van. See Fig. 2 for the relative stratigraphic position of the large mammal bones.

tion of the bison neurocranium of Oriolo adds new elements to our knowledge of the early bison forms that inhabited the Italian peninsula.

Biometrical and morphological comparisons suggest a strong affinity with *Bison (Eobison)* fossil species, that are to be observed in the marked flatness of the horn cores near the base, the trapezoidal profile of the occipital region, the deep infra-temporal fossae and the notably constricted infra-temporal bridge. However, certain morphological features such as the high occipital region and broader infra-temporal bridge appear to be more evolved than in *B. (Eobison) degiulii*, implying an age younger than that of the Pirro FU, that falls nonetheless within the late Villafranchian upper boundary (Fig. 1). It is hard to admit the coeval presence of two bisons of different subgenera in Northern Italy and Central Europe given that the faunal composition in North-eastern Italy throughout the whole Quaternary comprises species of Central European provenience, in opposition to those of the Ligurian-Tyrrhenian versant and of Southern Italy. Thus, the Oriolo bison, which for its morphology is assigned to the *Eobison* subgenus, should be older than *Bison menneri* from Untermassfeld, which belongs to the subgenus *Bison* and can be roughly correlated with MIS 31.

5. GENERAL STRATIGRAPHIC DISCUSSION

The new taxonomic assignment of the Salita di Oriolo skull to *Bison (Eobison)* sp. as opposed to its previous identification as *Bison* aff. *schoetensacki*

(Masini, 1989, Masini et al., 1995), implies an age of the lower "Sabbie gialle" cycle (from which it was supposed to come from till now by many authors) possibly older than previously thought. This applies if the large mammal biochronology of central and northern Europe, as presently known, may be assumed to be reliable also for southern Europe. To correctly answer this question (1) the sampling position of the bison in the Salita section must be clarified, and (2) an integrated critical review of the most relevant dating sources of deposits in the Imola-Faenza "Sabbie gialle" basin needs to be performed.

At the end of quarrying activities in the mid-1990s the Salita di Oriolo quarry was buried under tens of m of residual detritus, except for a minor lateral wall of sand and mudstone still exposed up to 2 to 3 m of thickness in the deepest (and stratigraphically oldest) westernmost part of the abandoned quarry, where a small farm lake was excavated. What is left today of these beds was sampled recently by Muttoni et al. (2011, fig. 2, section D) and proved to pertain to a reverse palaeomagnetic interval, but was mistakenly placed by these researchers on top of the littoral "Yellow Sand" containing *Mammuthus meridionalis* according to Marabini et al. (1996, fig. 4). To restore a less fanciful and more reliable stratigraphy of the Salita section, we have reviewed all our original field data from 1987 to 1993 to better constrain the sampling position of the large mammals (Masini, 1989, Masini et al., 1995, Ferretti, 1999).

The updated stratigraphic column of the Salita di

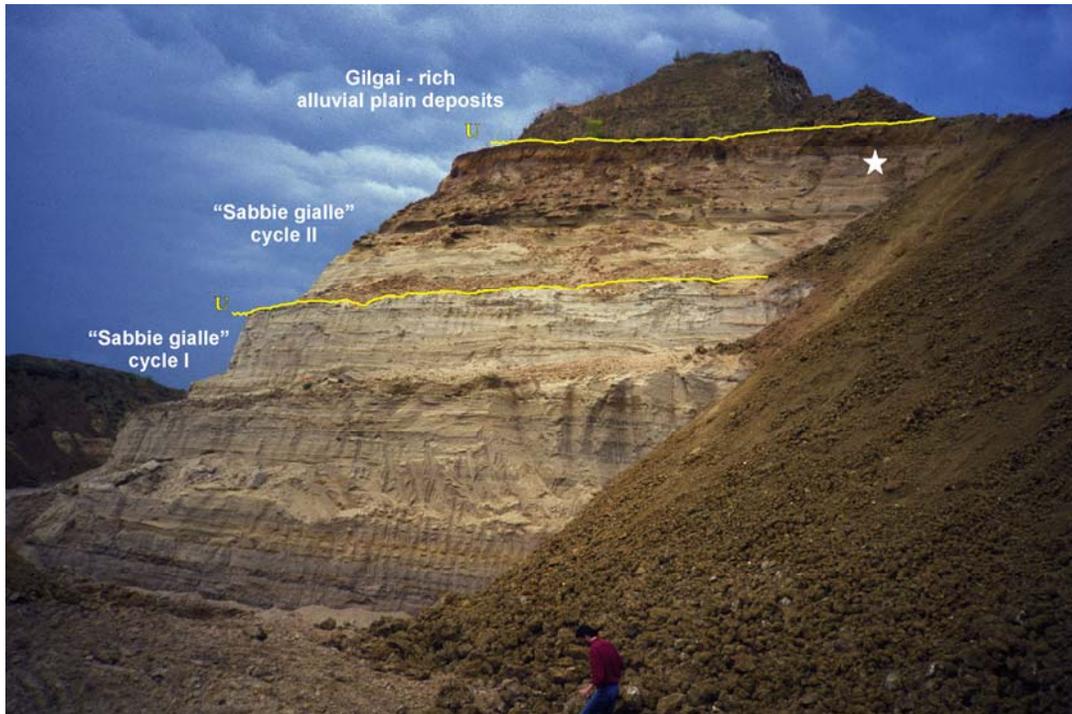


Fig. 5 - Western end of the Salita di Oriolo quarry in 1987 (photo by G.B. Vai). Main unconformities separating the two marine "Sabbie gialle" cycles, and the gilgai rich terrestrial deposits on top are shown. Again, white star (top right) indicates the projected stratigraphic position of the *Elephas (Mammuthus) meridionalis* skull found in the eastern part of the quarry.



Fig. 6 - Digging the *Elephas (Mammuthus) meridionalis* skull at the western end of Salita di Oriolo quarry in 1987 (photo by G.B. Vai). An umbrella and a white star indicate the digging and stratigraphic place of the *Elephas* near the top of "Sabbie gialle" cycle II, at an altitude equivalent to the nearby country home roof (about 110 m a.s.l.).



Fig. 7 - Tracing the Salita di Oriolo section from East to West across the quarry in 1987 (photo by G.B. Vai). Two main unconformities are shown. The lower separates the marine "Sabbie gialle" II cycle heavily rubefacted on top and gently dipping 9° - 10° to NE from the overlying almost flat terrestrial gilgai-rich deposits, in turn deeply incised by Late Pleistocene fluvial deposits (upper unconformity). Lighter coloured layer on top is a detrital nappe artefact.

Oriolo quarry (Fig. 2) basically repeats descriptions and figures given by Marabini et al., 1987a, 1987b; Vai, 1988, Marabini et al., 1996. New features are:

- (1) the downward extension of the column to incorporate data from an exploration trench of 1988; (2) the revised sampling position of the Bison skull in the stratigraphically lowermost trench of the quarry, possibly in the deepest sandy body available to exploitation; it follows that the *Bison* was emplaced at the top of the Argille Azzurre Fm;
- (3) the replacement of the bison, drawn in wrong position in the column of Marabini et al., 1996 (fig. 4), with a juvenile rhinoceros' jawbone (found by amateurs who mistakenly held that it had been excavated at about the same level of the bison). Slides taken in 1988 clearly show the sampling place of *Bison* and *Rhinoceros* in the western part of the quarry (Fig. 4), and the sandy layer yielding the *Mammuthus* skull at about 150 metres to the E (Figs. 5, 6, 7, 8);
- (4) the two unconformities separating the lower regressive sands ("Sabbie gialle" I cycle) from the upper transgressive littoral sands ("Sabbie gialle" II cycle), and in turn these "Sabbie gialle" from the uppermost terrestrial deposits are clearly though slightly angular (especially the upper one) (Fig. 3, 5);
- (5) the terrestrial deposits on top of the Salita di Oriolo section are now better correlated to the periglacial gilgai deposits (*suoli a cuspidi e depressioni* in Marabini et al. 1987a, p. 33) (Fig. 5, 7) rather than to the Oلماتello Fm (Vai, 1984, Marabini et al., 1996),

which instead is probably present on top of the Falcona section.

According to Amorosi et al. (1998a, p. 86) and Vaiani (2000), clays and silts of the uppermost Argille Azzurre (AA) Fm based on strontium isotope stratigraphy are associated with a latest Early Pleistocene (or Sicilian) age (Qm1 marine sequence); the following transitional to marine (Qm2) sequence has an earliest Middle Pleistocene (or 'Ionian') age (Fig. 1). Their biostratigraphic analyses, though consistent with the above dating, have not provided marker fossils of closer resolution. However, a top Sicilian age for the uppermost AA Fm in the Faenza sections is supported by three peaks of "northern guests" in the Romagna Apennines (Marabini et al., 1996, p. 271; Vai, 1995, p. 173) which correlate with the three northern mollusc migrations in Sicily (Raffi 1986). Note, however, the quite different ages given by various authors to the top of the Sicilian substage (see f.e. Amorosi et al., 1998b, fig. 4), waiting for a formal definition of the 'Ionian' GSSP (Fig. 1).

Even more important are the new biostratigraphic data in Muttoni et al., 2011 (tab. 1), which report *Gephyrocapsa* sp. 3 from their lower C section (that is correlated with the IMO 1 member of the Imola Sands) suggesting deposition during late Early-Middle Pleistocene part of Zone NN19 (about 1.02-0.61 Ma) that is latest Sicilian to early 'Ionian'.

It should be pointed out that all such isotopic and faunal dating elements derive from clayey intercalations in pure muddy or partly sandy AA Fm that always

underlie our “Sabbie gialle” first sandy cycle, except for section C which indeed could perhaps overlap our first sandy cycle.

To sum up, revised original field data definitely show that the *Mammuthus* skull of the Salita di Oriolo quarry was excavated from sands lying stratigraphically about 25 m higher than the revised Bison L and some 150 m East of it (Fig. 8).

New stratigraphic evidence more firmly supports an early Middle Pleistocene age of the “Sabbie gialle” cycle II in the Faenza foothills yielding a *Mammuthus meridionalis* skull. The underlying “Sabbie gialle” cycle I is best correlated with the upper part of the Matuyama reversed chron, most probably above the Jaramillo subchron.

As the layers containing the *Bison* sand body have resulted also to be reversed (Marabini *et al.* 1996, Muttoni *et al.*, 2011), it follows that the skull might actually correlate with an Early Pleistocene Sicilian age slightly younger or slightly older than the Jaramillo subchron.

To clarify this uncertainty further investigations are advocated for detecting the Jaramillo subchron in the thick, better exposed Faenza sections, showing transition from Blue Clay (Argille Azzurre) Fm to Yellow sand bodies, as the Falcona and equivalent sections.

ACKNOWLEDGEMENTS

We are indebted to Marco Sami (Museo di Scienze Naturali Faenza) for providing a colour slide of quarrying operation in 1988, and to the brothers Battista and Roberto Geminiani for technical assistance in the field work.

REFERENCES

- Ambrosetti, P., Bartolomei, G., De Giuli, C., Ficcarelli, G., Torre, D. (1979) - La breccia ossifera di Slivia (Aurisina-Sistiana) nel carso di Trieste. *Bollettino Società Paleontologica Italiana*, 18 (2), 207-220.
- Amorosi A., Caporale L., Cibin U., Colalongo M.L., Pasini G., Ricci Lucchi F., Severi P., Vaiani S.C. (1998a) - The Pleistocene littoral deposits (Imola Sands) of the northern Apennines piedmont. *Giornale di Geologia*, 60, 83-118.
- Amorosi A., Barbieri M., Castorina F., Colalongo M.L., Pasini G., Vaiani S.C. (1998b) - Sedimentology, micropaleontology, and strontium-isotope dating of a lower-middle Pleistocene marine succession (“Argille Azzurre”) in the Romagna Apennines, northern Italy. *Bollettino Società Geologica Italiana* 117, 789-806.

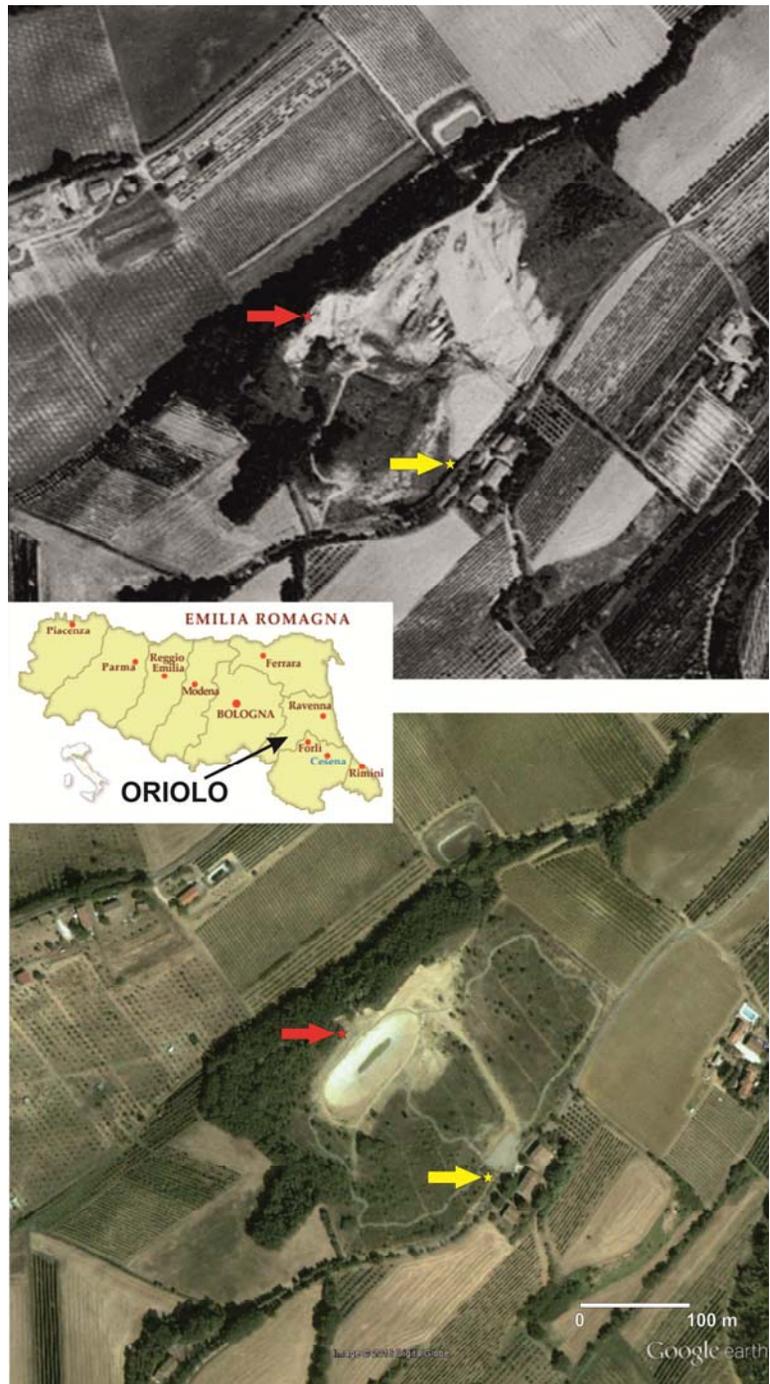


Fig. 8 - Air photo and Google Map views of large mammal fauna sampling sites in the former Salita di Oriolo (near Faenza) quarry, including bison (red star) and one side and mammoth (yellow star) on the other side.

- Azzaroli A., Berzi A. (1970) - On an Upper Villafranchian fauna at Imola, Northern Italy, and its correlation with the marine Pleistocene sequence of the Po plain. *Palaeontographia Italica*, 66, 1-12.
- Bukhsianidze M. (2005) - The fossil Bovidae of Dmanisi, PhD, dissertation. The International Doctorate “Environmental, Humans and Compartmental

- Dynamics" XVI cycle 2001-2004, University of Ferrara. pp. 192.
- Castellarin A., Vai G.B. (1986) - Southalpine versus Po Plain Apenninic arcs. In: Wezel F.C. (ed), *The Origin of Arcs*, Amsterdam, Elsevier, 253-280.
- Catalano R., Di Stefano E., Infuso S., Sulli A., Vail P.R., Vitale F.P. (1997) - Sequence and systems tracts calibrated by high-resolution bio-chronostratigraphy: the Central Mediterranean Plio-Pleistocene record. In: Catalano R. (ed), *Time Scales and Basin Dynamics. 8th Workshop ILP Task Force "Origin of Sedimentary Basins"*, Field Guidebook, 107-132.
- Champion D.E., Lanphere M.A., Kuntz M.A. (1988) - Evidence for a new geomagnetic reversal from lava flows in Idaho: discussion of short polarity intervals in the Brunhes and late Matuyama polarity chrons. *Journal Geophysical Research*, 93, 11667-11680.
- Coe R.S., Singer B.S., Primble M.S., Zhao X. (2004) - Matuyama-Brunhes reversal and Kamikatsura event on Maui: paleomagnetic directions, ⁴⁰Ar/³⁹Ar ages and implications. *Earth Planetary Science Letters*, 222, 667-684.
- De Giuli C., Masini F., Torre D. (1986) - The Latest Villafranchian faunas in Italy: the Pirro Nord fauna (Apricena, Gargano). *Palaeontographia Italica*, 74, 56-62.
- Farabegoli E. (1985) - Note geologiche del territorio di S. Lazzaro di Savena. In: Lenzi F., Nenzioni G., Peretto C. (cur), *Materiale ed documenti per un museo della preistoria*. Catalogo. Nuova Alfa Editoriale Bologna, 13-26.
- Farabegoli E., Onorevoli G. (1991) - La sezione di S. Mamante (Faenza) nel quadro evolutivo neotettonico ed eustatico del Quaternario dell'Appennino romagnolo. *Mem. Descr. Carta Geol. d'It.*, 46, 417-432.
- Farabegoli E., Onorevoli G., Ruffino C., Costantini B. (1997) - Struttura del sottosuolo quaternario continentale della Pianura Padana meridionale (Provincia di Ravenna - Italia). Università di Bologna e Agip, 12 tables.
- Ferretti M.P. (1999) - *Mammuthus meridionalis* (Mammalia, Proboscidea, Elephantidae) from the "Sabbie Gialle" of Oriolo (Cava La Salita, Faenza, Northern Italy) and other European late populations of southern mammoth. *Eclogae Geologicae Helvetiae*, 92(3), 503-515.
- Fischer K.H. (1965) - *Bison Reste* (Bison schoetensacki voigtstedtensis ssp. n.) aus den altpleistozänen Tonen von Voigtstedt in Thüringen. *Paläontologische Abhandlungen, Abteilung A. Paläozoologie*, 2, 2-3, 364-377.
- Flerov C.C. (1975) - Die *Bison Reste* aus der Travertinen von Weimar-Ehrigsdorf. *Palaeont. Abh.*, 23, 171-99.
- Flerov C.C. (1979) - Systematic and Evolution. In: Sokolov, V. F., Eds.: *European Bison*, 475 pp, Moscow.
- Gliozzi E., Abbazzi L., Argenti P., Azzaroli A., Caloi L., Capasso Barbato L., Di Stefano G., Esu D., Ficcarelli G., Giroto O., Kotsakis T., Masini F., Mazza P., Mezzabotta C., Palombo M.R., Petronio C., Rook L., Sala B., Sardella R., Zanolà E., Torre D. (1997) - Biochronology of selected Mammals, Molluscs and Ostracods from the Middle Pliocene to the Late Pleistocene in Italy. The state of the art. *Riv. Ital. di Paleont. e Stratigr.*, 103, 3, 369-388.
- Gunderson K., Pazzaglia F.J., Picotti V., Anastasio D.A., Kodama K.P., Rittenour T., Frankel K.F., Ponza A., Berti C., Negri A., Sabbatini A. (2014) - Unraveling tectonic and climatic controls on synorogenic growth strata (Northern Apennines, Italy). *GSA Bulletin*, 126, 532-552.
- Kahlke R.D. (2009) - Les communautés de grands mammifères du Pléistocène inférieur terminal et le concept d'un biochrone Épivillafranchien. *Quaternaire*, 20, 4, 415-427.
- Marabini S., Costa G.P., Giusberti G., Sami M., Taviani M., Ricci Lucchi F., Vai G.B. (1987a) - Rinvenimento di un cranio di *Elephas* nella parte alta delle "Sabbie Gialle" presso Faenza (Pleistocene). *Rendiconti Società Geologica Italiana* 10, 55-58.
- Marabini S., Taviani M., Vai G.B., Vigliotti L. (1996) - Yellow sand facies with *Arctica islandica*: low stand signature in an early Pleistocene Front-Appennine basin. *Giornale di Geologia* 57, 259-275.
- Martinetto E., Sami M. (2001). Paleoflora delle "Sabbie gialle" medio-pleistoceniche di Oriolo, presso Faenza (Ravenna). *Quaderno Studi Notizie Storia Naturale Romagna*, 14, 1-28.
- Martínez-Navarro B., Ros-Montoya S., Espigares M. P., Palmqvist P. (2011) - Presence of the Asian origin Bovini, *Hemibos* sp. aff. *Hemibos gracilis* and *Bison* sp., at the early Pleistocene site of Venta Micena (Orce, Spain). *Quaternary International*, 243, 1, 54-60.
- Masini F. (1989) - I Bovini Villafranchiani dell'Italia. PhD dissertation, University of Modena and Florence, pp. 152.
- Masini F., Abbazzi L., Ferretti M., Mazza P. (1995) - Fauna a mammiferi terrestri dalle «Sabbie gialle» quaternarie di Imola. In: Pacciarelli M., Vai G.B. (cur) *La collezione Scarabelli*, 1, 314-318.
- Masini F., Palombo M.R., Rozzi R. (2013) - A reappraisal of the Early to Middle Pleistocene Italian Bovidae. *Quaternary International*, 288, 45-62.
- Masini F., Sala B. (2007) - Large- and small-mammal distribution patterns and chronostratigraphic boundaries from the Late Pliocene to the Middle Pleistocene of the Italian peninsula. *Quaternary International*, 160, 43-56.
- Muttoni G., Scardia G., Kent D.V., Morsiani E., Tremolada F., Cremaschi M., Peretto C. (2011) - First dated human occupation of Italy at 0,85 Ma during the late Early Pleistocene climate transition. *Earth Planetary Science Letters*, 307, 241-252.
- Moyà-Solà S. (1987) - Los bóvidos (*Artiodactyla*, Mammalia) del yacimiento del Pleistoceno inferior de Venta Micena (Orce, Granada, España). *Paleontología I Evolució, Memoria Especial*, 1, 181-236.

- Picotti V., Pazzaglia F.J. (2008) - A new active tectonic model for the construction of the Northern Apennines mountain front near Bologna (Italy). *Journal of Geophysical Research* 113, B08412. doi: 10.1029/2007JB005307.
- Picotti V., Ponza A., Pazzaglia F.J. (2009) - Topographic expression of active faults in the foothills of the Northern Apennines. *Tectonophysics* 474, 285-294.
- Raffi S. (1986) - The significance of marine boreal molluscs in the Early Pleistocene faunas of the Mediterranean area. *Palaeogeography Palaeoclimatology Palaeoecology* 52, 3-4, 267-289. doi: 10.1016/0031-0182(86)90051-9
- Ricci Lucchi F., Colalongo M.L., Cremonini G., Gasperi G., Iaccarino S., Papani G., Raffi I., Rio D. (1982) - Evoluzione sedimentaria e paleogeografica del margine appenninico. In: Cremonini G., Ricci Lucchi F. (cur.), *Guida alla geologia del margine appenninico-padano*. Guide Geologiche Regionali Società Geologica Italiana, Bologna, 17-46.
- Rubinato G., Sami M., Fanti F., Marabini S., Sala B., Vai G.B. (2013) - Terrestrial vertebrates in MIS 6 to MIS 5 deposits of the Zannona quarry (Faenza, Italy). *Alpine and Mediterranean Quaternary*, 26, 55-63.
- Ruggieri G., (1944) - Il Calabro e il Siciliano nella Valle del Santerno. *Giornale Geologia*, 2, 17 (1943-1944), 95-113.
- Ruggieri G., Selli R. (1949, 1950) - Il Pliocene e il Pstpliocene dell'Emilia. *Giornale Geologia*, 20, 1-14; XVIII Int. Geol. Congress, London 1948, 9, 85-93, London.
- Sala B. (1986) - *Bison schoetensacki* Freud from Isernia la Pineta (early Mid-Pleistocene, Italy) and revision of the European species of bison. *Palaeontographia Italica*, 74, 113-170.
- Scarabelli G. (1849) - Sui depositi delle ossa fossili esistenti nell'Imolese. *Nuovi Annali delle Scienze Naturali*, 2, 10, 297-302.
- Scarabelli G. (1881) - *Carta Geologica del Monte Castellaccio e dintorni presso Imola*. Virano e Teano Roma.
- Selli R. (1949a) - Smottamenti costieri avvenuti durante il Siciliano al margine dell'Appennino bolognese. *Atti XIV Congr. Geol. It.*, 387-388.
- Selli R. (1949b) - Le conoscenze geologiche sul Quaternario gassifero del Polesine e del Ferrarese settentrionale. *Atti VI Convegno Nazionale per il Metano*, Succ. Penada Stampatori Padova, p. 515-537.
- Selli R. (1962) - Le Quaternarie marin du versant Adriatique Jonien de la Peninsule italienne. *Quaternaria* 6, 391-413.
- She A.V. (1997) - An Early Quaternary bison population from Untermassfeld: *Bison menneri* sp. nov. *Das Pleistozän von Untermassfeld bei Meiningen (Thüringen)*, Teil 1, 101-180.
- Torre D., Albanelli A., Bertini A., Ficarelli G., Masini F., Napoleone G. (1996) - Paleomagnetic calibration of Plio-Pleistocene mammal localities in central Italy. *Acta Zool. Cracov.*, 39, 1, 559-570.
- Teilhard de Chardin P., Piveteau J. (1930) - *Les mammifères fossiles de Nihowan (Chine)*. Masson et Cie, pp. 136.
- Vai G.B. (1984) - Quando barrivano sul Castellaccio gli ultimi elefanti. In: *Pagine di vita e storia imolesi*, CARS Imola, 2, 195-219.
- Vai G.B. (1988) - A field trip guide to the Romagna Apennine geology: The Lamone valley. In: De Giuli C., Vai G.B. (eds.), *Fossil Vertebrates in the Lamone Valley, Romagna Apennines*, Int. Work. "Continental faunas at the Miocene/Pliocene Boundary", 7-37.
- Vai G.B. (1989) - Migrazione complessa del sistema fronte deformativo-avanfossa-cercine periferico: il caso dell'Appennino Settentrionale. *Memorie Società Geologica Italiana* 38 (1987), 95-105.
- Vai G.B. (1995) - Introduzione alla geologia dell'Appennino nord-orientale, sulle orme di Scarabelli. In: Pacciarelli M., Vai G.B. (cur.), *La collezione Scarabelli 1*. Geologia, Musei civ. Imola Cat. Raccolte, Grafis Ed., 154-177.
- Vai G.B., Castellarin A. (1993) - Correlazione sinottica delle unità stratigrafiche nell'Appennino Settentrionale. *Studi Geol. Camerti*, vol. spec. (1992/2) Crop 1-1A, 171-185.
- Vaiani S.C. (2000) - Testing the applicability of Strontium Isotope Stratigraphy in marine to deltaic Pleistocene deposits: an example from the Lamone River Valley (northern Italy). *Journal of Geology* 108, 585-599.
- Vereshchagin N.K. (1957) - *Mammal Remains of the Lower Quaternary Deposits of the Taman Peninsula*, vol. 22, Trudy Zoological Institute, Leningrad, 9-49.
- Vislobokova I.A. (2008) - The major stages in the evolution of Artiodactyl communities from the Pliocene-early middle Pleistocene of northern Eurasia: Part 1. *Paleontological Journal*, 42, 3, 297-312.

