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A new age within MIS 7 for the *Homo neanderthalensis* of Saccopastore in the glacio-eustatically forced sedimentary successions of the Aniene River Valley, Rome

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ABSTRACT

Field observations as well as borehole, sedimentological and geochronologic data allow us to reconstruct the geologic setting of the Aniene River Valley in northern Rome, framing it within the recently recognized picture of temporally constrained, glacio-eustatically forced aggradational successions of this region. The sedimentary successions cropping out in this area include those described in the literature of the early 20th century in Saccopastore, where two skulls of *Homo neanderthalensis* were recovered. Based on the geometry, elevation and sedimentologic features of the investigated sedimentary deposits, the stratigraphic record of Saccopastore is correlated with the aggradational succession deposited in response to sea-level rise during glacial termination III at the onset of MIS 7 (i.e. ~250 ka), corresponding to the local Vitinia Formation, as opposed to previous correlation with the MIS 5 interglacial and a locally defined "Tyrrhenian" stage (~130 ka). This previous attribution was based on the interpretation of the sedimentary succession of Saccopastore, occurring between 15 and 21 m a.s.l., as a fluvial terrace formed around 130 ka during the Riss-Würm interglacial, ca. 6 m above the present-day alluvial plain of the Aniene River. In contrast to this interpretation, a $^{40}Ar/^{39}Ar$ age of 129 ± 2 ka determined for this study on a pyroclastic-flow deposit intercalated in a fluvial-lacustrine sequence forming a terrace ~37 m a.s.l. near the coast of Rome constrains the aggradational succession in this area to MIS 5, precluding the occurrence of an equivalent fluvial terrace at lower elevation in the inland sector of Saccopastore. We therefore interpret the stratigraphic record of Saccopastore as the basal portion of the aggradational succession deposited in response to sea-level rise during MIS 7, whose equivalent fluvial terrace occurs around 55 m a.s.l. in this region. We also review the published paleontological and paleoethnological records recovered in Saccopastore and demonstrate their compatibility with the faunal assemblages and lithic industries occurring in the sedimentary deposits of the Vitinia Formation, while we show the lack of any unequivocal Late Pleistocene (MIS 5) affinity. We therefore propose that the chronostratigraphic position of the Saccopastore deposits containing the two skulls should be around 250,000 years, as opposed to a previously preferred age of 130,000 years. The revised age makes these skulls the oldest Italian occurrences of *H. neanderthalensis* and provides evidence for a substantially coeval appearance and evolutionary path with respect to central-northern Europe.

1. Introduction

Two human skulls attributed to *Homo neanderthalensis* were recovered, successively, in the years 1929 and 1935, within gravel beds exposed by quarrying along the Aniene River Valley north of

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Rome, at a site called Saccopastore (Sergi, 1929; Breuil and Blanc, 1935a) (Fig. 1a). The deposits hosting the human remains were attributed to the "Tyrrhenian" stage (~130 ka) (Blanc, 1939a; Segre, 1948a, 1948b) based on the geomorphologic classification of the outcrop in which they occurred, forming a small hill with top about five meters above the adjacent alluvial plain of the Aniene River (Fig. 1b). This attribution was based on identification in this sector of the Aniene River Valley of two (Blanc GA, 1935; Breuil and Blanc, 1935b, 1936) and then three terrace complexes, correlated with the Günz-Mindel, the Mindel-Riss, and the Riss-Würm interglacials (~600–130 ka) (Blanc, 1946, 1948; Segre, 1948a, 1948b), following the geomorphologic and geochronologic criteria of the times in which the discovery was made, which relied on the studies of the Alpine glaciations (Penk and Brückner, 1909). The Saccopastore deposits were identified as part of the lowest terrace above the present-day alluvial plain of the Aniene River, therefore correlated to the Last Interglacial (Riss-Würm). Indeed, the marine deposits correlated with this interglacial gave rise to the new definition of Tyrrhenian Stage (Issel, 1914), and the name was then informally extended to the continental Saccopastore deposits to indicate the coeval age of the fluvial terrace.

A number of studies on the human remains at Saccopastore have been published (Bruner and Manzi, 2006, and references therein) in which the attribution of the deposits to the last interglacial was assumed as established. None of them questioned the actual age of the skulls, representing the earliest documented evidence of *H. neanderthalensis* in Italy, until recent work proposed an age as old as 170,000 yr for the Neanderthal skull of Altamura (Lari et al., 2015). Several authors have tentatively correlated the fluvial-lacustrine succession of Saccopastore with two consecutive temperate and humid-temperate climatic oscillations within Marine Isotopic Stage 5, either 5.5–5.3 or 5.3–5.1 (e.g., Caloi and Palombo, 1986, 1994a, 1994b; Caloi et al., 1989; Manzi et al., 2001; Palombo, 2004), dating between 123,000 and 82,000 yr BP, although there is no geochronologic evidence supporting this correlation, which is based on paleoclimatic considerations.

Numerous studies conducted in the last 20 years have framed the geology around Rome within a detailed, geochronologically constrained picture in which a strict link between glacio-eustasy and sedimentation has been evidenced, and a series of "aggradational successions" correlating with the different Marine Isotope Stages (MIS) in the last 900 kyr has been recognized (Alvarez et al., 1996; Karner and Renne, 1998; Karner and Marra, 1998; Marra et al., 1998; Karner et al., 2001a; Florindo et al., 2007; Marra et al., 2008; Marra and Florindo, 2014). Moreover, six glacio-eustatic cycles are now recognized from 600 ka to preceding the Würmian-Holocene (i.e.: MIS 16–15, 14–13, 12–11, 10–9, 8–7, 6–5; Huybers and Wunsch, 2004, and references therein), instead of the three known at the time of the discovery in Saccopastore. Nevertheless, the traditional attribution to the last interglacial Riss-Würm, although variously renamed (e.g., Late Pleistocene *pro parte*, Saccopastore Formation SKP, Melpignano Faunal Unit), was never questioned (e.g., Palombo et al., 2004; Funiciello et al., 2008; Kotsakis and Barisone, 2008; Petronio et al., 2011; Fabbri et al.,

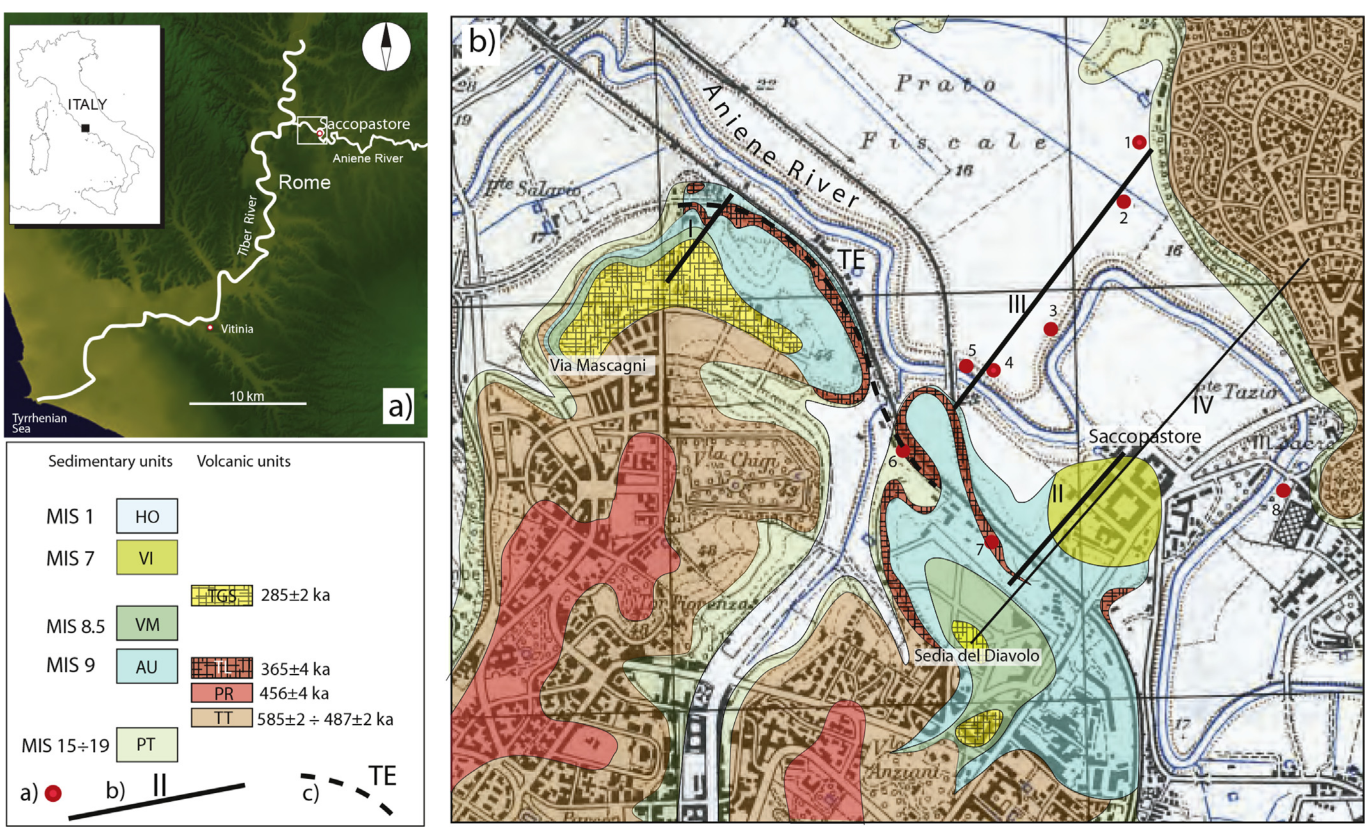


Fig. 1. Geologic map of the Aniene River valley north of Rome, drawn by integrating literature data (Verri, 1915; Servizio Geologico d'Italia, 1967; Marra and Rosa, 1995) with new field data collected during construction of the Tangenziale Est road, and borehole data. Sedimentary deposits are correlated to marine isotopic stages (MIS) following criteria and nomenclature established in Karner and Marra, 1998. HO: Recent alluvial deposits (Upper Pleistocene–Holocene); VI: Vitinia Formation (Conato et al., 1980); VM: Via Mascagni succession (Marra et al., 2014a); AU: Aurelia Formation (Conato et al., 1980); PT: Paleo-Tiber units 2, 3, 4 (Marra and Florindo, 2014); TGS: Tufo Giallo di Sacrofano (Karner et al., 2001b; Sottili et al., 2010); TL: Tufo Lionato (Marra et al., 2009); PR: Pozzolane Rosse (Marra et al., 2009); TT: pyroclastic products of the Early Tuscolano artemisio phase (Marra et al., 2009) and Monti Sabatini volcanic district (Marra et al., 2014b). a) borehole location; b) I–II–III trace of composite cross-section shown in Fig. 2b, IV trace of cross-section by Segre (1948) shown in Fig. 2d; c) Tangenziale Est road cut.

2014).

In the present work we have reviewed the published data on Saccopastore and we re-interpret the stratigraphic setting of this site in the light of the newly obtained geochronologic, tectonic, morphostratigraphic and paleogeographic constraints for this region, evidencing correlation of the fluvial-lacustrine deposits hosting the human skulls with the local Vitina Formation (Conato et al., 1980), deposited during MIS 7 following glacial termination III, in the time span 270–230 ka (Karner and Marra, 1998).

Based on this correlation we discuss the paleontological and palaethnological record recovered in Saccopastore, comparing it with that recovered within the deposits of the Vitinia Formation at other locations in Rome, and demonstrate its age compatibility with MIS 7. In contrast, attribution to MIS 5 is disfavored, based on a series of geomorphologic, paleogeographic, paleoclimatic, paleoethnological and paleontologic considerations.

2. The glacio-eustatically forced aggradational successions of the Rome area

Glacio-eustatic forcing of the sedimentary sequences deposited in the delta and within the coastal fluvial sections of the Paleo-Tiber River and its tributaries flowing through the city of Rome has been demonstrated by means of $^{40}Ar/^{39}Ar$ ages of pyroclastic layers intercalated within the sedimentary deposits, as well as by means of paleomagnetic constraints (Karner and Renne, 1998; Karner and Marra, 1998; Marra et al., 1998; Florindo et al., 2007; Marra and Florindo, 2014). The geochronological constraints allowed these authors to compare aggradation of the different successions deposited in the Paleo-Tiber delta in the last 900 ka with the $\delta^{18}O$ record, evidencing the strict link between sedimentation and sea-level changes in the area of Rome.

Typically an aggradational succession should consist of the stratigraphic record of each complete glacially forced sea-level oscillation in a coastal area, which is represented by a basal erosive surface, progressively excavated as a consequence of coastline regression and lowering of sea level during glacial periods, followed by a fining-upward sequence of clastic sediments, rapidly deposited during sea-level rise in response to deglaciation (Fig. 2a). Generally, the aggradational successions recognized in Rome (Karner and Marra, 1998) display a gravel and sand layer at the base of each section. This basal coarse-grained deposit reaches up to 10 m in thickness within the main Tiber course and in the coastal plain, while it is only 2–3 m thick in the tributary courses, and is followed by a relatively thin sand horizon, which grades upward into a several meters thick package of silt and clay deposits that represents the largest portion of each aggradational succession.

The sedimentary features of these aggradational successions encompass fluvial to lacustrine and lagoon to coastal facies, as described in Conato et al. (1980) and references therein. A detailed facies analysis of the deposits cropping out in the coastal area of Rome is provided in several papers (e.g. Milli et al., 2008, and references therein) describing a suite of fourth order depositional sequences, whereas correlation of the deposits defined based on the sequence stratigraphic approach with the glacio-eustatically controlled aggradational successions of the Paleo-Tiber River can be found in Marra et al. (2014a). Based on the revised definition of stratigraphic sequence by Zecchin and Catuneanu (2013), all the recognized aggradational successions represent the innermost part of high-frequency sequences linked to glacio-eustasy. Radiocarbon (^{14}C) age constraints on the sedimentary record deposited within the valley and in the coastal plain of the modern Tiber River (Marra et al., 2008, 2013) have demonstrated that the deposition of gravel marked a unique time in the depositional history of the river, occurring during a ~7 kyr interval between the end of the Last Glacial Maximum (21–18 ka) and the onset of the last glacial termination (~14 ka). Continuous transportation of coarse material should occur during the entire phase marking the passage from the previous highstand to the following lowstand. However, this material cannot accumulate within the fluvial incision or within the coastal plain, as a consequence of the continued regression of the coastline following a lowering sea level, causing its removal and re-deposition seaward, while the base level of the sedimentary record is progressively deepened. Indeed, transportation by the Tiber River of gravel with grain diameter >5 cm required exceptional hydrologic conditions that have not been repeated during the Holocene. Such conditions typically exist only during glacial terminations due to the combination of several factors such as the increased sediment supply to the Tiber drainage basin, caused by rapid melting of Apennine glaciers releasing a large amount of clastic material, combined with the low sea level causing a steeper gradient, and hence greater river transport capacity. These conditions would have worked in concert during the 21–14 ka interval, until the accelerated sea-level rise during the glacial termination led to a rapid drop in capacity of transport by the Tiber and, consequently, to the start of sandy clay deposition and filling of the fluvial incisions.

The basal gravel layer is much less thick in the aggradational sections of tributary rivers, including those of the Aniene River in the Saccopastore area. This is a consequence of the smaller hydrographic basin drained by the Aniene River with respect to the Tiber, resulting in a lesser capacity of sediment transport and in a smaller source area for the gravel, which derives from erosion of the carbonatic rocks of the Apennine mountain range. Indeed, the basal gravel layer here has a major component of reworked volcanic rocks, largely outcropping in the area of Rome, with respect to a larger carbonate component within the tributary valleys of the Tiber.

The stratigraphic study of the older sedimentary deposits integrated by $^{40}Ar/^{39}Ar$ dating of interbedded tephras allowed Marra et al. (2008) to extend this sedimentary model to the previous glacial cycles, spanning MIS 22/21 through MIS 6/5. The aggradational successions in the area of Rome are therefore a discontinuous stratigraphic record, constituted by a succession of ten major aggradational units deposited during MIS 21 thorough MIS 1, plus several minor successions corresponding with the more pronounced sub-stages, representing the physical remnant of the same number of glacio-eustatic sea-level cycles in this time span. The correspondent sedimentary deposits have been designated by formal formation names, newly conceived or based upon previous literature (Karner and Marra, 1998, and references therein).

It is noteworthy that the majority of the Middle Pleistocene fossil vertebrate assemblages of Italy have been sampled near Rome in the alluvial deposits of the Paleo-Tiber River and its tributaries (Caloi et al., 1998; Di Stefano et al., 1998; Milli et al., 2004; Petronio et al., 2011), exposed by continuous uplift affecting this area. Regional uplift and resultant river terraces in response to the combined effect of erosional/sedimentary isostasy and climatic changes are a common occurrence in all parts of the world (e.g. Bridgland and Westaway, 2008a; 2008b; Westaway et al., 2009). In the area of Rome, it has been hypothesized that a major tectonic component, linked with back-arc geodynamic processes, superposed the regional pattern and that the interplay between tectonic uplift and glacio-eustasy lead to the formation of the suite of aggradational successions and related terraces (Karner and Marra, 1998; Karner et al., 2001a), as suggested by the correspondence between the uplifted area and the “Roman Magmatic Province” (Peccerillo, 2005). Discussing the mechanism of formation of the terraces is beyond the scopes of the present work, and it does not

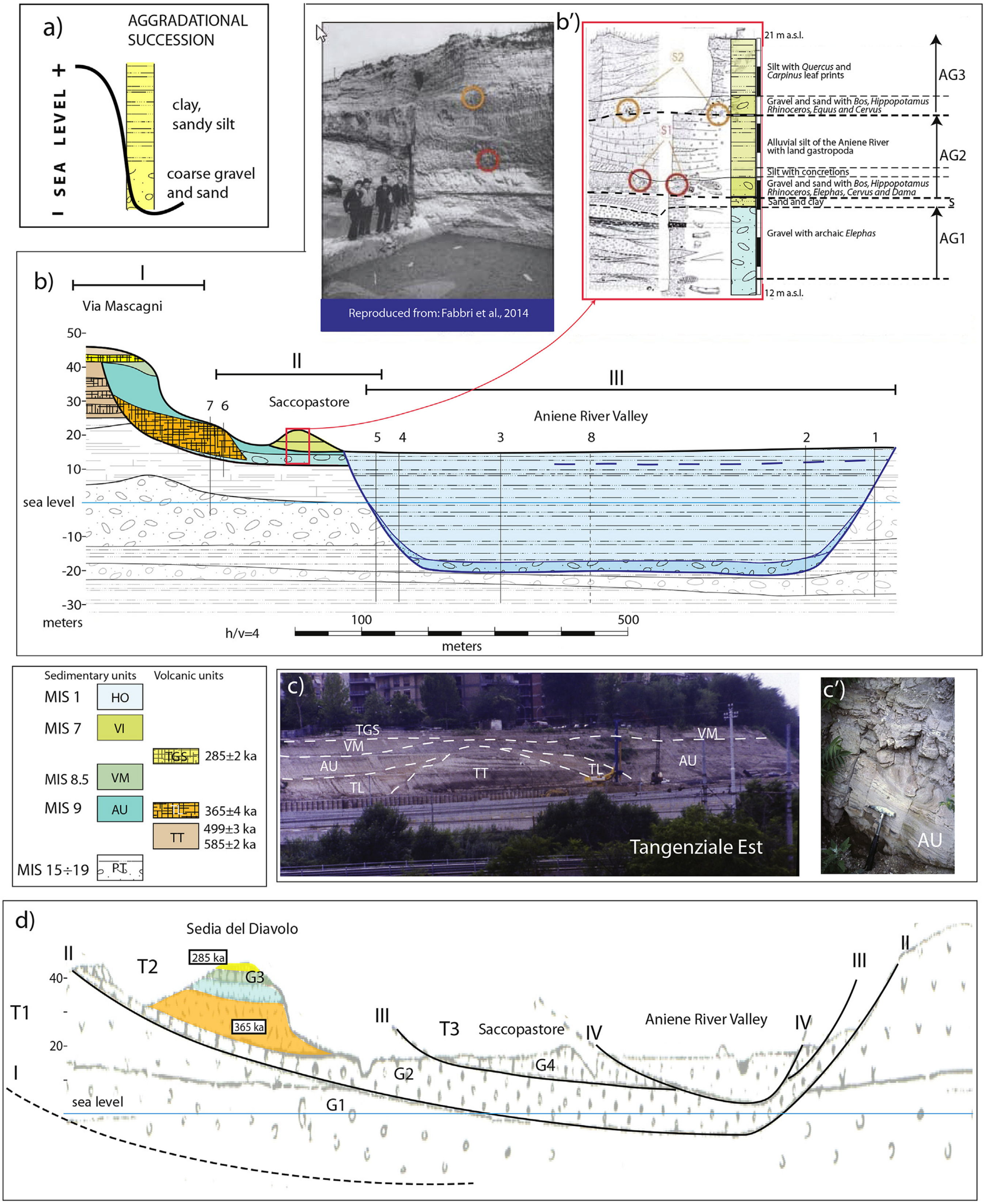
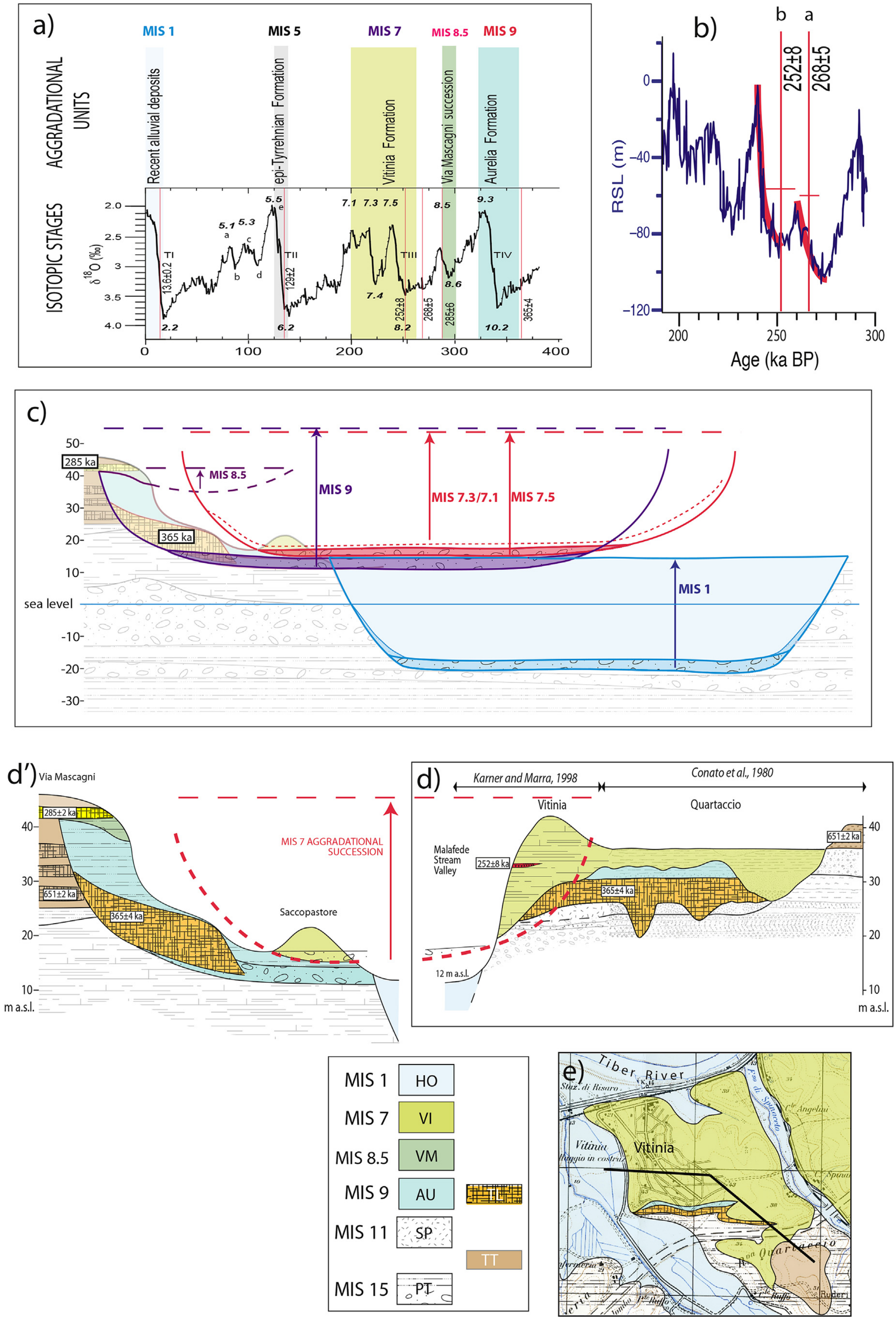


Fig. 2. a) Scheme of aggradational succession showing relationship between deposition of the fining-upward sedimentary record and sea-level rise (after Karner and Marra, 1998; Marra et al., 2008). b) Composite cross-section across the Aniene River Valley reconstructed with observed field and borehole data (see Fig. 1 for location); legend for stratigraphic units as in Fig. 1. The detail of the stratigraphy and a picture of the outcropping deposits at Saccopastore (red box) are shown. c) Photograph of the hill face cut by works for construction of Tangenziale East road (see Fig. 1 for location); in c' a detail of the lacustrine succession of Aurelia Formation is shown. d) Original interpretation of the stratigraphic setting along a cross-section parallel to that reconstructed here performed by Segre (1948b) (see Fig. 1 for location). The similar stratigraphy of Sedia del Diavolo and Via Mascagni hills is highlighted by reporting color for the sedimentary and volocanic units, and $^{40}Ar/^{39}Ar$ ages for the latter. See text for stratigraphic labels and comments (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).


a)
MIS 1
MIS 5
MIS 7
MIS 8.5
MIS 9
AGGRADATIONAL UNITS
Recent alluvial deposits
epi-Tyrrehnian Formation
Vitinia Formation
Via Mascagni succession
Aurelia Formation
ISOTOPIC STAGES
δ18O (‰)
13.6±0.2
129±2
252±8
268±5
285±6
365±4
TI
TII
TIII
TIV
b)
b
a
252±8
268±5
RSL (m)
Age (ka BP)
c)
285 ka
365 ka
MIS 8.5
MIS 9
MIS 7.3/7.1
MIS 7.5
MIS 1
sea level
d')
Via Mascagni
285±2 ka
651±2 ka
365±4 ka
MIS 7 AGGRADATIONAL SUCCESSION
Saccopastore
m a.s.l.
d)
Karner and Marra, 1998
Conato et al., 1980
Vitinia
Quartaccio
Malafede Stream Valley
252±8 ka
365±4 ka
651±2 ka
12 m a.s.l.
m a.s.l.
MIS 1
HO
MIS 7
VI
MIS 8.5
VM
MIS 9
AU
TL
MIS 11
SP
TT
MIS 15
PT
e)
Tiber River
Vitinia

affect the chrono-biostratigraphic and climatic inferences made here, therefore we remand to the above-mentioned studies for an in depth discussion and global framing of this topic.

According to the hypothesized tectonic influence, two principal pulses of uplift around 800 and 600 ka, coincident with the start of the main eruptive phases at the Monti Sabatini and Colli Albani volcanic districts, and a later uplift of ca. 40 m since 200 ka have been recognized this area (Karner et al., 2001a). As a consequence of this later phase of uplift, the terraced marine deposits of MIS 7 and MIS 5 presently occur along the Tyrrhenian Sea coast of Latium at ca. 40 and ca. 25 m a.s.l., respectively (Hearty and Dai Pra, 1986; Bordoni and Valensise, 1998; Karner et al., 2001a; Ferranti et al., 2006). The correspondent alluvial plains of the valleys filled by sediments during these two glacio-eustatic cycles display similar elevation gain of 40 and 25 m, respectively, with respect to those of the present-day hydrographic network.

3. The Saccopastore site

In this paragraph, for historical reasons, we report the nomenclature of the Authors for the fossil remains, while we provide their updated nomenclature in the section of Paleontological considerations.

Fortuitous discovery of a human skull (Saccopastore 1, S1 in Fig. 2b), together with mammal fossil remains exposed by quarry cuts for gravel exploitation along the Aniene River Valley in Saccopastore, was firstly reported by Sergi (1929). In the year 1935, a second skull (Saccopasore 2, S2 in Fig. 2b) was found at this same locality, along with lithic industry and vertebrate fossil remains (Breuil and Blanc, 1935a). The skulls occurred within two gravel layers at the base of a fining-upward succession of fluvial-lacustrine deposits (AG2 and AG3, Fig. 2b), characterized by fluvial gravel and cross-laminated sand, followed by lacustrine silt. The two skulls, a female (1) and a male (2), were originally classified as *H. neanderthalensis*, “Neandertal type” (Sergi, 1929, 1930, 1931, 1935) or “Paleàntropo” (Sergi, 1941, 1948). Successive studies have remarked on the “archaic” Neanderthal features of the skulls (Bruner and Manzi, 2006, and references therein); in particular, Piperno and Segre (1984) had already pointed out the strong affinity of Saccopastore 2 with the European Middle Pleistocene palaeoanthropos.

Sergi (1929) and subsequently De Angelis D'Ossat (1930) attributed the sedimentary record of Saccopastore to the Riss-Würm interglacial based on the presence of “warm” fauna (*Elephas antiquus*, *Hippopotamus major*, *Rhinoceros Mercki*, *Cervus elaphus* and *Bos primigenius*), similar to those from other sedimentary successions cropping out in that area (Sedia del Diavolo, Prati Fiscali, Cava della Bonifica), thought to be coeval. Subsequently, Köppel (1935) and Blanc (1935) recognized a lower terrace (Saccopastore) with respect to an upper (oldest) terrace (e.g., Sedia del Diavolo). A detailed stratigraphic study of the site was undertaken by the Istituto Italiano di Paleontologia Umana and Istituto di Antropologia of Rome University after the discovery of the second skull and the associated lithic industry (Breuil and Blanc, 1935a, 1935b, 1936). Results of this study confirmed the interpretation of the gravel layers in Saccopastore as the lowest of a series of fluvial terraces within the Aniene Valley, which necessarily correlated with the lowest marine terrace along the Latium coast, attributed to the Tyrrhenian, and thus to the last Riss-Würm interglacial, based on the presence of the warm exotic mollusc *Strombus bubonius*, as opposed to the higher terraces which correlated with the older interglacial stages (Blanc, 1939a, 1939b, 1942, 1946, 1948). Finally, Segre (1948a, 1948b) performed a reconstruction of the morpho-stratigraphic setting of the area (Fig. 2 d) in which he distinguished an “high” terrace (>40 m a.s.l., T1 in Fig. 2d) attributed to the Günz-Mindel, an “intermediate” terrace (30–40 m a.s.l., Sedia del Diavolo, T2 in Fig. 2d) attributed to the Mindel-Riss and the Riss, and a “lower” terrace (20–25 m a.s.l., Saccopastore, T3 in Fig. 2d) attributed to the Riss-Würm. An absolute age of 130 ka for the Saccopastore deposits was estimated (Blanc, 1939b) based on Milankovitch's glacial timescale (1920). Notably, a duration as long as 60 kyr was assigned to the Riss-Würm interglacial in those years (Malatesta, 1985; with references and discussion therein), which included at least the terminal part of what is presently designated as MIS 7 (Fig. 3a); however, the young age for the Saccopastore deposits was inferred based on their low elevation, the presence of warm fauna (De Angelis D'Ossat, 1930; Sergi, 1930, 1931, 1948) including relatively “modern” species (i.e., *Equus hydruntinus*; Blanc GA, 1936; Blanc, 1942, 1946, 1948), and of Mousterian lithic industry (Blanc, 1948). A presumably complete list of the faunal remains recovered through the years in Saccopastore was compiled by Sergi (1948) and by Segre (1948a, 1948b), and repeated subsequently (e.g., Segre, 1983a, 1983b; Piperno and Segre, 1984).

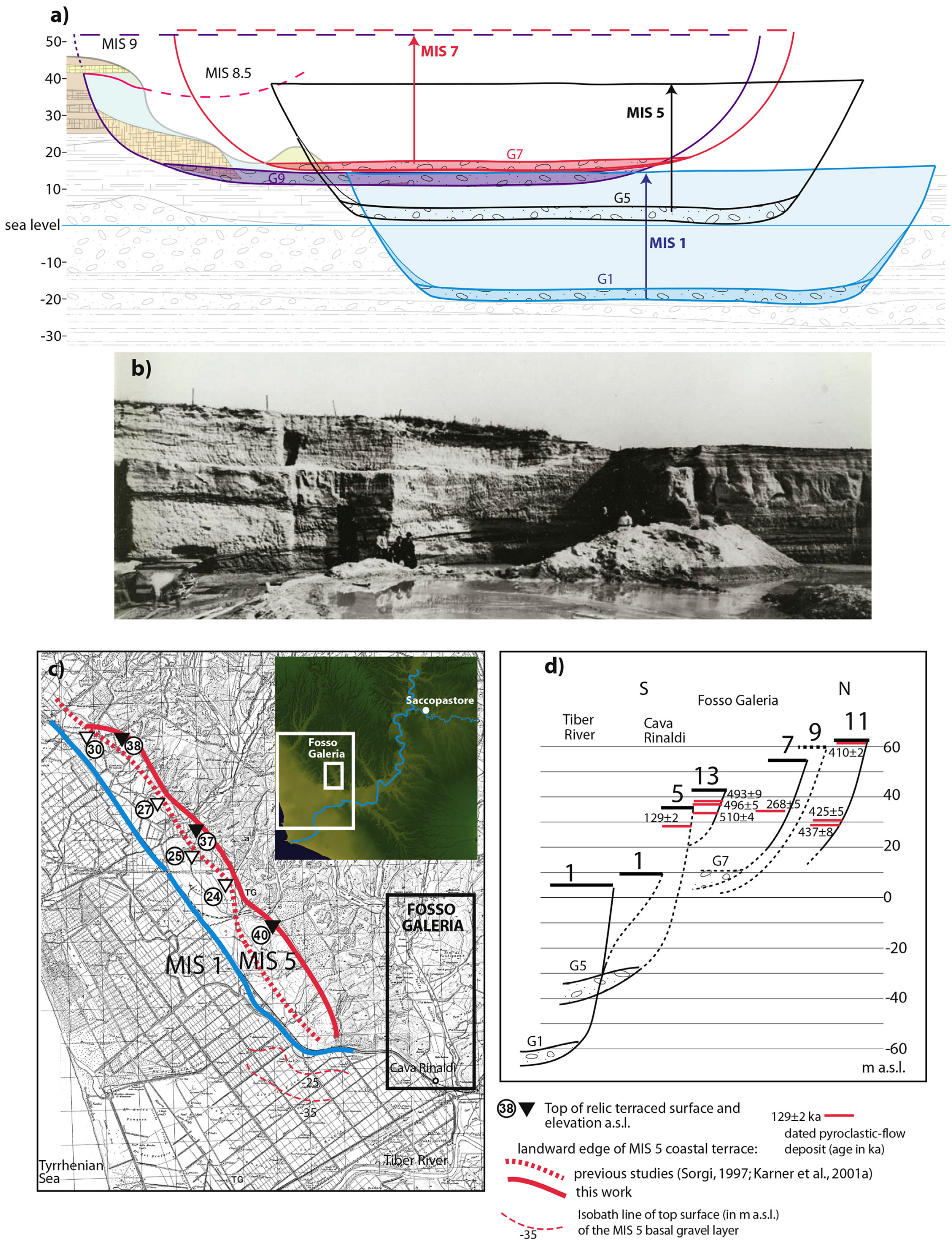
The faunal assemblage recovered within the basal gravel layer of the upper succession AG3 comprises: a fragmentary skull of *B. primigenius* (at the base of the gravel layer hosting also Saccopastore 2), as well as *H. major*, *Dicerorhinus mercki*, *Equus caballus*, *E. hydruntinus* and *C. elaphus* (see Sergi, 1948; Segre, 1948a, 1948b), along with 11 flint artefacts attributed to a Mousterian lithic industry (Blanc, 1939a, 1942,1946, 1948). Leaf prints of *Corylus avellana, Quercus, Populus* and *Carpinus* vel *Ostrya* (see Tongiorgi, 1939) occurred in the overlying suite of clayey deposits in the AG3 succession.

Within the lower gravel layer of the AG2 succession, *E. antiquus*, *D. mercki*, *H. major*, *B. primigenius*, *C. elaphus* and *Dama dama* have been reported (Sergi, 1948; Segre, 1948a, 1948b). The overlying silty deposit yielded several dwarf forms of land gastropoda (Kennard, in Breuil and Blanc, 1936) providing paleoclimatic and environmental information but no biochronologic constraint.

Finally, a skull of “archaic” *E. antiquus* (see Breuil and Blanc, 1936; Blanc, 1948; Sergi, 1948; Segre, 1948a, 1948b) was recovered within the gravel layer of the earliest aggradational succession AG1, along with *D. mercki* (see Sergi, 1948; Segre, 1948b). Also from the sandy–clayey layer (S in Fig. 2b) above the lowest gravel layer, Segre (1948a, 1948b) reported *E. antiquus*, *D. mercki*, *H. major*, *B. primigenius* and *Dama dama*.

Remarkably, the above-mentioned faunal assemblages, as well as the scanty plant taxa described, did not provide an exclusive

Fig. 3. a) Correlation between the Oxygen isotope record (from Lisiecki and Raymo, 2005) and the aggradational successions of the Paleo-Tiber River basin deposited in the last 400 kyr. Vertical red lines are the age constraints derived by the $^{40}Ar/^{39}Ar$ dating of the volcanic deposits intercalated within the aggradational units of the Paleo-Tiber River; each shaded box individuates a period of sea-level rise that accounts for the deposition of the sedimentary successions in the coastal area of Rome. b) Curve of global relative sea level (RSL) in the time span 300–200 ka (Grant et al., 2014), showing the occurrence of an early peak at around 270 ka, preceding that associated to Glacial Termination III (T III) around 250 ka; Ages of the two volcanic layers (vertical red lines, a and b) constraining aggradation of as many sedimentary successions of the Vitinia Formation (Pantano di Grano and Vitinia locations, Karner and Marra, 1998), and matching the two sea-level oscillations are shown. c) Reconstruction of geometry and elevation of the sedimentary bodies of aggradational successions deposited during sea-level rises of MIS 9, MIS 8.5 and MIS 7, based on geologic remnants of the original deposits, and comparison with that of the last aggradational succession of MIS 1, based on borehole data (see Fig. 2). An elevation gain of ca. 40 m is observed between the reconstructed alluvial plains of the deposits correlated with MIS 9 and MIS 7 with respect to that of MIS 1, consistent with the occurrence of ca. 40 m of regional uplift since 200 ka (Karner et al., 2001a). d) Stratigraphy of the type-section of the Vitinia Formation and geochronologic constraints derived by $^{40}Ar/^{39}Ar$ ages of intercalated volcanic deposits, and comparison with the equivalent section in Saccopastore (d'). e) Geologic map of the Vitinia area showing location of the cross-section d; legend of stratigraphic units as in Fig. 1, with SP: San Paolo Formation (Karner and Marra, 1998) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).


a)
50-
40-
30-
20-
10-
sea level
-10-
-20-
-30-
MIS 9
MIS 8.5
MIS 7
MIS 5
MIS 1
G7
G9
G5
G1
b)
c)
Saccopastore
Fosso
Galeria
30
38
27
37
25
24
40
TG
MIS 1
MIS 5
FOSSO
GALERIA
Cava Rinaldi
-25
-35
Tyrrhenian
Sea
Tiber River
d)
S
N
Fosso Galeria
Tiber
River
Cava
Rinaldi
1
1
5
13
7
9
11
129±2
493±9
496±5
510±4
268±5
410±2
425±5
437±8
G7
G5
G1
60
40
20
0
-20
-40
-60
m a.s.l.
Top of relic terraced surface and
elevation a.s.l.
129±2 ka
dated pyroclastic-flow
deposit (age in ka)
landward edge of MIS 5 coastal terrace:
previous studies (Sorgi, 1997; Karner et al., 2001a)
this work
Isobath line of top surface (in m a.s.l.)
of the MIS 5 basal gravel layer
-35

attribution to the Late Pleistocene, and the Saccopastore deposits were attributed to the Riss-Würm interglacial based on the assumed "warm" character of the recovered fauna and on the geomorphologic criterion that recognized it as the lowest terrace above the Aniene floodplain (Blanc, 1958, and references therein).

4. Stratigraphic setting

The geologic setting of the sector of the Aniene River Valley north of Rome in which the Saccopastore site is located has been reconstructed (Fig. 1b) integrating previous studies (Marra and Rosa, 1995) and cartography (Verri, 1915; Ventriglia, 1971) with field observations performed in the early '90s during the excavations for the construction of the "Tangenziale Est" road (Fig. 2c), and with borehole data from drillings performed for the subway line "Metro B" and other civil engineering prospections in the last decades. Remarkably, these new data shed light on the stratigraphy of this area after the almost complete obliteration of the original landscape (and associated outcrops) due to intense urbanization since the '60s. As a consequence, all the studies successive to the finding of the two skulls in Saccopastore in 1929 and 1935 relied on a referred description of the geology provided by the works of Blanc and Segre up to the year 1948, and on the chronostratigraphy developed in those previous years.

The new observations have allowed us to reconstruct the composite cross-section shown in Fig. 2b, merging stratigraphic information from three adjacent sectors of the left hydrographic bank of the Aniene (tracks I, II, III in Fig. 1b), obtained by respecting the horizontal scale for each one of them. The profile is compared to the interpretative geologic section drawn by Segre (1948b), showing previous interpretation of the ancient terraces and the related deposits of the Aniene Valley in the Saccopastore area (Fig. 2d).

The sedimentary fill of the modern Aniene Valley, as reconstructed in the present study by borehole stratigraphy, is a lenticular body with a 3–4 m thick layer of coarse gravel at the base, overlain by a ca. 30 m thick package of sandy clayey deposits (Fig. 2b). As demonstrated by Marra et al. (2013), the aggradational successions filling the valley incision of the Tiber and its tributaries were deposited during the post-glacial sea-level rise after 18 ka. When compared to the geologic reconstruction performed by Segre (1948b) and reported in Piperno and Segre (1984), it is clear that these authors largely underestimated the depth of the incision excavated during the last lowstand of MIS 2 (surface IV in Fig. 2d). The profile by Segre (1948b) overestimates the depth reached by the erosional surface (II in Fig. 2d) overlain by the deposits of the second terrace (T2 in Fig. 2d) attributed to the Mindel-Riss interglacial (ca. 470–350 ka), which includes the Tufo Lionato pyroclastic-flow deposit, dated at 365 ± 4 ka (Marra et al., 2009). The basal gravel layer of T2 (G2 in Fig. 2d) underlies the Tufo Lionato, as well as the deposits of Saccopastore (G4 in Fig. 2d) attributed by Segre (1948b) to the subsequent Riss-Würm interstadial (130–80 ka). According to borehole data and field evidence reported in the cross-section of Fig. 2b, this gravel is the basal coarse-grained horizon of the aggradational succession correlated with MIS 9 (Aurelia Formation, Conato et al., 1980), deposited during the late regressive phase of MIS 10 and at the onset of glacial termination IV, in a time-span ranging 365–335 ka (Fig. 3a; Karner and Marra, 1998). An up to 20 m thick package of well bedded, white lacustrine muds, including diatomic layers and sandy horizons (Fig. 2c), overlies the basal gravel in Saccopastore, as well as the Tufo Lionato cropping out along the southern bank of the Aniene River Valley (Figs. 1b and 2b). A minor aggradational succession, characterized by a 1–2 m thick layer of fine-grained gravel followed by more lacustrine muds, has been observed in Via Mascagni above an erosional surface cutting the top of the fluvial-lacustrine succession of the Aurelia Formation (Marra and Rosa, 1995). This second aggradational succession is overlain by the pyroclastic-flow deposit of Tufo Giallo di Sacrofano, dated at 285 ka (Karner et al., 2001b) (Fig. 2b–c). This same pumiceous pyroclastic deposit is described by Blanc (1948) to occur also above the gravelly and clayey deposits (G3 in Fig. 2d) occurring at Sedia del Diavolo, and at another section (Monte delle Gioie), in which faunal assemblages referred to the Vitinia FU and correlated with MIS 7 have been reported (Caloi and Palombo, 1994c; Caloi et al., 1998; Di Stefano et al., 1998; Petronio et al., 2011). However, based on the age determination performed by Karner et al. (2001b) on the pyroclastic layer, yielding 285 ± 2 ka, Marra et al. (2014a) have ruled out correlation of the deposit with MIS 7 (spanning 250–200 ka), and have reinterpreted the minor succession of Via Mascagni, Sedia del Diavolo and Monte delle Gioie as a sub-sequence, overlaying eroded deposits of MIS 9, and deposited during the minor sea-level oscillation associated with isotopic substage 8.5. Indeed, the geochronologic constraints provided by Tufo Lionato and Tufo Giallo di Sacrofano on the two aggradational successions cropping out in this sector of the Aniene Valley demonstrate their strict correlation with MIS 9 (Aurelia Formation) and MIS 8.5 (Via Mascagni succession) (Fig. 3a).

When the new chronostratigraphic setting illustrated in cross-section of Fig. 2b is depicted, it becomes apparent that the deposits erosionally overlying those of the Aurelia Formation at Saccoppastore may be correlated better either with those of MIS 8.5 or with the subsequent MIS 7, as reported in our interpretation, rather than with those of MIS 5. Indeed, based on comparison with the deposits of the Vitinia Formation (Conato et al., 1980) occurring at the geochronologically constrained (Karner and Marra, 1998) type section in southern Rome (Fig. 3c; see Fig. 1a for location), in the next paragraph we show that the deposits of Saccopastore match well the paleontologic, paleoethnologic, sedimentologic, paleogeografic, geometric and altimetric characters of the MIS 7 aggradational succession, whereas their correlation with MIS 5 should be regarded as unlikely, for a series of reasons discussed in the following paragraphs.

5. Correlations with the geochronologically constrained aggradational successions

Fig. 3c shows a reconstruction of the geometry of the aggradational succession filling the alluvial valley of the Aniene River

Fig. 4. a) Inferred geometry and elevation of the sedimentary body of MIS 5 aggradational succession, based on regional data about tectonic uplift in the last 200 ka. Consistent with elevation gain between the marine terrace of MIS 5 and the Present-Day alluvial plain along the coast of Rome (see inset c), top and base of the sedimentary filling of the Aniene Valley deposited after the penultimate glacial termination are expected to occur circa 20 m above their equivalent ones of MIS 1, and circa 20 m below those of MIS 7 and MIS 9. In particular, the expected elevation for the basal gavel layer of MIS 5 aggradational succession is around the Present-day sea-level: i.e., circa 20 m lower than the Saccopastore gravel beds. b) Photograph taken in the 1930s, showing the sedimentary features of the Saccopastore deposits: the occurrence of a well-graded, fining-upward succession, with a striking planar attitude over a large area is evidenced, consistent with the basal portion of an aggradational succession deposited during a phase of sea-level rise at the onset of the glacial termination. c) Relic terraced surfaces correlated to MIS 5 (Hearty and Dai Pra, 1986; Bordoni and Valensise, 1998; Ferranti et al., 2006) and to MIS 7 (Sorgi, 1994) along the coast of Rome; dashed portion of the inner edge indicate sector where the surfaces are eroded. d) Suite of alluvial terraces reconstructed in the Fosso Galeria tributary stream valley (Karner et al., 2001a), displaying elevation gain consistent with that affecting the related marine terrace of MIS 7 and MIS 5 with respect to MIS 1. $^{40}Ar/^{39}Ar$ ages of pyroclastic layers from (Karner and Renne, 1998; re-calculated in Marra et al., 2014b and re-calibrated here according to the age of 28.02 Ma for the Fish Canyon Tuff sanidine (Renne et al., 1998). Age relative to the MIS 5 deposit in Cava Rinaldi performed for the present work (Table 1).

during the sea-level rise of MIS 9, based on available borehole and outcrop data. Consistent with the similar amplitude of the isotopic record of MIS 9 with respect to MIS 1, the reconstructed alluvial body of the Aurelia Formation (violet bounding lines in Fig. 3c) also displays similar thickness to that of MIS 1, both in the basal gravel layer as well as in the overlying clayey section, whose top, based on outcrop data, reaches 48 m a.s.l., at least. Extending inland the differences in elevation observed along or close to the present-day coast among the terraced surfaces correlated to MIS 5 and MIS 7 and that of MIS 1 would be affected by a bias due to the progressively changing hydrographic gradient, occurring in response to the tectonic uplift and related regression of the coastline. However, an alluvial plain occurring around 55 m a.s.l. is consistent with an expected elevation gain of circa 40 m with respect to that of the present-day Aniene River at around 15 m a.s.l. (blue bounding lines in Fig. 3c), as provided by an approximately equivalent tectonic uplift since 200 ka.

A smaller amplitude is inferred for the aggradational succession correlated to MIS 8.5 (purple bounding lines in Fig. 3c), according to the occurrence of the basal gravel layer of the Via Mascagni succession at higher elevation with respect to its analogue layer of MIS 9, as observed at Sedia del Diavolo (Blanc, 1948) and in the Via Mascagni (Marra and Rosa, 1995) outcrops, and consistent with the smaller isotopic signal of this sub-stage (Fig. 3a). Based on these features, we conclude that the gravel layers of Saccopastore, occurring between 15 and 20 m a.s.l., may not be correlated with the Via Mascagni succession and MIS 8.5.

In contrast, gravel of the lowest aggradational succession (AG2, Fig. 2b) above that of the Aurelia Formation (AG1, Fig. 2b) in Saccopastore matches the expected elevation for the basal coarse-grained deposit of MIS 7 (red bounding lines in Fig. 3c). Indeed, isotopic stage 7 has similar amplitude with respect to MIS 9 and, consequently, similar thickness and a similar elevation are expected for the sedimentary bodies corresponding to aggradational successions of the Aurelia and the Vitinia Formations (Fig. 3a). This assumption is verified by stratigraphic and geometric features of the sedimentary deposit of the Vitinia Formation at its type-locality (Fig. 3d). The cross-section of Fig. 3d merges the stratigraphic scheme reported by Conato et al. (1980), corresponding to the locality of Quartaccio, with the adjacent one studied and sampled in Vitinia by Karner and Marra (1998), where age of a pyroclastic layer dated at 252 ± 8 ka (Karner and Renne, 1998) demonstrates correlation with MIS 7and shows that the deposits of MIS 7 reach up to 43 m a.s.l. (see also Fig. 3e) and have a base level lower than 20 m a.s.l.. When these geomorphologic features, combined with stratigraphic relationships with respect to the deposits of the Aurelia Formation and of Tufo Lionato at the Vitinia-Quartaccio section, are compared to those observed in the Aniene River valley (Fig. 3d–d'), it becomes apparent that the deposit of Saccopastore should be correlated with the basal portion of the aggradational succession of MIS 7 (Vitinia Formation *sensu* Karner and Marra, 1998). Fig. 3c shows that the reconstructed aggradational succession of MIS 7 is represented by a sedimentary body of slightly smaller size with respect to that of MIS 9, but occurring at the same elevation: therefore, the deposit of the Vitinia Formation is embedded within that of the Aurelia Formation, consistent with an absence of vertical uplift during the time span 300–200 ka (Karner et al., 2001a). Moreover, the occurrence of two superimposed aggradational successions correlated with MIS 7 at Saccopastore (AG2 and AG3, Fig. 2b) is consistent with the double culmination of this isotopic stage. MIS 7 is indeed characterized by two consecutive, sharp peaks (MIS 7.5 and MIS 7.1 Fig. 3a), accounting for as many repeated sea-level oscillations, with which a double stratigraphic record is expected to be associated. However, based on study by Dutton et al. (2009), and according also to the sea-level curve by Grant et al. (2014), the main sea-level oscillations were associated with MIS 7.5 and MIS 7.1, with a maximum sea-level reached during the last isotopic peak (Fig. 3b). Finally, the presence of a sandy–clay horizon that according to Sergi (1935, 1948) and Segre (1948a, 1948b) contains remains of *Dama dama*, that replaced *Dama clactoniana* since MIS 8.5 (Di Stefano and Petronio, 1997, 2002; Marra et al., 2014a), below the gravel of the AG2 succession (s in Fig. 2b), may be considered consistent with the long duration of aggradation of MIS 7, as testified by two age determinations of 268 ± 4 and 252 ± 8 ka from two different successions dated in Pantano di Grano and in Vitinia, respectively (Karner and Marra, 1998), and with the occurrence of an early peak of sea-level rise around 270 ka preceding Termination III (Grant et al., 2014). Remarkably, the two age constraints provided on the MIS 7 deposits in Rome match the two consecutive sea-level oscillations evidenced in this time span (Fig. 3b).

In contrast, a coarse-grained basal deposit of the aggradational succession deposited during MIS 5 (G5 in Fig. 4a) should be found at intermediate elevation with respect to those of MISs 7 and 9 (G7 and G9 in Fig. 4a) and that of MIS 1 (G1 in Fig. 4a), consistent with observations in the area around Fosso Galeria (Karner et al., 2001, Fig. 4c–d). Here, the alluvial terrace of MIS 5 recognized in Cava Rinaldi by the present study occurs about 37 m a.s.l., ca. 25 m above that of MIS 1 and ca. 20 m below that of MIS 7 (Fig. 4d). Consistently, the basal gravel layer of MIS 5 in the Tiber River coastal plain (G5 in Fig. 4d) occurs ca. 25 m above that of MIS 1 (G1 in Fig. 4d), whereas correlation with the fluvial deposit in Foso Galeria indicates a significantly higher elevation for the basal gravel of MIS 7 (G7 in Fig. 4d). Indeed, the gravel layer found in boreholes and attributed to MIS 5 (Marra et al., 2013) is well correlated with an alluvial terrace occurring 37 m a.s.l. in Cava Rinaldi at the end of the Grottaperfetta stream valley (Fig. 4d), which is geochronologically correlated to MIS 5 by means of a $^{40}Ar/^{39}Ar$ age determination of 129 ± 2 ka (Table 1) performed for the present work on a pyroclastic-flow deposit intercalated within the fluvial-lacustrine clay deposit cropping out at this location. When an elevation of ~37 m a.s.l. for the alluvial terrace of MIS 5 near the coast is compared with elevation of 20–21 m a.s.l. for the Saccopastore deposits, the interpretation of the latter as a coeval, more inland alluvial terrace has to be disregarded, evidently. The alluvial terrace of MIS 5 in this sector of the Aniene River valley must be higher than 37 m a.s.l., and should be placed 25 m above the present-day alluvial plain, at the least (Fig. 4a). Consistently, the gravel of MIS 5 aggradational succession must be placed below those of MIS 9 and MIS 7, and above that of MIS 1, with proportional elevation gains in comparison with those observed near the coast.

We also note that the identification of a marine terrace at 40 m a.s.l. correlated with MIS 7 on the coast of Rome (dashed red line in Fig. 4c; Sorgi, 1994; Karner et al., 2001a) should be revised based on the occurrence of the MIS 5 fluvial terrace 37 m a.s.l. at Cava Rinaldi (Fig. 4d). Indeed, in the Fosso Galeria Valley the fluvial terrace correlated with MIS 7 occurs 55 m a.s.l. (Karner et al., 2001a), therefore the coastal terrace is not expected at significant lower elevation, whereas a culmination as low as 40 m a.s.l. matches the datum for MIS 5 coastal terrace from Cava Rinaldi.

The lack of other fluvial terraces attributable to MIS 5 within the hydrographic networks of the Tiber and Aniene Rivers in the inland area of Rome suggests that the occurrence of a unique MIS 5 relic terrace in this area, represented by the deposit cropping out in Saccopastore, should be regarded as unlikely. In particular, all the geologic sections along the Aniene River Valley in Rome in which fossiliferous fluvial-lacustrine deposits have been documented (Monte delle Gioie, Sedia del Diavolo, Prati Fiscali; Casal de' Pazzi, Ponte Mammolo) are correlated with MIS 9 through MIS 7 (Marra et al., 2014a, and references therein). Indeed, the complete

Table 1
$^{40}Ar/^{39}Ar$ experimental data for sample NCR-2 collected in Cava Rinaldi. Age determination performed at the University of Wisconsin Rare Gas Geochronology Laboratory by single crystal total fusion on sanidine from a pyroclastic-flow sample. Sample preparation and analytical procedures follow those in Jicha et al. (2012).

Complete $^{40}Ar/^{39}Ar$ results

Laser – Single crystal fusion

Sample: NCR-2

Material: sanidine

File	J-value: 0.0018367 ± 0.0000024 (2σ)													K/Ca	Included in wtd. Mean
	^{40}Ar(cps)	±2σ_{40} (cps)	^{39}Ar(cps)	±2σ_{39} (cps)	^{37}Ar (cps)	±2σ_{37} (cps)	^{36}Ar (cps)	±2σ_{36} (cps)	$^{40}Ar^*/^{39}Ar_K$	±2σ	%^{40}Ar*	Age (ka)	±2σ (ka)		
NAC6749	33556.0	±31.1983	383272.2	±126.480	3437.21	±943.31	62.119	±2.739	0.039279	±0.002141	44.92	132.0	±7.2	48.0	✓
NAC6752	29980.1	±31.9717	479859.5	±174.927	3599.78	±996.22	37.187	±2.787	0.039340	±0.001741	63.05	132.2	±5.9	57.4	✓
NAC6755	73241.4	±52.5867	656651.4	±209.779	5999.64	±691.54	160.911	±3.923	0.038507	±0.001785	34.57	129.4	±6.0	47.1	✓
NAC6758	22575.7	±27.3867	280824.1	±99.486	3093.18	±839.64	39.754	±2.328	0.038405	±0.002485	47.84	129.1	±8.4	39.1	✓
NAC6761	11095.8	±22.1925	244744.5	±89.643	2910.00	±902.03	7.200	±2.271	0.036904	±0.002783	81.51	124.0	±9.4	36.2	✓
NAC6764	62391.1	±45.8372	587635.6	±180.152	4209.14	±849.19	133.955	±2.938	0.038089	±0.001498	35.92	128.0	±5.0	60.1	✓
NAC6767	176902.8	±78.4334	717174.3	±195.982	10211.90	±905.40	488.982	±4.290	0.043630	±0.001792	17.71	146.7	±6.0	30.2	
NAC6770	80998.6	±58.3526	1190833.2	±349.702	9850.45	±889.32	120.267	±2.814	0.037929	±0.000709	55.84	127.5	±2.4	52.1	✓
NAC6773	73634.8	±53.5187	717242.0	±221.872	6962.15	±763.78	152.351	±3.030	0.039420	±0.001265	38.45	132.5	±4.3	44.4	✓
NAC6776	93341.5	±57.7717	732341.6	±214.741	6855.48	±710.93	216.527	±3.505	0.039330	±0.001432	30.90	132.2	±4.8	46.0	✓

Atmospheric argon ratios

$^{40}Ar/^{36}Ar$	298.56	±0.31	Lee et al. (2006)
$^{38}Ar/^{36}Ar$	0.1885	±0.0003	Lee et al. (2006)

Interfering isotope production ratios

$(^{40}Ar/^{39}Ar)_K$	$(5.4 \pm 1.4) \times 10^{-4}$	Jicha and Brown (2014)
$(^{38}Ar/^{39}Ar)_K$	$(1.210 \pm 0.002) \times 10^{-2}$	Jicha and Brown (2014)
$(^{39}Ar/^{37}Ar)_{Ca}$	$(6.95 \pm 0.09) \times 10^{-4}$	Renne et al. (2013)
$(^{38}Ar/^{37}Ar)_{Ca}$	$(1.96 \pm 0.08) \times 10^{-5}$	Renne et al. (2013)
$(^{36}Ar/^{37}Ar)_{Ca}$	$(2.65 \pm 0.022) \times 10^{-4}$	Renne et al. (2013)

Decay constants

λ_{40Ar}	$(0.580 \pm 0.014) \times 10^{-10}$ a^{-1}	Min et al. (2000)
λ_{B^-}	$(4.884 \pm 0.099) \times 10^{-10}$ a^{-1}	Min et al. (2000)
^{39}Ar	$(2.58 \pm 0.03) \times 10^{-3}$ a^{-1}	
^{37}Ar	$(8.23 \pm 0.042) \times 10^{-4}$ h^{-1}	
^{36}Cl	$(2.303 \pm 0.046) \times 10^{-6}$ a^{-1}	

Values have been corrected for instrument background, source mass bias, detector efficiency, and decay of 37Ar and 39Ar.
All dates in this table are relative to 1.186 Ma for the Alder Creek sanidine standard.

erosion of the deposit of the penultimate glacio-eustatic cycle during the regressive phase associated with the Last Glacial has a reliable morpho-structural explanation. The occurrence of a first pulse of uplift of ca. 20 m between MIS 7 and MIS 5 caused a paleogeographic change which had a significant geomorphologic implication: the fluvial valleys excavated during the sea-level lowstand of MIS 6 where characterized by steeper flanks with respect to those incised during the previous, tectonically stable phase, and the alluvial plains remained confined within ~20 m height flanks at the end of the aggradational phase of MIS 5 (Fig. 5b). This "canyon-like" morphology, with river beds confined within the steep valley flanks, unlike previous erosional cycles during which the water courses were free to shift laterally with only partial erosion of the sedimentary deposits of previous aggradational phases (Fig. 5a), caused the erosional phase of MIS 2 to cut deep through the deposits of MIS 5, likely preventing their preservation as relic terraces throughout the inland hydrographic network of the Tiber and Aniene Rivers (Fig. 5c).

Although the hypothesis that the two fining upward successions of Saccopastore may represent a coarse debris fan deposit onlapping the bank of the MIS 5 Aniene River Valley cannot be excluded, geometric and sedimentologic features of the deposits do not support it. Indeed, such an onlap would be possible in correspondence of the gentle slope of a tributary valley, a feature missing in this portion of the Aniene River Valley (see Fig. 1b), characterized by a relatively steep southern bank (see cross-section in Fig. 2b), over which only colluvial deposits would be expected to occur. However, the sedimentary features of the Saccopastore deposits are not those of colluvium, characterized by massive, unsorted texture, but are well-graded, fining-upward deposits, with a striking planar attitude over a large area (Fig. 4b), consistent with the basal portion of an aggradational succession deposited during a phase of sea-level rise at the onset of the glacial termination: a fact excluding correlability with MIS 5. Indeed, the major basis for correlation with the last interglacial was the erroneous identification of the Saccopastore deposit with a "terrace", which is a morphologic evidence of an alluvial plain and therefore of deposition during a sea-level highstand. In contrast, the Saccopastore gravel layers represent the basal coarse deposit of two aggradational successions deposited at the end of a sea-level lowstand, during the glacial termination.

6. Paleoclimatic considerations

The occurrence of several dwarf forms of land gastropoda species of cool continental climate (*Zenobiella incarnata, Vitrea diaphana, Candidula conspurcata, Candidula profuga, Theba cartusiana* var. *complanata, Chrondula tridens*; see Kennard, in Breuil and Blanc, 1936; Blanc, 1948) within the silty deposits of the lower AG2 succession of Saccopastore induced several authors to suggest that deposition of the two fining-upward successions matched climatic oscillations correlated with the MIS 5 interstadial sub-stages (e.g., Caloi and Palombo, 1986, 1994a, 1994b; Caloi et al., 1989; Manzi

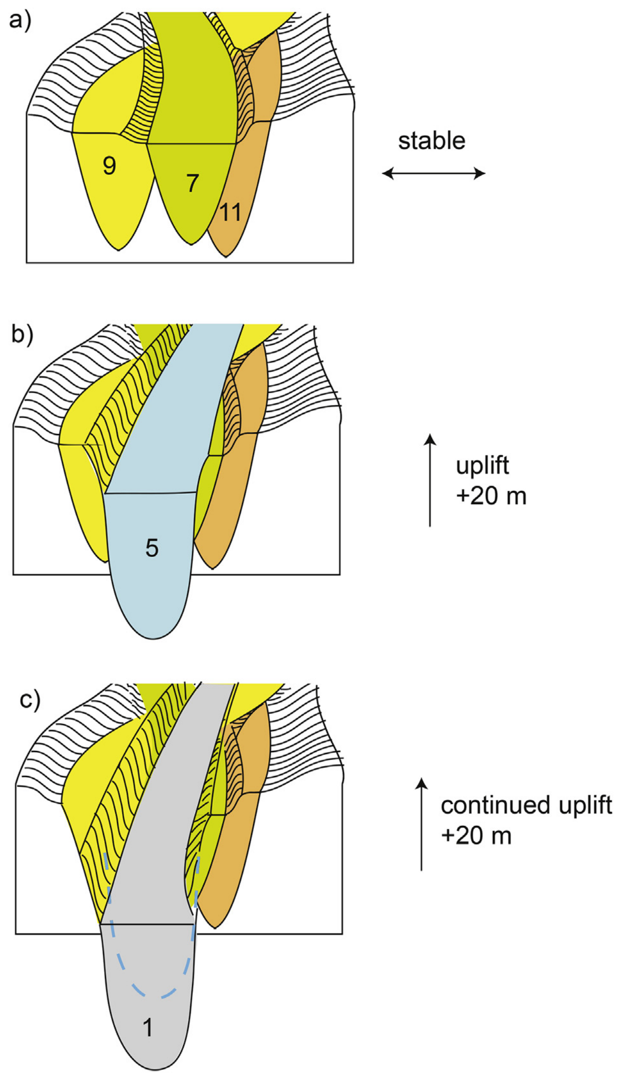


Fig. 5. Morpho-structural sketch showing a possible mechanism causing the complete erosion of the terraces and associated sedimentary deposits of MIS 5 aggradational succession within the hydrographic basin of the Tiber and Aniene rivers, in consequence of repeated tectonic uplift pulses since 200 ka. See text for explanations.

et al., 2001; Palombo, 2004). Indeed, the occurrence of such indicators of relatively cold climate conflict with the interpretation of the Saccopastore deposit as a "Tyrrhenian terrace", which implies correlation with highstand and warm climatic conditions.

Moreover, the presence of the vegetal taxa *C. avellana*, *Quercus*, *Populus* and *Carpinus* vel *Ostrya*, revealed by leaf prints within the lacustrine deposit of the upper AG3 succession, suggests environmental conditions referable to the intermediate portion of the inner mountain zone (Tongiorgi, 1939), presently occurring at higher elevation with respect to the Aniene Valley in Rome, as remarked by Blanc (1939a) and Follieri (1983).

Taking into account the paleogeographic and paleomorphologic evidences reported here, indicating that AG2 and AG3 are the remnant of the basal portion of two aggradational successions and were therefore deposited during the glacial termination at the transition between the lowstand and successive highstand, the presence of cool climate indicators is fully justified, and supports the proposed correlation with glacial termination III at the onset of MIS 7. Whereas such features may fit the successive consecutive peaks of MIS 5.3 and 5.1, rather than 5.5 and 5.1 as tentatively proposed by the above-mentioned authors, this correlation would imply ages as young as 100 ka and 80 ka for the two skulls (Fig. 3a), conflicting with their referred "archaic" characters which, according to Piperno and Segre (1984), approaches those of the European Middle-Pleistocene hominins. We remark that even an age of 130,000 years would be in conflict with the generally recognized "archaic" features of Saccopastore 1, in light of the recently established age of 170,000 years for the other Italian *H. neandertalensis* occurrence at the Altamura karst cave (Lari et al., 2015). Indeed, Bruner and Manzi (2006) have recently stated that "this combination of features in which traits that are recurrent among Würmian Neanderthals blend with those shared by Middle Pleistocene hominins" (…), when the dating within MIS 5 of the Saccopastore 1 skull is considered, (…) "suggests that the impact of the preceding cold stage (MIS 6, around 200–130 ka) was probably decisive in the definition of the Neanderthal phenotype". We wonder if such statement would fit even better with the observed trait-d'union features, when Saccopastore 1 is placed at the MIS 8-MIS 7 transition, around 250 ka, also according to a recently discussed early divergence time between *H. neandetalensis* and *H. sapiens* dating as back as 410 ka (i.e., MIS 11; Hublin, 2009).

7. Paleontological considerations

Fossil remains recovered in Saccopastore are presently stored in different museums (e.g., Istituto Italiano di Paleontologia Umana, Museo di Antropologia dell' Università "Sapienza" di Roma, Museo Nazionale Preistorico Etnografico "Luigi Pigorini" di Roma). In the present study we will refer to the detailed descriptions of the stratigraphic position and to the faunal attributions provided in Segre (1948b) (see Fig. 2b). However, a re-examination of the fossil remains is in order and it will be addressed in the future, after completion of the procedure for getting permission of study from the various institutions.

Following Segre's (1948a,b) nomenclature, the faunal record of Saccopastore included:

- "archaic" *Elephas antiquus* and *Dicerorhinus mercki*, within the basal gravel of AG1;
- *Elephas antiquus*, *Dicerorhinus mercki*, *Hippopotamus major*, *Cervus elaphus*, *Dama dama* and *Bos primigenius*, within AG2 including the Saccopastore 1 skull;
- *Dicerorhinus mercki*, *Equus caballus*, *Equus hydruntinus*, *Hippopotamus major*, *Cervus elaphu* and *Bos primigenius*, within AG3 including the Saccopastore 2 skull.

Although all previous authors included the above-mentioned taxa, with the exception of the "archaic" *E. antiquus*, within a homogeneous single "warm" faunal assemblage, we observe that the fossil remains within the upper AG3 succession, among which equids are present and elephant and fallow deer are missing, suggest a different environmental scenario, characterized by a wider diffusion of clearings, with respect to the more forested one referable to the faunal assemblage of the lower AG2 succession.

Several successive studies have essentially re-proposed the list above (Segre, 1983a, 1983b; Piperno and Segre, 1984), with the only new inclusions being *Felis leo and Aquila heliaca* (see Cassoli and Tagliacozzo, 1986), or have reviewed and updated the nomenclature of the vertebrate remains basically based on their chronologic attribution (Caloi and Palombo, 1994a; Kotsakis and Barisone, 2008; Petronio et al., 2011). However, none of these authors had access to the fossil remains, with the exception of the very few specimens housed at the Museo Nazionale Preistorico Etnografico "Luigi Pigorini" and at the Museo di Antropologia dell'Università Sapienza in Rome.

Based on the occurrences listed above, in the following section we report their implications with reference to the biochronology for the Italian Peninsula.

Several species occurred during a wide temporal range spanning the Middle Pleistocene (Galerian Land Mammal Age, LMA, Gliozzi et al., 1997) to the early Late Pleistocene, such as *E. antiquus* (i.e. *Palaeoloxodon antiquus*), or to the early Holocene, such as *Felis leo* (i. e. *Panthera spelaea*) and *E. caballus* (i.e. *Equus ferus*), or even extinguished in historical times, such as *B. primigenius* (Gliozzi et al., 1997; Bedetti et al., 2001; Petronio et al., 2007, 2011; Conti et al., 2010; Pandolfi et al., 2011; Masseti and Salari, 2012; Marra et al., 2014a), and therefore cannot provide any useful information to distinguish between MIS 7 and MIS 5.

Similarly, *E. hydruntinus* was first recorded in Italy during the late Middle Pleistocene (Aurelian LMA, Vitinia FU, MIS 8.5/7) (Conti et al., 2010; Petronio et al., 2011; Marra et al., 2014a), it became more common during the Late Pleistocene, and became extinct during the middle Holocene (Conti et al., 2010; Salari and Masseti, in press). It is therefore indicative either of MIS 7 or MIS 5.

H. major is synonymous of *Hippopotamus antiquus* (see Caloi et al., 1980b with references), a Villafranchian species that occurs at several Early and early Middle Pleistocene localities of Italy, and became rare during the second half of the Middle Pleistocene when it was replaced by *Hippopotamus amphibius* (see Petronio, 1986, 1995; Gliozzi et al., 1997; Petronio et al., 2011). However, among the fossils reported in the past to *H. major* and subsequently reviewed, some were attributed to *H. antiquus*, while others are referred to *H. amphibius* (see Caloi et al., 1980b; Petronio, 1986, 1995), which endured until the Late Pleistocene, and was extinguished probably at the beginning of MIS 4 (Petronio et al., 2007, 2011).

Dicerorhinus mercki is synonymous with *Stephanorhinus kirchbergensis* (see Billia and Petronio, 2009 with references). However, the fossils reported in the past as Merck's rhinoceros and recently reviewed were attributed to three different species (Pandolfi and Petronio, 2011; Pandolfi et al., 2013; Pandolfi and Tagliacozzo, 2013, 2015) which have distinct occurrences in Italy: *S. kirchbergensis* (MIS 13-8.5; doubtfully recorded during the early Late Pleistocene in Northern Italy), *Stephanorhinus hemitoechus* (MIS 13-3), and *Coelodonta antiquitatis* (with scanty occurrences limited to the Last Glacial) (Marra et al., 2014a; Pandolfi and Marra, 2015). According to these occurrences, the only species among the abovementioned which would be compatible with the temporal range encompassing MIS 5 and MIS 7 is therefore *S. hemitoechus*, which does not provide discrimination between these stages.

Also *C. elaphus*, which still lives in Italy, is not a useful discriminator between MIS 7 and MIS 5, because such distinction might be provided by identification at the sub-species level only, and can be made by comparison of the antlers, which are not reported among the fossil remains of Saccopastore. In particular the endemic forms *C. elaphus aretinus* and *C. elaphus rianensis* occurring during MIS 9 and 7 (Torre in Pietra and Vitinia Faunal Units) were replaced by *C. elaphus elaphus* at the beginning of Late Pleistocene (Di Stefano and Petronio, 1993, 2002; Petronio et al., 2007, 2011; Di Stefano et al., 2015).

Finally, a potential discriminating element might be the species *Dama dama* with the subspecies *D. dama tiberina*, whose first occurrence during MIS 8.5 is constrained by the $^{40}Ar/^{39}Ar$ age of 285 ± 2 ka for the Tufo Giallo di Sacrofano (Karner et al., 2001b) occurring at the outcrops of Sedia del Diavolo and Monte delle Gioie (Marra et al., 2014a) and which also occurs in the Vitinia FU, and the subspecies *D. dama dama* which replaced it in the Late Pleistocene (Di Stefano and Petronio, 1997, 2002; Petronio et al., 2007, 2011). However, in this case also distinction between subspecies can be established only by comparison of specific skeletal parts (Di Stefano and Petronio, 1997; Petronio et al., 2014), therefore its identification at the species level in Saccopastore does not shed light on the attribution of the deposits to MIS 5 rather than to MIS 7.

These considerations above indicate that the paleontological record, at the species level, is not diagnostic in clarifying attribution of the Saccopastore deposits to the Middle or to the Late Pleistocene, whereas the possible presence of *S. kirchbergensis* and/or *H. antiquus* would exclude any correlation with MIS 5.

More significant, in our opinion, is the general homogeneity among the faunal assemblages of the MIS 7 Vitinia Formation described at Vitinia (Caloi et al., 1981), Casal de' Pazzi (Anzidei, 1984) and Torre in Pietra upper level (d) (Caloi and Palombo, 1978) and that recovered in Saccopastore (Table 2). In particular, when the occurrences of *D. dama* and *C. elaphus* at Saccopastore are considered at species level, a substantial identity of the Vitinia FU and the faunal assemblage of Saccopastore is evidenced. The only remarkable difference is the occurrence of *E. hydruntinus* at Saccopastore, which is missing at these localities, where *E. ferus* is present. This fact, however, rather enhances similarity with the older site of Sedia del Diavolo (Table 2). Indeed, the faunal assemblage of Sedia del Diavolo, geochronologically constrained at 285 ka, is identical to that of Saccopastore, showing the lack of any paleontological evidence supporting correlation of the latter with the 150,000 years younger MIS 5.

Table 2
Herbivorous mammals from Saccopastore and from some sites of in the area around Rome referred to the Vitinia Faunal Unit. Aur: Aurelian Land Mammal Age; Vit: Vitinia Faunal Unit; MIS: Marine Isotope Stage. Data from Caloi and Palombo (1978), Caloi et al. (1980a, 1981), Anzidei (1984), Segre and Segre Naldini (1984), Di Stefano and Petronio (1997), Pandolfi (2011) and Petronio et al. (2011).

Localities	Saccopastore	Torre in Pietra (d)	Vitinia	Casal de' Pazzi	Sedia del Diavolo	Monte delle Gioie
Land Mammal Age	Aur	Aur	Aur	Aur	Aur	Aur
Faunal Unit		Vit	Vit	Vit	Vit	Vit
MIS		7	7	7	8.5	8.5
Palaeoloxodon antiquus	X	X	X	X	X	X
Stephanorhinus sp.	X			X		
Stephanorhinus hemitoechus		X	X		X	X
Equus ferus	X	X		X	X	
Equus hydruntinus	X				X	
Hippopotamus sp.	X					
Hippopotamus amphibius		X		X	X	X
Sus scrofa		X		X	X	
Cervus elaphus	X					
Cervus elaphus rianensis		X	X	X	X	X
Dama dama	X			X		
Dama dama tiberina		X	X		X	X
Capreolus capreolus		X		X		
Bos primigenius	X	X	X	X	X	X

8. Palaethnological considerations

The scarce lithic industry recovered at Saccopastore is represented by 11 lithic artefacts made on chert, occurring within the basal sandy gravel layer of the youngest aggradational succession (AG 3, Fig. 2b). The lithic artefacts have been recovered in two successive surveys: three were discovered in 1935 in strict connection with the second human skull, and other eight were excavated from the same layer, in which also the fossil remains described in the previous sections were recovered, one year later (Breuil and Blanc, 1935b, 1936; Blanc, 1939a, 1942, 1946, 1948).

According to Blanc (1948, and references therein), seven artefacts displayed sharp edges and four were slightly blunt, suggesting that they had not been subject to long-distance transport in water. The small number of specimens prevents a reliable attribution of the Saccopastore lithic industry to a specific cultural context. Blanc (1948, and references therein) attributed the assemblage to the Mousterian and remarked on its less rough features with respect to the Mousterian lithic industry recovered at the nearby sites of Sedia del Diavolo and Monte delle Gioie, which were attributed to a "proto-Pontinian" (Taschini, 1967), representing a transitional complex between the lower and the middle Paleolithic.

Based on a few characters like laminarity, presence of Levallois technique, of a Mousterian point and of a discoidal nucleus, firstly Piperno and Biddittu (1978), then Bietti (1983a, 1983b) and Piperno and Segre (1984), noted the similarity of the Saccopastore assemblage with the Mousterian lithic industry occurring in the upper level (d) of the Torre in Pietra Paleolithic site. Remarkably, the upper level (d) of Torre in Pietra, previously attributed to the Late Pleistocene (Maspinian; Malatesta, 1978a, 1978b), has been more recently correlated with MIS 7 (Caloi et al., 1981; Gliozzi et al., 1997; Petronio et al., 2011) and represents one of the sites, along with Casal de' Pazzi (Caloi and Palombo, 1986), in which the Vitinia FU is defined (Di Stefano and Petronio, 1997). Moreover, the slightly archaic features noted by Blanc (1948) for the Mousterian lithic assemblages of Sedia del Diavolo and Monte delle Gioie with respect to that of Saccopastore, is in good agreement with the recent constraining of the former sites within MIS 8.5 (Marra et al., 2014a), and is consistent with the interpretation proposed here of a MIS 7 correlation for the sedimentary succession of Saccopastore.

9. Conclusions

The recognition of a fluvial terrace at an elevation of 37 m a.s.l. and $^{40}Ar/^{39}Ar$ dating provide a link to MIS 5 and allow us to substantiate a robust framework of geochronologically constrained, spatially defined aggradational successions in this region, correlating all the glacio-eustatic cycles spanning MIS 19 thorough MIS 1 (Marra et al., 2008, and references therein). Based on the reconstructed geometry and geographic distribution of these aggradational successions through the area of Rome, we confidently frame the Saccopastore deposits within the boundaries of the MIS 7 glacio-eustatic cycle, which occurs 20–25 m above the following cycle of MIS 5, as a consequence of a 40 m uplift since 200 ka (Karner et al., 2001a).

Based on the geometry, elevation and sedimentologic features of the investigated sedimentary deposits, the stratigraphic record of Saccopastore is therefore correlated with the basal portion of the aggradational succession deposited in response to sea-level rise during glacial termination III at the onset of MIS 7, corresponding to the local Vitinia Formation (Conato et al., 1980; Karner and Marra, 1998), as opposed to previous correlation with interglacial of MIS 5 and a locally defined "Tyrrhenian terrace" (Blanc, 1948; Segre, 1948a,b). The review of the paleontological record recovered and described by the authors at Saccopastore demonstrates its remarkable similarity to the faunal assemblages of the Vitinia Faunal Unit (see Table 2), occurring within the sedimentary successions correlated with MIS 7 (Vitinia Formation). Moreover, the Mousterian lithic industry recovered in Saccopastore shows strong affinity with that of the upper stratigraphic level of Torre in Pietra (Piperno and Segre, 1984), which is also correlated with MIS 7. In contrast, no paleontological and palethnological evidence from Saccopastore displays a distinctive Late Pleistocene character. Indeed, previous attribution to the last interglacial was based on a preliminary, improper evaluation of a supposedly "warm" faunal assemblage, joined to the incorrect interpretation of the morphologic feature of the outcrop in Saccopastore as a fluvial terrace and its framing within an incomplete chronology of the glacio-eustatic cycles, which provided, at the time, only three interglacials (Günz-Mindel, Mindel-Riss, Riss-Würm) instead of the six presently recognized in the last 600 kyr (MIS 15 through MIS 1).

The revised attribution of the Saccopastore deposits to the beginning of MIS 7, around 250 ka, is consistent either with evidence of relatively cold fauna and flora, and with its coarse-grained sedimentologic features, suggesting proximity to a sea-level lowstand rather than to the interglacial highstand. Moreover, it may also account for the repeatedly remarked "archaic" *neanderthalensis* characters of the recovered skulls (Bruner and Manzi, 2006 and references therein), which may suggest affinity with the Middle Pleistocene fossils of central-northern Europe. Indeed, while a discussion of the paleoanthropological implications of the proposed older age for the Saccopastore skulls is clearly beyond the scope of this work, which is simply aimed at providing a better geomorpho-stratigraphic correlation of the sedimentary succession with MIS 7, we note that the above-mentioned archaic features may fit within a perspective envisaging that most of the braincase morphology of *H. neanderthalensis* was already established at the end of MIS 7 (Rougier, 2003). The origin and evolution of *H. neanderthalensis* is still debated (Hublin, 2009, and references therein) and the very recent developments of the genomic studies have shown that a full divergence of the lineages leading to *H. sapiens* and *H. neanderthalensis* was achieved since 300,000 years BP, at the least (e.g., Sankararaman et al., 2014): in this light, the proposal of an age of 250,000 years for the Saccopastore skulls may provide new insights to the discussion.

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