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THE LATEST CONTINENTAL FILLING OF VALLE UMBRA (TIBER BASIN, CENTRAL ITALY) DATED TO ONE MILLION YEARS AGO BY MAGNETOSTRATIGRAPHY

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ABSTRACT: Bizzarri R., Albianelli A., Argenti P., Baldanza A., Colacicchi R. & Napoleone G., *The latest continental filling of Valle Umbra (Tiber Basin, central Italy) dated to one million years ago by magnetostratigraphy*.

Paleogeography of central Italy during Pliocene and Pleistocene is characterized by the on-setting of continental basins, oriented almost parallel to the uplifting Apennine mountain chain and marked by the valleys of main rivers Arno, Chiana, Tevere, together with minor intermountain basins (e.g.: Colfiorito). The internal range, with its complex of intermountain basins, was bounded by coastal marine deposits of the Tyrrhenian and Adriatic seas. Due to a decidedly established palaeoenvironmental and magnetostatigraphic scenery for Valdarno, Valtiberina and Colfiorito Basins, the short section at Arquata in the Valle Umbra Basin, here presented, may be constrained much more closely to the evolutionary pattern of the former ones by means of a similar magnetostratigraphic characterization. In particular, detailed magnetostratigraphy led to date the earliest deposits in the Valdarno Basin at 3.3 Ma, whereas in Valtiberina the oldest analyzed deposits, which don't reach the substratum yet, postdate 2.8 Ma.

Upward, the two above mentioned main sedimentary profiles reach 2.0 Ma and 2.1 Ma, respectively, and in the shorter section of Colfiorito only the youngest dates are attained, until 0.78 Ma. The same younger date was detected in the Valdarno, where also the Olduvai chron (1.95-1.77 Ma) is recorded, followed by the Jaramillo chron (1.05-0.97 Ma) after a long sedimentary hiatus.

The Valle Umbra profile exposed near Bevagna is dated across the Jaramillo chron, the duration of its deposition extending approximately 300 ky. Both results are very close to the previously mentioned final fillings of Valdarno and Colfiorito.

RIASSUNTO: Bizzarri R., Albianelli A., Argenti P., Baldanza A., Colacicchi R. & Napoleone G., Il riempimento continentale più recente della Valle Umbra (Bacino Tiberino, Italia centrale) datato a un milione di anni fa attraverso la magnetostratigrafia.

La Valle Umbra, nel settore orientale del Bacino Tiberino in Umbria, ha sinora offerto pochi dati per integrare la transizione paleogeografica, da ovest verso est, che ha interessato sia gli adiacenti bacini continentali più ampi (Valdarno, Val di Chiana, Valle Tiberina), sia i bacini intermontani minori e più orientali (Colfiorito), tutti con asse orientato circa NW-SE, parallelo alla nascente catena appenninica. Nel loro insieme, questi bacini intermontani, appartenenti alla zona centrale della catena appenninica, sono confinati tra fasce costiere peritirreniche e periadriatiche. Il quadro paleoambientale e magnetostratigrafico, già individuati per i suddetti bacini, ha permesso ora di fissare anche quello della Valle Umbra. La successione sedimentaria della porzione sommitale, messa a giorno nella Cava Arquata a Bevagna, permette di integrare il quadro conoscitivo dell'evoluzione paleoambientale più recente dell'Italia centrale, poiché conclude quelle fasi del sollevamento appenninico iniziate alla data di 3.3 Ma nel Valdarno e quelle presumibilmente coeve della Valtiberina, interrottesi rispettivamente a 2.0 Ma e 2.1 Ma. Il nuovo ciclo deposizionale è cominciato subito dopo, datato solo nel Valdarno, da 1.9 Ma a 1.7 Ma, mentre il ciclo finale, nel Valdarno e a Colfiorito, contiene il magnetocrono Jaramillo (1.05-0.97 Ma). Nella successione di Colfiorito, inoltre, viene raggiunta la data più recente, testimoniata dalla registrazione dell'inizio dell'ultimo magnetocrono, a 0.78 Ma. I depositi studiati in Valle Umbra sono marcati molto nettamente dalla presenza del crono Jaramillo e la deposizione della successione analizzata a Bevagna, nei pressi di Foligno, ha avuto una durata stimata di 300 ky. La parte finale del Pleistocene inferiore e il passaggio Pleistocene inferiore - Pleistocene medio sono calibrati alla data di Jaramillo e all'inizio dell'ultimo magnetocrono (Brunhes), rispettivamente. Entrambi i segnali sono registrati nella sezione di Colfiorito. Si può ritenere che la deposizione conclusiva fluvio-lacustre della Valle Umbra sia ragionevolmente coeva con quella dell'Altopiano di Colfiorito.

Key Words: Valle Umbra, Magnetostratigraphic dating, Jaramillo chron, Apennine basins, Early Pleistocene, Central Italy.

Parole-chiave: Valle Umbra, Datazione magnetostratigrafica, Crono Jaramillo, Bacini Appenninici, Pleistocene Inferiore, Italia Centrale.

1. INTRODUCTION

The Northern Apennine intermountain basins represent bench-marks of structural and stratigraphic significance for updating most of the present environmental studies on continental deposition occurring through the recent geological past. Basin infills were firstly assigned Pliocene and Pleistocene ages according to the lithological subdivision of blue and dark-green clay underlying yellowish sand, with both the lithologies closely equivalent to marine analogous deposits ascribed to the end of Pliocene and the beginning of Quaternary (e.g., see NAPOLEONE *et al.*, 2003; VAN COUVERING, 1997).

Such ages, though, have recently been calibrated to dates by means of magnetostratigraphy, which right in Umbria provided the conceptual and more complete tool for defining the numerical timing for marine sedimentary successions. The present example is aimed at testing a different approach to a short interval of continental deposits, devoid either of direct lithostratigraphic correlation with adjacent sections or of a significant fossiliferous record. Actually, biochronologic ages used for classifying mammal fauna stages in the richest non-marine deposits of Italy (AZZAROLI, 1977; AZZAROLI *et al.,* 1988) were made equivalent to the biostratigraphic ages once they were both calibrated to the same global scale of geomagnetic polarity reversals, currently used for geochronology (ALVAREZ, 2009). The process was first verified in the nearby Upper Valdarno, where local lacustrine to deltaic successions had magnetostratigraphically been dated in million years (Ma) and several classical Villafranchian Faunal Units, from there established for biochronology, were labelled with an absolute reference (NAPOLEONE *et al.*, 2003). The Upper Valdarno profile contained also the thickest continuous profile and earliest mammal fossil record, so to become the calibration frame for other Apennine continental successions, beginning with Valtiberina and Colfiorito Basins in Umbria. These intermountain basins, therefore, have assumed the dates in million years of the geomagnetic polarity time scale. In particular, the Valdarno sequence was calibrated since 3.3 Ma to 1.7 Ma, and with a resolution of few thousand years (ky) (ALBIANELLI *et al.,* 1997) and even 1 ky (NAPOLEONE & AZZAROLI, 2002).

With recently collected data (ALBIANELLI *et al.*, 2002; NAPOLEONE *et al.*, 2003), and following the calibration of the Chronostratigraphic Time Scale to the Geomagnetic Polarity Time Scale (GPTS), for the “Plio-Pleistocene Boundary and the Beginning of the Quaternary” it is possible to relate the ages of continental deposits to those of marine sequences, both calibrated to the Gauss and Matuyama chrons including Olduvai. To the Olduvai chron the Pliocene/Pleistocene boundary was fixed at 1.796 Ma in the Vrica stratotype (VAN COUVERING, 1997), albeit, recently, the Pliocene/Pleistocene boundary has been repositioned at 2.58 Ma (GIBBARD *et al.,* 2010). The magnetostratigraphic analysis of the Valle Umbra continental sediments has therefore been done for identifying particular intervals (magnetozones) co relatable to the chrons of the geomagnetic time scale, by which the biochronologic “stages” could be calibrated. The magnetostratigraphic survey has been carried out on the profile exposed in the Arquata quarry, near Bevagna (Perugia), in order to attain the continuous dating for the ages expected in the about 65 m thick deposit, from prominent sedimentological and biochronologic evidences selected in the adjacent basins. For that section, sedimentological features, fossil content and magnetostratigraphic calibration are here considered, and firstly some time constrains for Valle Umbra deposits are proposed, allowing to insert also the eastern branch of Tiber Basin into a Northern Apennine Basins comprehensive evolutionary scheme.

2. GEOLOGICAL SETTING OF VALLE UMBRA

The paleogeographic evolution of central Italy was marked since Piacenzian by the setting and development of large continental basins along the inner Apennine Chain. Basin complex was bordered by coastal marine deposits on both sides, from the Tyrrhenian and Adriatic seas, although direct correlations among continental and marine domains are not always clearly documentable. Such basins, as the major ones of Mugello and Upper Valdarno, Valdichiana and Valtiberina, were structurally aligned NW-SE, almost parallel to the Apennines Mountain range, and occur together with the intermountain minor basins, as Tavernelle-Pietrafitta, Gubbio, Gualdo, Colfiorito, Norcia etc. (Fig. 1). The structural assessment for all of them lies within tectonic depressions bordered by direct faults belonging to the extensional phase, which followed the compressional one acting since Miocene on the whole area of Tuscan-Umbrian and Latium regions. Right because linked to the W-to-E migration of the Apennine over-thrusting front, ages of the extensional basins and related infill become progressively younger with the same trend (Fig. 1). The master-fault system, mainly dipping to SW and associated to the antithetic one, produced half-graben structures with displacements of several hundreds of meters (BARCHI *et al.,* 1991; MENICHETTI, 1997). Pliocene and Pleistocene continental deposits cover nearly one third of the Umbrian territory (LOTTI, 1917, 1926) and mainly belong to the Tiber Basin and its split major valleys, Valtiberina (from Sansepolcro to Terni) and Valle Umbra (from Perugia to Spoleto). They are respectively confined by the Meso-Cenozoic mountain belts of Massicci Perugini, Mt. Peglia and Narnese-Amerina chain, due west, and Mt. Catria-Mt. Nerone-Mt. Serano Mountains, due east and separated by the Martani mountain range (CONTI & GIROTTI, 1977; AMBROSETTI *et al.*, 1977, 1978, 1987, 1989, 1995a; BASILICI, 1992, 1995; MARTINI & SAGRI, 1993). The whole basin underwent extensional deformation phases (due to faults reactivation), from Gelasian-Calabrian to Late Pleistocene (GREGORI & CATTUTO, 1986; BARCHI *et al*., 1991; BONINI, 1998).

Contrary to the Valtiberina where several exposures are available, Valle Umbra is fairly poor of outcrops, thus hampering an appropriate recognition of its most recent geologic history (Fig. 1.2). In south Valle Umbra (Spoleto area), COLTORTI & PIERUCCINI (1997) identified two important depositional phases referable to Pliocene and Pleistocene, respectively, separated by a “tectono-sedimentary discontinuity”. The earlier deposits, unconformably laying on the pre-Pliocene substratum, are made of fluvial-lacustrine and alluvial fan-delta sediments. The older are exposed in the Spoleto area, in the lignite-bearing levels outcropping at Morgnano. The mammal fauna there recovered was classified to belong to the Triversa Faunal Unit, and assigned to the earliest stage of the Early Villafranchian Mammal age in the biochronologic classification of AZZAROLI (1977). In the Valdarno Basin a comparable fauna was dated 3.1 Ma in the Kaena magnetochron (ALBIANELLI *et al.*, 1997). Most of these lower deposits from Valle Umbra are made of clays, containing lignite dark levels interbedded with thin sandy levels; in the upper part they mainly alternate with banks of coarser sand and fine-grained conglomerates. The younger sedimentary phase, on the contrary, is represented by thick alluvial-fan conglomerates deposited in the southern valley by a number of streams draining the western flank of the Serano-Brunette ridge and the eastern flank of the Martani Mts. (COLTORTI & PIERUCCINI, 1997).

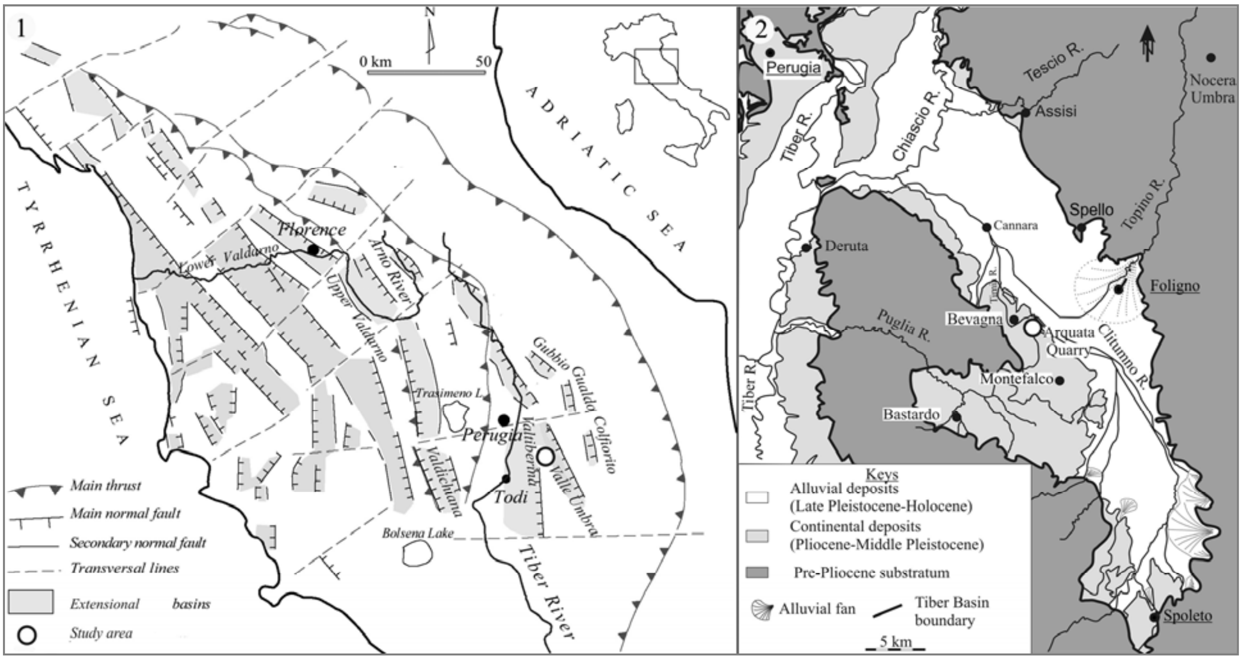


Fig. 1 - 1) Sketch of northern Apennine extensional basins and geographic collocation of the study area (modified after Napoleone *et al.*, 2003). 2) Schematic geological setting of Valle Umbra.

1) Schema dei Bacini estensionali dell'Appennino settentrionale e ubicazione geografica dell'area studiata (da Napoleone et al., *2003, modificato). 2) Assetto geologico schematico della Valle Umbra.*

Tectonics played an important role in modeling the present morphology of Valle Umbra since Middle-Late Pleistocene, even until last interglacial stage (Gregori & Cattuto, 1986). Two major fault systems were acting: one, in the eastern side uplifting the Serano-Brunette ridge along the border fault, while its piedmont accumulated in fan deposits; the other one, the antithetic east-dipping fault system was uplifting the conglomerates of the second sedimentary phase (presumably), originally laying at the plain level, up to the present Montefalco hill, nearly 180 meters above the valley. Immediately before this phase of uplift, small ponds were isolated, with local carbonate-siliceous deposition (Colacicchi *et al.*, 2007).

3. THE ARQUATA QUARRY STRATIGRAPHIC SECTION

The whole available succession of the Valle Umbra sediments, representative of latest evolution of the basin, is here exposed across a nearly 65 m thick stratigraphic profile (Figs. 2, 3). The examined deposits are mainly formed by clays and sands containing lignite levels, which dip to the SW by 10°-12°. A well visible extensional fault in the mid-profile, almost E-W striking and dipping southward, suggests a minor displacement of few metres (Fig. 3). Some minor surfaces may be locally recognized, either produced by tectonics or sin-depositional collapses, each less than 1 m in displacement.

3.1 Sedimentological features

The succession may be referred to a depositional lacustrine and fluvial-lacustrine frame, and two depositional environments are documented: a shallow-water lake and an alluvial plain with distal fluvial supplies (Fig. 3). The facies associations are divided accordingly (Colacicchi & Bizzarri, 2005; Colacicchi *et al.*, 2007), as:

*Facies Association **A** (shallow lake environment)* - The association groups facies referable to a shallow water lacustrine environment. Facies **A$_1$** is mainly represented by massive to thin-laminated, fossils bearing clay beds (Fig. 4.1). Thin fine sand lenses showing wave and current ripples locally occur. Fossils are both scattered or grouped in thin (up to 5 cm thick) layers, and banks of vegetal matter also occur as thin lignite levels, but more commonly enhancing the lamination. Facies **A$_2$** is represented by alternations of thin laminated clay and ripple laminated silt/fine sand, with the latter prevailing (Figs. 4.2, 4.3). Both facies **A$_1$** and **A$_2$** are referable to a shallow lake environment with stable and presumably faint wave motion.

Facies **A$_3$** is characterized by wave ripple laminated sand (Fig. 4.4), locally with hardened top and bottoms and polygonal drying cracks (Figs. 4.5, 4.6), documenting subaerial exposure such as of lake beach. Wave ripple laminated sands locally contain clay chips, vegetal matter and root remains. Facies **A$_4$** is represented by dune- to ripple-laminated sand resulting from minor turbidites (Fig. 4.7), due to distal fluvial flooding and/or sediments remobilization possibly after seismic shocks or strong wind action. Some of these sandy bodies evolve to a clearer beach deposits, also showing drying polygons and root remains, as a proof of sedimentation in a not deep environment.

*Facies Association **B** (alluvial plain environment)* - Facies **B$_1$** is prevalently composed of laminated silty clay, deposited in an alluvial-plain environment, whereas facies **B$_2$** is described as root-bearing massive to laminated clay and is interpreted as poorly drained paleo-

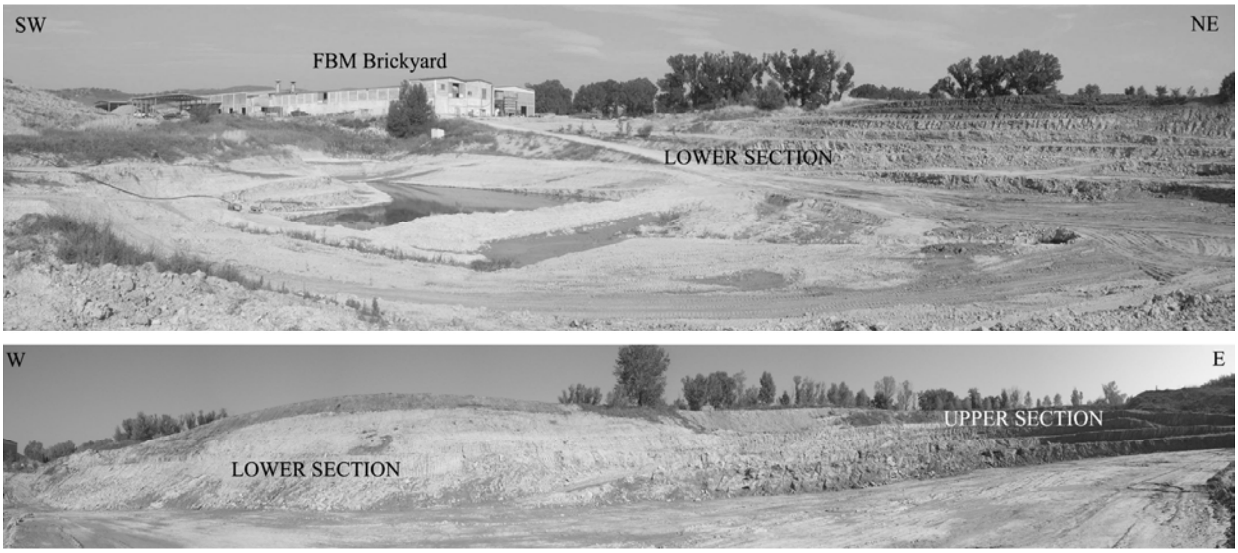


Fig. 2 - Panoramic views of Arquata quarry, along SW-NE (up) and W-E (down) profiles.
Panoramiche di cava Arquata: vista SW-NE (in alto), vista W-E (in basso).

soils (Fig. 4.10). Facies $\mathbf{B_3}$ shows decimeter-to-meter thick levels of massive to slightly laminated silty sand (Figs. 4.8, 4.9), locally associated with facies $\mathbf{B_4}$, the latter described as current ripple and/or cross laminated sand (Figs. 4.11, 4.12). The both latter two facies are interpreted as produced by distal fluvial influxes (river flooding).

*Facies Association **C** (palustrine or marsh-pond environment)* - Facies $\mathbf{C_1}$ (Fig. 4.13) is formed by less than 1 meter-thick lignite levels, usually bearing larger gastropods and *Unio* sp. Grey clayey palustrine paleosoils with rooted radical apparatuses, scattered vegetal material, fossils, remains of the original lamination and reddish surfaces are associated in facies $\mathbf{C_2}$, which can be indicated as root-bearing massive clay (Fig. 4.13). The lignite levels and the massive clayey paleosoils (facies $\mathbf{C_1}$ and $\mathbf{C_2}$ respectively) are anyhow constantly associated, leading to a poorly oxygenated and strongly reducing environment, able to maintain organic matter almost un-altered. Both associations represent swampy lake flanks as well as small ponds and marsh within the alluvial plain.

Facies architecture - The lower two thirds of the succession (Unit 1: Fig. 3) are dominated by Associations **A** of more frankly lacustrine environment, while alluvial plain deposits (Associations **B**) prevail in the final portion (Unit 2: Fig. 3). The variable thicknesses of lignite and clays of palustrine deposition (Associations **C**) may be present in both environments, often transitional from **A** to **B** (Fig. 3). Rhythmicity is a recurring characteristics in the **A** associations, both within a single association and vertically shifting from to one another. Long-lasting and stable lacustrine conditions, still with minor variations due to seasonality, supply variations, etc., characterize the lower section, with the predominance of $\mathbf{A_1}$ and $\mathbf{A_2}$ facies (Fig. 3) whereas the shift from lacustrine to alluvial plain conditions may be most probably linked to longer period of climatic fluctuation.

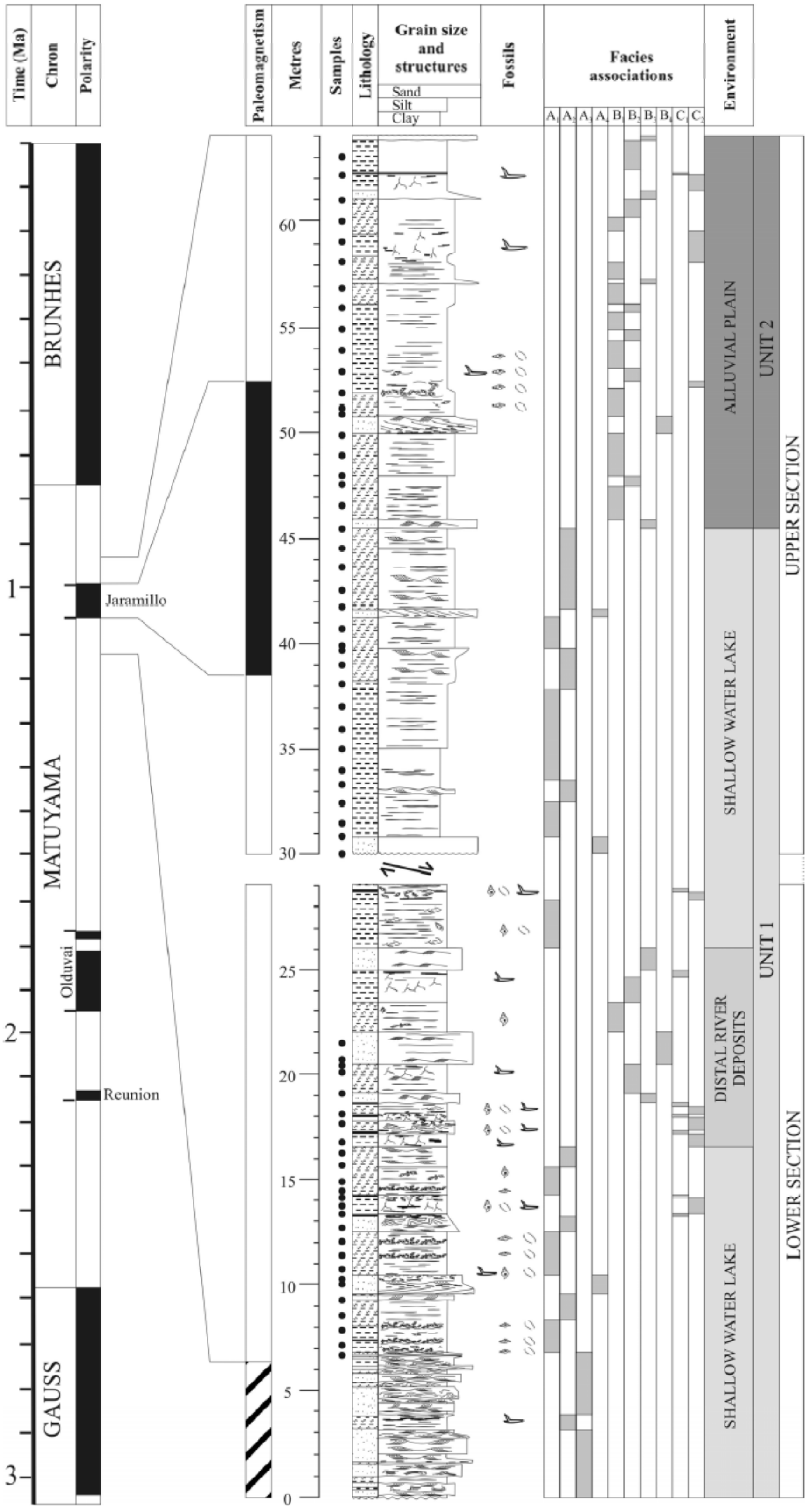
Post-depositional structures, such as convolute lamination (Fig. 4.14) and micro-faulting (Fig. 4.15) commonly occur throughout the entire section and are documented in all the described facies. Particularly, structures due to subaqueous remobilization of partially lithified deposits (Fig. 4.16) suggest a probable seismic origin which testifies of tectonic pulses coeval to sedimentation.

3.2 Paleontological record

Macropalaeontological content is represented by rare vertebrate remains (fragments of carapace and long bones of turtle *Emys orbicularis* and only one scapula fragment of amphibian) and abundant non-marine molluscs, associated to palaeocarpological remains. The malacological assemblage (Colacicchi *et al.*, 2005; Caprai, 2010) collected in the lower portion (Unit 1) is characterized by *Melanopsis (Melanopsis) affinis*, *Theodoxus* (*Neritina*) *groyanus*, *Viviparus* (*Viviparus) belluccii*, *Prososthenia* cf. *P. oblonga*, *Neumayria priscillae*, *Emmericia umbra*, *Melanoides* (*Melanoides*) *curvicosta*, *Unio pillai*, *Dreissena polymorpha*, *Pisidium* sp*., Hauffenia minuta, Valvata interposita, V. piscinalis* (Fig. 5). The assemblages are almost comparable with the ones reported by Petronio *et al.* (2000-2002). Occurrence of terrestrial gastropods, as *Carychium (Saraphia) tridentatum* and *Vertigo (Vertilla) angustior*, although previously reported (Simonetti, 1996) have not been here documented. Assemblages contain only few species which occur from Middle Villafranchian (*M. affi-*

Fig. 3 - Magnetostratigraphic and sedimentological section in the Arquata quarry deposits. In addition to the calibration to GPTS scale, recognized facies, fossil content and paleoenvironmental restoration are also provided.

Sezione magnetostratigrafica e sedimentologica nei depositi di Cava Arquata. Oltre alla calibrazione con la scala GPTS, sono riportati anche le facies riconosciute, il contenuto paleonotologico e l'interpretazione paleoambientale.


Time (Ma)
Chron
Polarity
BRUNHES
MATUYAMA
GAUSS
Jaramillo
Olduvai
Reunion
1
2
3
Paleomagnetism
Metres
Samples
Lithology
Grain size and structures
Sand
Silt
Clay
Fossils
Facies associations
A_1 A_2 A_3 A_4 B_1 B_2 B_3 B_4 C_1 C_2
Environment
0
5
10
15
20
25
30
35
40
45
50
55
60
ALLUVIAL PLAIN
SHALLOW WATER LAKE
DISTAL RIVER DEPOSITS
SHALLOW WATER LAKE
UNIT 2
UNIT 1
UPPER SECTION
LOWER SECTION
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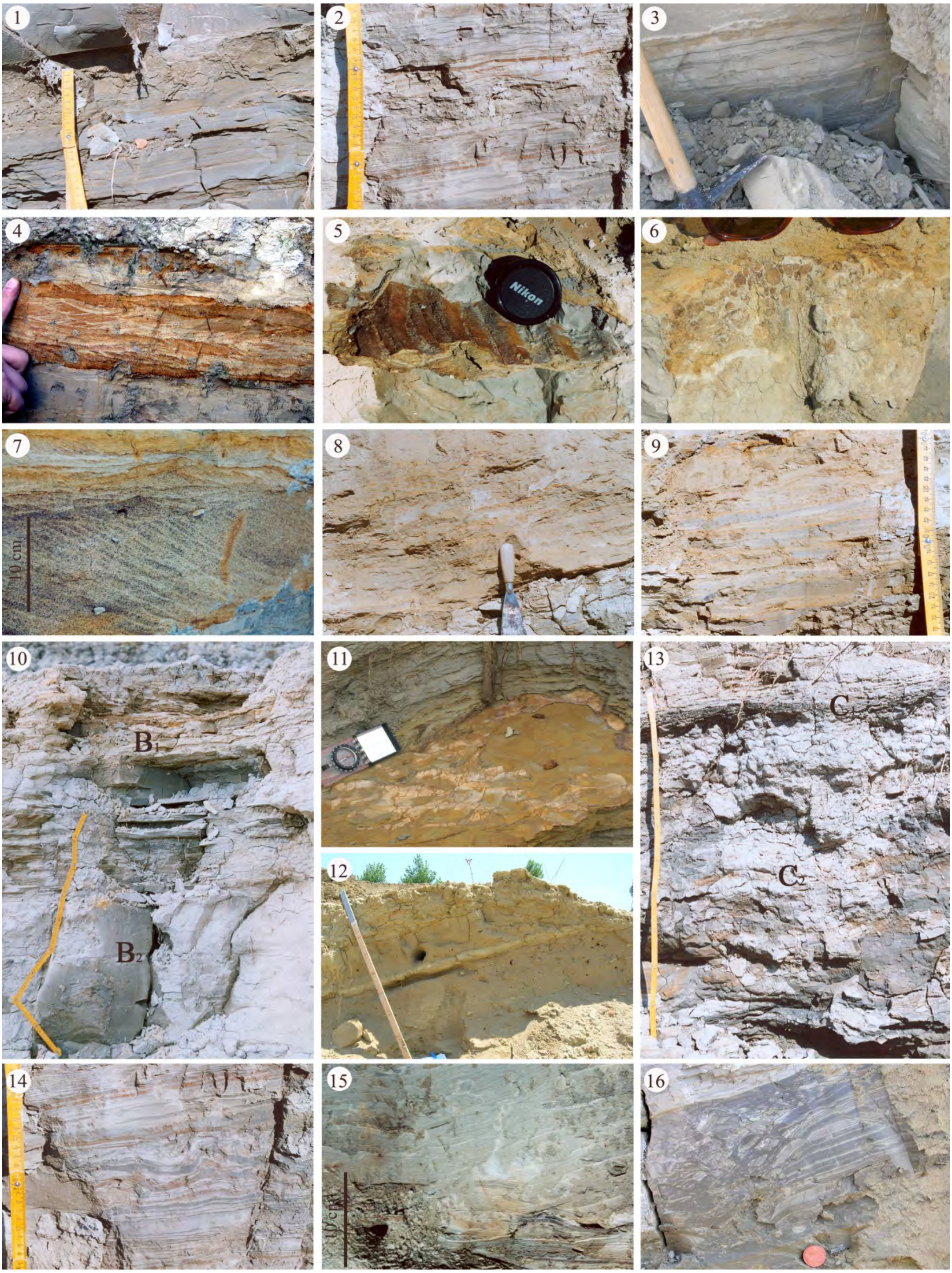

Fig. 4 - Sedimentary facies in the Arquata quarry deposits. 1) Massive and thin laminated clay (facies **A**$_1$). 2, 3) Alternations of thin laminated clay and wave ripple-laminated sand/silt (facies **A**$_2$). 4) Wave ripple-laminated sand (facies **A**$_3$). 5) Particular of hardened top of wave ripples in the facies **A**$_3$. 6) Polygonal drying cracks in facies **A**$_3$. 7) Dune- to ripple-laminated sand resulting from minor turbidites (facies **A**$_4$). 8, 9) Massive to slightly laminated silty sand (facies **B**$_3$); picture 8 also shows channeled base surface. 10) Laminated silty clay (facies **B**$_1$) associated to root-bearing massive to laminated clay (facies **B**$_2$). 11) Top hardened surface of current ripple (facies **B**$_4$).

12) Cross laminated sand, bearing clay chips (facies **B**$_4$). 13) Lignite level (facies **C**$_1$), at the top of root-bearing massive to poorly laminate grey clay (palustrine paleosoils, facies **C**$_2$). 14) Convolute lamination in clay and silt of facies **A**$_2$. 15) Micro-fractures showing less than 5 cm of dislocation (“micro-faulting”) probably effect of sediment adjustments. 16) Sin-sedimentary remobilization of partially lithified clay and silt, due to seismic shocks.

Facies sedimentarie descritte nei depositi di Cava Arquata. 1) Alternanza di argille massive e sottilmente laminate (facies ***A***$_1$*). 2, 3) Alternanze di argille sottilmente laminate e sabbie o silt con ripple da onda (facies* ***A***$_2$*). 4) Sabbie con ripple da onda (facies* ***A***$_3$*). 5) Particolare della superficie indurita dei ripple da onda nella facies* ***A***$_3$*. 6) Poligoni di disseccamento nella facies* ***A***$_3$*. 7) Sabbie laminate, con dune nella parte inferiore passanti verso l’alto a ripple da onda, prodotte da correnti di torbida (facies* ***A***$_4$*). 8, 9) Sabbie siltose, da massive a sottilmente laminate (facies* ***B***$_3$*); l’immagine 8 mostra anche la superficie erosiva canalizzata alla base del deposito. 10) Argille siltose laminate (facies* ***B***$_1$*) associate ad argille da massive a laminate, contenenti resti di apparati radicali (facies* ***B***$_2$*). 11) Superficie sommitale indurita nei ripple da corrente della facies* ***B***$_4$*. 12) Sabbie a laminazione incrociata, con plasti di argilla (facies* ***B***$_4$*). 13) Livello di lignite (facies* ***C***$_1$*), al tetto di argille grigie, massive o debolmente laminate, con apparati radicali (paleosuoli di palude, facies* ***C***$_2$*). 14) Lamine convolute nelle argille e silt della facies* ***A***$_2$*. 15) Microfratture con dislocazione inferiore a 5 cm (“micro-faulting”), probabilmente risultanti dall’assestamento del sedimento. 16) Rielaborazione sinsedimentaria di argille e silt parzialmente litificati, dovuta a shock sismici (micro-sismite).*

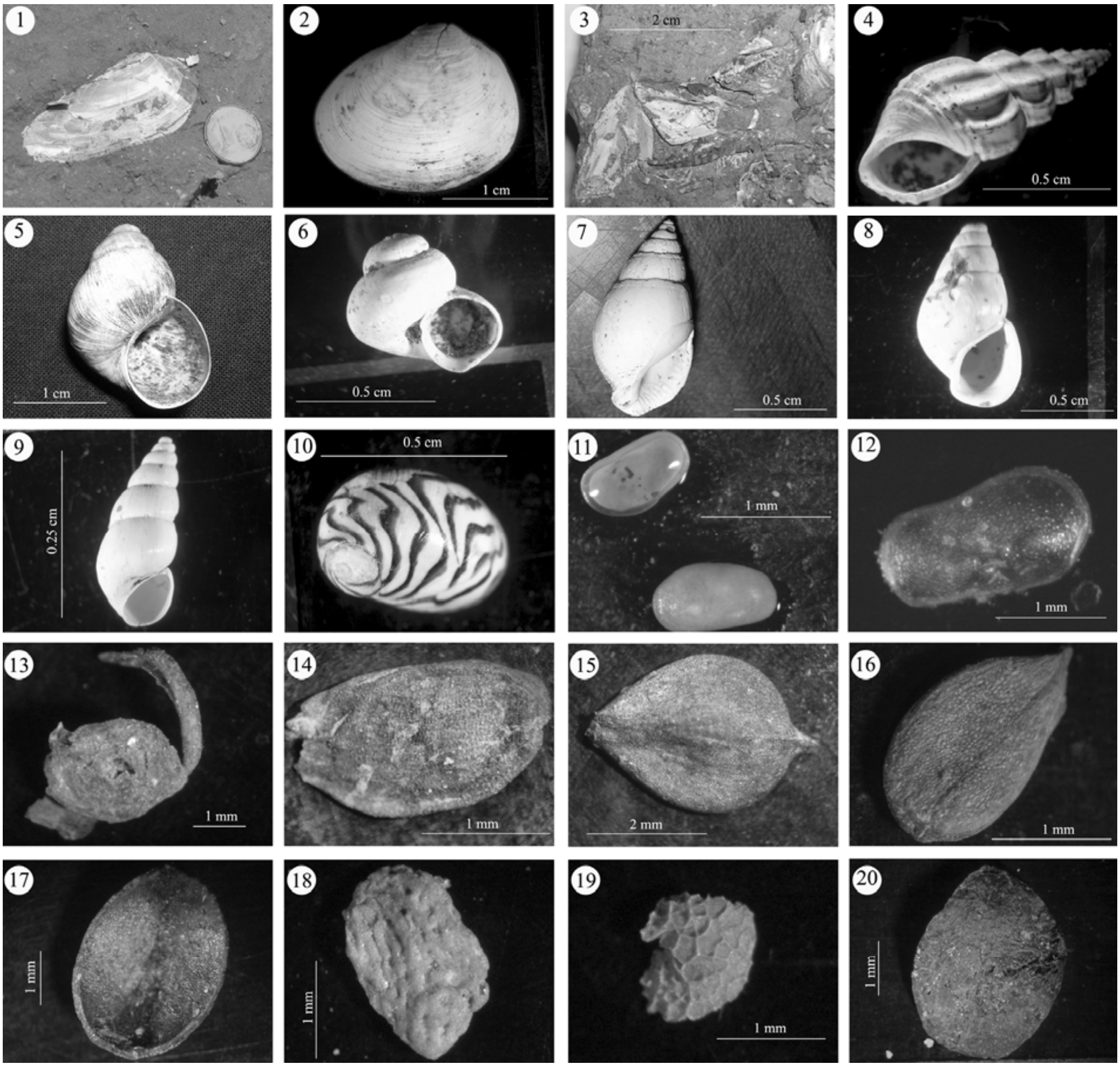

Fig. 5 - Fossil record in the Arquata quarry deposits. 1) *Unio pillai*. 2) *Pisidium* sp. 3) *Dreissena polymorpha*. 4) *Melanoides* (*Melanoides*) *curvicosta.* 5) *Viviparus* (*Viviparus) belluccii*. 6) *Valvata interposita.* 7) *Melanopsis (Melanopsis) affinis.* 8) *Emmericia umbra.* 9) *Prososthenia oblonga.* 10) *Theodoxus* (*Neritina*) *groyanus*. 11) *Cyprideis torosa.* 12) *Ilyocypris bradyi.* 13) *Potamogeton* sp. 14) *Itea europaea.* 15) *Scirpus isolepioides.* 16) *Ranunculus pseudoflammula* (achene) 17) *Mallotus maii* (seed). 18) *Rubus* sp. 19) *Selaginella* gr. *pliocenica* (macrospore). 20) *Thalictrum minimum.*

Record paleontologico nei depositi di Cava Arquata. 1) Unio pillai*. 2)* Pisidium sp. *3)* Dreissena polymorpha. *4)* Melanoides (Melanoides) curvicosta. *5)* Viviparus (Viviparus) belluccii. *6)* Valvata interposita. *7)* Melanopsis (Melanopsis) affinis. *8)* Emmericia umbra. *9)* Prososthenia oblonga. *10)* Theodoxus (Neritina) groyanus. *11)* Cyprideis torosa. *12)* Ilyocypris bradyi. *13)* Potamogeton sp. *14)* Itea europaea. *15)* Scirpus isolepioides. *16)* Ranunculus pseudoflammula (achene). *17)* Mallotus maii (seme). *18)* Rubus sp. *19)* Selaginella gr. pliocenica (macrospora). *20)* Thalictrum minimum.

nis, *T. groyanus*, *E. umbra* and, dubitatively, *U. pillai*) or Olivola F.U. (*P. oblonga*) to Farneta F.U.; *N. priscillae* is reported only in the Tasso F.U., whereas *V. belluccii, M. curvicosta* and *V. interposita* are still currently documented in the Tasso and Farneta Faunal Units (GLIOZZI *et al.*, 1997). Furthermore, the genera *Prososthenia* and *Neumayria* are considered extinct at the end of Early Pleistocene, as well as *E. umbra* and *M. affinis*, which do not survive beyond Early Pleistocene (AMBROSETTI *et al.*, 1995b; GLIOZZI *et al.*, 1997; PETRONIO *et al.*, 2000-2002; GIROTTI *et al.*, 2003).

Mollusc assemblages coming from the upper section (Unit 2) only contain *D. polymorpha*, lacking stratigraphic relevance.

The palaeocarpological analyses evidence two different types of assemblages referable to particular edaphic conditions: 1) hygrophilous plants *Scirpus isolepioides*, *Ranunculus pseudoflammula*, cf. *Itea europaea,* living and accumulated in situ, and 2) mesophilous plants *Potamogeton* sp., *Rubus* sp., *Melissa elegans*, *Ficus potentilloides*, *Mallotus maii, Thalictrum minimum* of warm-temperate climate, living in the surrounding area and carried by rivers into the basin (Fig. 5). These specimens are accompanied by common *Characee* oogonia and other remains. Among the latter, a much altered bract and a *Selaginella* gr. *pliocenica* macrospore (Fig. 5.19), a present-day species of humid and shady environment, tropical to sub-tropical (CAVALLO & MARTINETTO, 2001), are included. Microfossils are only represented by freshwater ostracods *Cyprideis torosa* and *Ilyocypris bradyi* (Figs. 5.11, 5.12), known in Central Italy Basins from Early Pleistocene (Tasso F.U.) onward (AMBROSETTI *et al.*, 1987, 1995b; GLIOZZI *et al.*, 1997). Both forms are very abundant in the taphocenosys, and probably well represent the biocenosys: absence of competition and food richness probably supported a well developed community. Both species prefer clay or silty-clay bottoms and tolerates anomalous salinity, probably finding here ideal conditions to develop, also due to dissolved salts coming from surrounding exposed rocks. Abundance of *Cyprideis torosa*, together with dark-grey colour of deposits, is indicative of low oxygen level at the basin floor, with partial re-oxygenation due to wind and/or rain, which may have remixed the thin water column.

Biochronology **-** Malacological assemblages and the occurrence of *Cyprideis torosa* suggest, for the lower section, a Late Villafranchian age not older than Tasso F.U. Some *taxa*, such as *V. belluccii, M. curvicosta and V. interposita*, indeed, have been considered as typical of Tasso-Farneta F.U. interval and never documented afterward (GLIOZZI *et al.*, 1997). On the other hand, the upper section is characterized by rare fluvial and/or lacustrine specimens, mainly represented by *D. polymorpha*, occurring on the whole Late Villafranchian record from Tasso F.U. onward, lacking biochronological meaning.

3.3 Paleoenvironmental reconstruction

Facies analysis allows hypothesizing an alluvial plain environment, with contemporaneous occurrence of shallow lakes, with both palustrine margins and beaches, ponds, swamps and creeks, the latter draining from the nearby mountain flanks toward the basin (COLACICCHI & BIZZARRI, 2005; COLACICCHI *et al*., 2005; COLACICCHI *et al*., 2007). Such an interpretation is congruent, indeed, with paleocarpologic data, which indicate riverine transport from surrounding areas. Facies associations can be compared to the ones described in the western branch of Tiber Basin in the upper portion of Fosso Bianco and S.M. di Ciciliano Units (AMBROSETTI *et al.*, 1995a, 1995b; BASILICI, 1997, 2000). Particularly, the depositional context seems the same as in the partially coeval S.M. di Ciciliano Unit, except for the organized river channel deposits totally missing in the Arquata section. A long-lasting alluvial plain environment, probably endoreic and devoid of an organized drainage, can be proposed for the Early Pleistocene of Valle Umbra. Some inferences on sedimentation rates can be proposed here. In fact, in the adjacent basins, sedimentation rates vary from 20-24 m/100 ky on lacustrine deposits, both in the Tiber Basin and in the Valdarno, to 35 m/100 ky on fluvial sands in Valdarno (NAPOLEONE *et al.*, 2003). As the two thirds of Arquata section are represented by lacustrine deposits, intermediate values of sedimentation rates between lacustrine and river deposits could be expected. Most of the malacofauna has been collected into vegetal remains-rich beds, whereas the ostracods characterize only the purely lacustrine facies. As documented in similar contexts (e.g. Fosso Bianco lacustrine clay), absence of vertebrates, and particularly of micromammifers, seems mainly due to taphonomy and lack of preservation rather than to paleoecology.

4. THE MAGNETOSTRATIGRAPHIC PROFILE

4.1 Paleomagnetic sampling

The succession of sediments across the lithostratigraphic profile appears quite regular, as remarked above, with noticeable repetitions of sedimentary structures as well as of facies. Sampling for magnetic measurements has been carried out at an average spacing of one meter (Fig. 3), preferably in the less sandy levels in order to avoid sediment formed under active motion where particle orientation would have been dispersed under a uniform inducing field. The choice helped to better enhance the paleomagnetic vector in sharpening its resolution power for definition of magnetozone boundaries, even in material very weakly magnetized. Each sample was extracted from levels excavated across the few meter thick steps used in quarrying operations across the above mentioned profile, and their resulting location was thence accurately fixed in stratigraphic order and of fresh rock material. As remanent magnetizations were presumably weak and no metal protections around, in a nearly 0° declination field, samples were oriented by magnetic compass using manual simple operations. The average spacing of collected levels was chosen at one meter distance, as that used in the other intermountain basins previously investigated so far, considering a presumably recorded time span of some hundreds of ky, and having in accordance the accumulation rate of 30-40 m/ 100 ky been assumed. A second aim, indeed, led collecting unoriented samples at 15-20 cm distances to be measured for their magnetic content under the present field, the magnetic susceptibility, which depends on the amount of magnetic particles under magnetic induction from the present Earth's field.

Changes in susceptibility were measured in Umbria and central Italy for either continental or oceanic

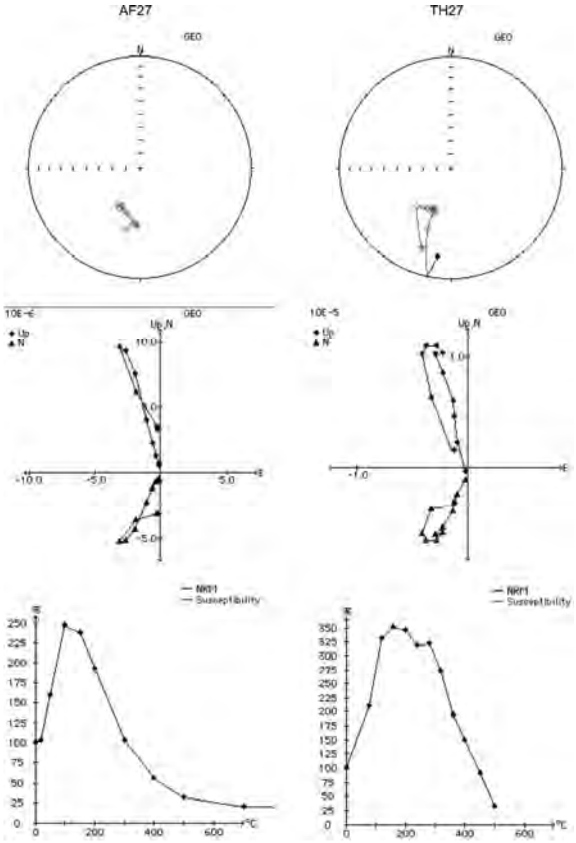

Fig. 6 - Alternate-field (AF, left) and Thermal (TH, right) demagnetization procedures applied to the same sample of reversed polarity (Aq27), showing a straightforward magnetization path. The Zijderveld polar diagram in the middle line shows the initial overprint of the present-day normal field, cleaned after the first demagnetization steps and releasing the primary remanence into the reversed characteristic vector.

Procedure di smagnetizzazione applicate allo stesso campione, a magnetopolarità inversa (Arq 27): Campo alternato (AF, a sinistra) e Termica (TH, a destra). Entrambe le procedure evidenziano l'esistenza dello stesso chiaro andamento della magnetizzazione. Il diagramma polare di Zijderveld, nella linea centrale, mostra l'iniziale sovrimpressione del campo magnetico attuale, che viene rimosso dopo i primi gradini di smagnetizzazione, e restituisce la magnetizzazione residua caratteristica del vettore inverso.

rock types outcropping, and correlated with climate changes driven by changes in solar radiation due to the orbital forcing, as accounted by the Milankovitch theory. The effects of all such parameters were tested (in eccentricity, obliquity and precession modes) either in the former sediments from Valdarno and Valtiberina (Napoleone *et al.* 2004) or in the latter ones (Napoleone & Ripepe, 1989). In the present work such results are not reported.

A sampling interruption occurred in the Arquata profile at about its middle portion, where a marked fault is visible, and above which the vegetation cover did not allow sampling for nearly 10 m. The fault had been interpreted as relevant at the local scale, possibly cutting a slice of the sequence in the order of some meters. Also the top profile was not sampled because covered by reworked material from the quarrying activities, as well as its bottom fully occupied by a pond (Fig. 3).

4.2 Laboratory measurements

Paleomagnetic measurements were carried out on cubic or prismatic specimens of nearly one-inch side cut from the oriented hand samples. All samples yielded more than two specimens, so that remanence of each level was measured using demagnetization procedures of both types (Fig. 6), thermal and by alternative fields (AF). The latter using the new built-in degausser of the ETH Magnetic Laboratory at Zurich where all the lacustrine sediments from central Italy studied in last two decades had been measured. The laboratory procedures were the same as summarized for the Upper Valdarno Basin, which represents the magnetostratigraphic reference for rock types of the analogous continental basins bordering the Apennine mountain range (Napoleone *et al.*, 2003). Stepwise thermal demagnetization was carried out on samples, of each level bed, at closely spaced temperature intervals, in order to detect even minor changes occurring in those weakly magnetized sediments that would have affected the original direction of the primary vector (Fig. 6). A complete study on rock magnetism is beyond the aims of the paper; nevertheless, some consideration can be pointed out. No particular changes were noticed for the presence of sulphide minerals, which on the contrary did affect some significant intervals in the lignite-bearing levels of the Valdarno with unstable magnetizations. In the final deposits of Valle Umbra, the paleoenvironmental conditions produced minor oxidation on their magnetic mineralogy. Such a behaviour was mainly enhanced by the smooth trend of the AF curves (Fig. 6), which otherwise assumed in several other occasions for the Apennine continental deposits completely inconsistent directions at any successive demagnetization step. This was particularly evident in the Valdarno Basin beds closer to the thick lignite-bearing level, due to the anoxic conditions there acting during deposition and presence of sulphides still pervading the overlying sediment for more than 50 m in thickness. Therefore, the straightforward direction shown by both demagnetization treatments of the paleomagnetic vector to the characteristic primary magnetization is interpreted as the typical behaviour due to the presence of a single component in the magnetic signature; in fact, the characteristic remanent magnetization (ChRM) was well isolated already at temperatures above 100-200 °C or at applied fields above 0.2-0.3 mT (Fig. 6). On our skill, and according to former results on analogous deposits (Albianelli *et al.*, 2003; Napoleone *et al.*, 2003), analyses are reasonably consistent with the original paleomagnetic field and enhance magnetozones with different polarity.

4.3 Results

The total of 55 analyzed levels yielded three intervals of polarity directions, two reversed (R1 and R2) bracketing a normally magnetized zone (N1), within which the polarity change occurs in an evident continuity of the lithostratigraphic profile (Fig. 3). The three magnetozones have to be correlated to the chrons of the GPTS in order to become calibrated to their dates in million years. That is, they will represent the absolute dating at each limit of a polarity change and a steady time flow throughout the profile, having the GPTS been the time expression, in continuous sequence, of the ocean floor magnetic anomaly stripes recorded for a steadily expanding oceanic crust. At Arquata is applied the same criterion as in Valtiberina, where for the Gauss and Reunion chrons, through Matuyama, the time resolution was obtained for the total time span 2.8-to-2.0 Ma (PONTINI *et al.*, 2002). Here, it has to be taken into account that the Olduvai chron lies in the Valdarno closely above Reunion (200 ky) and in a split mode as in the marine series in Marche (central Italy) and in Calabria (southern Italy) (NAKAGAWA *et al.*, 1997; ALBIANELLI *et al.*, 2003). After it and until Present, only two normal polarity intervals are contained in the GPTS, and of them the only normal chron followed by one of reversed polarity is Jaramillo. The dates bounding it last 1.05 to 0.97 Ma, and it has therefore to be correlated to the N1 magnetozone, whereas for both magnetozones of reversed polarity, R1 and R2, time values ascending and descending outward maintain open limits (Fig. 3). Thickness and characters of the N1 magnetozone, together with sedimentological consideration about sedimentation rate pertinent to depositional context recognized, agree to its attribution to the Jaramillo chron (BIZZARRI *et al.*, 2009; COLACICCHI *et al.*, 2009).

5. DISCUSSION

5.1 Magnetochronology in Northern Apennine basins

The role of magnetic stratigraphy is meant at providing a numerical date (or absolute dating) throughout a continuous succession of sediments whenever its magnetic signature enables to identify intervals of defined magnetic polarity (magnetozones) that can be related to magnetochrons of the Geomagnetic Polarity Time Scale (GPTS). It seems therefore a quite viable digression here to re-appraise the meaning of the results achieved in the magnetostratigraphic surveys carried out over sedimentary sequences in the intramountain basins close to Valle Umbra and dated in great detail (AMBROSETTI *et al*., 1995a, 1995b; FICCARELLI *et al.*, 1997; ALBIANELLI *et al.*, 1997, 2002, 2003; COLTORTI *et al.*, 1998; NAPOLEONE & AZZAROLI, 2002; NAPOLEONE *et al.*, 2003). Basins surrounding Valle Umbra provide therefore the primary source to inferring an age for the pile of a presumably much thicker succession, according to the thicknesses visible or estimated in several such basins (Fig. 7). But, unfortunately, the geologic and sedimentary history of Valle Umbra represents the less known portion of the continental deposition in the Tiber Basin. Its south-western branch, in fact, is best known, as the oldest sediments, although not the lowermost ones, released a date of 2.8 Ma (ALBIANELLI *et al.*, 2002), whereas the north-eastern sector yields most deposits belonging to the final filling. The basal deposition may be inferred, thence, to have begun largely after Miocene, considering that in the Valdarno Basin the exposed contact of the lacustrine facies on the pre-Pliocene substratum was dated 3.3 Ma by magnetostratigraphy, as early as in the Mammoth chron (ALBIANELLI *et al.*, 1997). The latest filling of Valdarno, indeed, contains the last magnetochrons centered at nearly 1 Ma, but a sedimentation gap lasting at least 0.7 million years (my) has been detected just before it. The mentioned lack of exposures in Valle Umbra does not enable to further hypothesize about earlier ages of its deposits. The closest comparison of its final filling may be done with the equivalent one in the nearby Colfiorito Basin (Fig. 7), where the outcrops of the uppermost deposits, exposed in the small towns of Colfiorito and Cesi, released dates respectively ranging from the well confined Jaramillo chron (1.05-0.97 Ma) to the initial Brunhes chron (across the limit of 0.78 Ma) (FICCARELLI *et al.*, 1997; COLTORTI *et al.*, 1998). It is worth recalling that the final Early Pleistocene and the beginning of Middle Pleistocene are respectively calibrated to these chrons.

In the Arquata profile, the less than 80 m exposure reduced by a slight dipping to about 65 stratigraphic meters represents a thin cover, whereas the oldest deposits visible in the Morgnano lignite mine (Spoleto in Valle Umbra) seem to equate the Valdarno lignite-bearing levels mined at Santa Barbara and dated 3.1 Ma (Fig. 7). Being the Arquata quarry profile the final filling phase, the affinity with the adjacent basins leads to infer that a long-lasting slice of time is unexposed and it might relate to the whole Late Gauss-to-Reunion interval (3.05-2.15 Ma), part of which was calibrated at Toppetti quarry in Valtiberina, and in the Valdarno through the Matuyama chron including Olduvai (1.95-1.77 Ma). As Valdarno and Colfiorito basin covers reach a Jaramillo and Brunhes dating, such values seem perfectly fitting the magnetostratigraphy results in Valle Umbra.

5.2 Geochronological and stratigraphic implications

The magnetochronologic result, of the Jaramillo date (Figs. 3, 7), represents the basic point supporting all stratigraphical considerations to be referred to. Firstly, once this 55 m sampled upper profile would be considered as deposited with constant sedimentation rate, the direct correlation between thickness and number of years of accumulation leads to assign 80 ky duration to the 14 m thick intermediate normal polarity level (Fig. 3). From this assumption it descends a duration of roughly 60 ky for the upper 11 m of reversed polarity and nearly 170 ky for the lower one 32 m thick, which includes the nearly 7 m unsampled section (Fig. 3). The overall duration would be nearly 300 ky, which leads to an accumulation rate close to 20 m/100 ky, excluding compaction rate, fairly low when compared to similar lithologies analyzed in Valtiberina and Valdarno basins. In these latter, in fact, the massive clay and/or of deeper lake deposition yielded a value of 24 m/100 ky, progressively reaching in the overlying levels, richer in silty sand, more that of 35 m/100 ky. More generally, the sedimentation rates calculated for the two basins (NAPOLEONE *et al.,* 2004) range from a minimum of 20 m/100 ky to a maximum of 35 m/100 ky, with averages of about 22 m/100 ky (Valtiberina) and 30 m/100 ky (Valdarno). Although the unknown variable of compaction rate, these values represent an agreeable datum point for the study section. In the lower levels of the Arquata quarry, sediments range from silty clay to silt and sand in the lacustrine facies, and are not as finely clayey as in Fosso Bianco Unit. On the other hand the alluvial plain sediments are lithologically analogous to the uppermost Valdarno deposits. With such a rate, the overall thickness of the Arquata profile would have been sensibly thicker, from 77 to 105 m, in contrast to the measured 65 m, which means that the inferred missing meters need an explanation. Some hypotheses can be provided.

1) It may be a consequence of compaction rates, which may reasonably differ from a basin to another, due

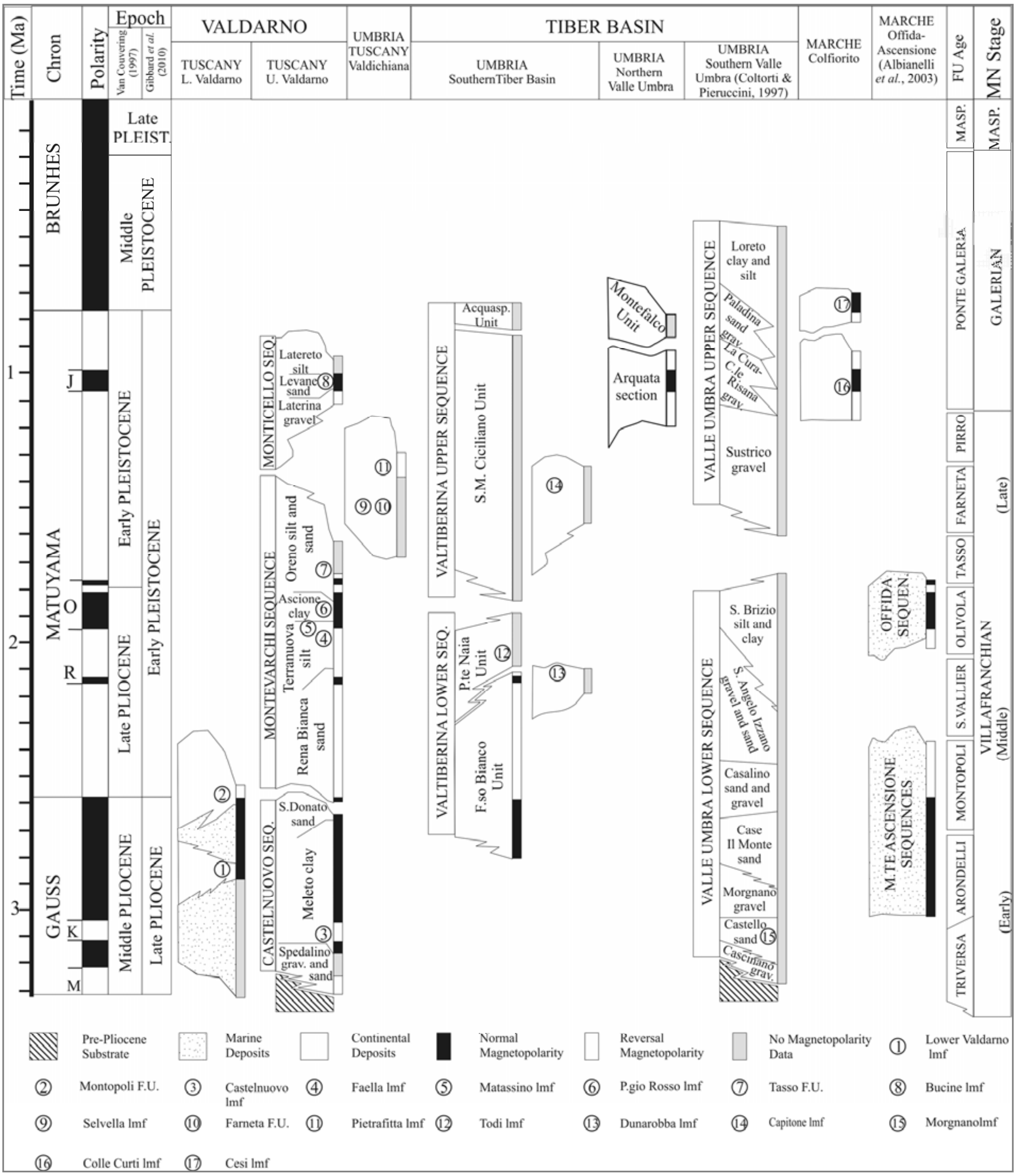

Fig. 7 - Magnetostratigraphic dating of Arquata quarry section and the Valle Umbra sedimentary sequences positioned within the Apennine Basins' evolution (redrawn and modified after Napoleone *et al.,* 2003). Calibration of local mammal faunas (lmf) and of main Faunal Units (F.U.) to GPTS is also shown.

Datazione magnetostratigrafica della sezione di Cava Arquata, ed inserimento delle sequenze sedimentarie della Valle Umbra nel quadro evolutivo dei Bacini Appenninici (da Napoleone et al., 2003, ridisegnato e modificato). È riportata anche la calibrazione delle faune locali a mammiferi (lmf) e delle principali Unità Faunistiche (F.U.) con la scala GPTS.

to local variations concerning petrology, grain size and organic matter amount (Einsele, 1992; Van Asselen *et al*., 2009, with refs.).

2) Contrary to Valdarno Basin, which on-sets on a more erodible sandstone substratum (*Macigno s.l. Auct.*), Tiber Basin, particularly Valle Umbra, largely set up on a limestone substratum, and sandstones (*Marnoso-Arenacea s.l. Auct.*) only locally crop out. Thus, a primary difference in sediments supply must been considered too.
3) In the case of Arquata, the above reported geostructural observations stressed the occurrence of the well visible fault cutting the profile, of minor interruptions due to the inclination (10°-12° SW) of the strata respect the steps of the quarry, as well as of fractures with a not significant dislocation in the upper profile. The latter have been sampled in detail on both sides for a better control. The sampled 55 m can be thence less than those actually deposited: although the disturbances seem at a direct view of minor size, two effects implicitly add to one another. On the one hand, the interval of normal polarity should be slightly thicker, leading to a larger accumulation rate and therefore closer to those measured in Valdarno and Valtiberina; on the other hand, duration in the adjacent intervals of reversed polarity is shortened and a certain amount of its thickness removed by this main fault, to become reduced significantly. It therefore appears quite likely an accumulation rate of 25-30 m/100 ky, which can become even higher in the final steps of filling - more alluvial and palustrine- as documented in the Valdarno basin (Napoleone *et al.,* 2004). In the latter occasion, the control was made by the cyclostratigraphic distribution of the magnetic signature through a 0.5 my long sequence, enhancing at least five steps of increasing sedimentation rates. The consequence would be, for the present profile, a reduction of the erased pile of sediments to less than 25 m, which is significantly shorter than earlier implied but still much more than it appears to a direct view.
4) If we consider the lack of about 5 to 15 m of the succession as exclusively due to the fault occurring between lower and upper sections, an average sedimentation rate of about 25-30 m/100 ky is still appropriate. To support the hypothesis, one more consideration may help, changing accumulation rates in the range from 24 m to 30 m/100 ky, with extremes reaching as much as 19 m to 35 m/ 100 ky: the datum is consistent with paleoenvironmental reconstruction, as the Jaramillo record occurs on both lacustrine clay and alluvial plain silty clay/ sand, that would remark a large shift in accumulation rates.

At last, an average 25 m/100 ky sedimentation rate, as well as values comprised between 19 m/100 ky and 30 m/100 ky, are perfectly comparable to these of other Basins (Valdarno, Valtiberina).

It seems plausible to assume for the top reversed interval of 11 m a date shortly younger than the upper limit of Jaramillo at 0.970 Ma, e.g., in the range of 0.940-0.920 Ma; for the lower reversed magnetozone a rate of 30 m/100 ky yields to a date ranging 1.050 Ma (on top) to one not older than 1.130-1.140 Ma (Fig. 3). Also assuming a lower average sedimentation rate (25 m/100 ky), the section bottom cannot be in any case considered older than 1.2 Ma. These time constrains, as well as the occurrence of Jaramillo, allow attributing the Arquata section to the end of Early Pleistocene, to which the Villafranchian-Galerian boundary has been also calibrated (Fig. 7). Mollusc and ostracod assemblages agree with a Late Villafranchian age, perfectly consistent with the attribution of the long reversal interval (R1 and R2 magnetozones) to the Matuyama chron. Furthermore, the fossil assemblages in the lower section, which have been collected inside the R1 reversal interval, more than 10 m from the base of N1 interval, are considered as not older than Tasso F.U. Moreover, *taxa* such as *V. belluccii, M. curvicosta* and *V. interposita*, as well as the occurrence of *C. torosa*, restrain the time interval to the Tasso and Farneta Faunal Units (Gliozzi *et al.*, 1997). Both Tasso and the successive Late Villafranchian F.U. (Farneta, Pirro) are calibrated to the reversal magnetopolarity interval successive to Olduvai, whereas to the latter are linked the transitional Olivola-Tasso faunas of Matassino and Poggio Rosso (Napoleone *et al*., 2003). The biochronological record, indeed, is still consistent with the date of nearly 1.140 Ma at the base and 0.940-0.920 Ma at the top, although clearly Galerian faunas have not been documented.

5.3 Cyclicities in the magnetic signal as produced by climate changes in Valdarno and Valtiberina

A short recalling is needed for the reported results from Valtiberina sediments also for their pollen content in cyclostratigraphic distribution, as well as a direct correlation with that in the Valdarno by the continuous dating tied between them. Palynological data from the Valdarno Basin have already shown when in its layer beds the vegetation changes marked the onset of a decidedly oscillating pattern from deciduous forest or still subtropical to an open field herbaceous cover of arid climate origin. Dates of such an onset and durations of the steady cyclic patterns were constrained by a high resolution accuracy provided by detailed magnetostratigraphy to have occurred since Pliocene throughout the beginning of Pleistocene, and they tightly correspond to the ones enhanced by the magnetic signal, across a 1.5 Ma record from Kaena through Olduvai chrons. Each limit of the various magnetochrons there present provided tie points to which the cyclic oscillations are tuned, in order to control their rhythms and/or duration in the accumulation hiatuses. Therefore, grouping in few classes the continuously varying cyclicities, major changes range from 21 m/100 ky in the lowermost lacustrine clay to 27 m/100 ky, 31 m/100 ky, up to 36 m/100 ky for the maximum influx of sand filling the deposit. When the signal processed in cycle length/meter is tuned to precisely timed tie points, the cycle length in years is expressed in intervals strikingly corresponding to the Milankovitch cyclicities. The shorter one among precession, obliquity and short eccentricity, prevails in the lower pile of sediments; at the date of 2.86-2.84 Ma a rather sudden increase of amplitude affects the obliquity cycle, while a marked eccentricity is already visible in the short profile of Olduvai time beginning just before the Gelasian-Crotonian boundary. When climate gets prevailingly driven by the short eccentricity cycle at dates close to Jaramillo, the shortness of time series in the Arquata profile would barely allow to detect such a cycle, unless it was strongly recorded as it occurred in the Olduvai profile for the Valdarno.

6. CONCLUSIONS

Two major conclusions may be stressed from the present study, both mainly descending from magnetostratigraphic dating. First, the fluvial-lacustrine deposition in Valle Umbra was over by nearly one million years ago. The inferred presence of sediments equivalent to the Montefalco conglomerates (Fig. 7), tectonically displaced in the nearby exposures, would imply a short duration for their deposition, which makes still rather long the missing time span until Present, i.e. up to the historic and protostoric times. Secondly, the time length recorded at Arquata would not exceed 300 ky, which leads to roughly imply that only 10-15% of the possibly 3-to-1 Ma of the Tiber Valley infilling is here exposed. From the purely geochronologic point of view one may recall another conclusion, i.e., all recorded proxies benefit a date to which their alleged ages are calibrated; having the direct chronologic reference, adjustments may be done for correlation with other exposed sequences. Such is the case of the present biochronologic record, whose assessment in the calibrated frame of the Apennine basins may be accomplished: the Tasso F.U. established in the Valdarno is calibrated to a date lasting 1.6-to-1.7 Ma, right after the end of Olduvai chron. The malacofauna recovered at Arquata, therefore, is dated quite younger than the vertebrate Tasso F.U., and confirms that biochronology by itself is a fairly weak tool for timing short intervals. A multidisciplinary approach, also involving magnetostratigraphy, if possible is therefore already preferable.

Another important result is that the Arquata section revealed, in the present study, a number of similarities in its evolutionary trend with other basins of central Italy, as well as a clearer assessment of the geological events through the Tiber Valley. Its magnetostratigraphic dating provides a second constrain for Valle Umbra evolution (Fig. 7), after the attribution of Morgnano lignite to Triversa F.U., dated to 3.3 Ma in the Valdarno basin. With such time limits, the two main sedimentary cycles here recognized by COLTORTI & PIERUCCINI (1997) are still confined. The lower cycle can be linked to Pliocene, whereas the top of the second one date to the end of Early Pleistocene (Fig. 7). Thus, this study in Valle Umbra adds a decisive element to define, until the date of 1 Ma, the evolution of Tiber Basin in the paleogeographic setting of Apennine basins. The intermediate cycle, well documented in the Valdarno basin and commonly accepted although not dated also for Valtiberina (NAPOLEONE *et al.*, 2003), still has not been recognized here, being probably buried below exposed sediments. Arquata date across the Jaramillo chron helps enhancing how facies associations in the eastern branch may be related to those in the western branch, the Valtiberina (Fig. 7). Here the earliest lacustrine deposition in the Fosso Bianco Unit, dated as old as late Gauss chron, constrains the overlying fluvial deposits of S.M. di Ciciliano Unit to be coeval with those of the Valdarno Basin final filling, but, while magnetostratigraphic data presently enable timing in detail the deposition of these two units of the Tiber Basin, it does not occur for the intermediate ones, for which it is desirable a direct time control. The immediate prospect is that several paleogeographic restorations can be quantitatively controlled by timing their evolutionary extent. It is also worth noting that the measured dates for the final filling of Valle Umbra Basin, marked also in the surrounding intermountain basins, are recorded in the marine hemipelagic deposits of the eastern Apennines belt of the Umbrian-Marchean realm, i.e. in the basins of the peri-Adriatic platforms (ALBIANELLI *et al*., 2003). Continental and marine sediments belonging to the same chrons, are then coeval in deposition. Even in the marine conditions, the depositional features followed similar rhythms, with a long continuous phase in the earlier ages of Pliocene since Mammoth and Kaena chrons followed by a shorter interval crossing the Olduvai; more displaced are the youngest deposits, but all dates are strikingly corresponding on both sides of the Apennine divide (Fig. 7).

On such prospects it would be important to pay careful attention on timing the intensive tectonics in the uplifting of peninsular Italy.

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