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The Plio-Pleistocene continental record in Italy: highlights on Stratigraphy and Neotectonics

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THE PLIO-PLEISTOCENE CONTINENTAL RECORD IN ITALY: HIGHLIGHTS ON STRATIGRAPHY AND NEOTECTONICS

TORINO, ITALY FEBRUARY 24 | 26, 2015

Editors Giovanni Monegato, Franco Gianotti e Maria Gabriella Forno

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Immagine di frontespizio

Panoramica della Dora Baltea nell'anfiteatro morenico di Ivrea presso Vische.
Foto di Franco Gianotti.

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In honour of Francesco Carraro

The congress is in honor of Francesco Carraro one of the AIQUA founding members and former President in 1997-2000. The congress focuses on major updates in the research fields that he fostered in the last fifty years: the methodological approach on the stratigraphy of Plio-Pleistocene Italian continental records, sediments, geomorphological evidence with also climatic and paleontological implications.
A further issue concerns the development of studies on active tectonics and seismic hazard. The meeting will be introduced by Giuseppe Orombelli and Fabrizio Galadini key-talks.

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Paleofloristic record from the late Matuyama-Jaramillo Chrons in central Italy (Valle Umbra, Tiberino Basin)

A. Baldanza[1], R. Bizzarri[1], R. Colacicchi[4], P. Corrado[2], D. Magri[2], E. Martinetto[3]

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From the Pliocene to present day, the eastern branch of the Tiberino Basin (Valle Umbra, Fig. 1) followed a peculiar sedimentary evolution, which significantly differed from the evolution of the south-western and northern portions [Ambrosetti et al., 1995; Coltorti and Pieruccini, 1997; Melelli et al., 2010; Martinetto et al., 2014]. The area evolved through time, still maintaining its organization of endorheic basin. Nonetheless, the sedimentary deposits record paleoecological and paleoclimatic changes ranging from subtropical swampy environments (Morgnano lignites, Triversa F.U.) [Pantanelli, 1886; Cappuccino et al., 2006] to the alternation of dry and rainy temperate periods in historical time [Colacicchi and Bizzarri, 2008].

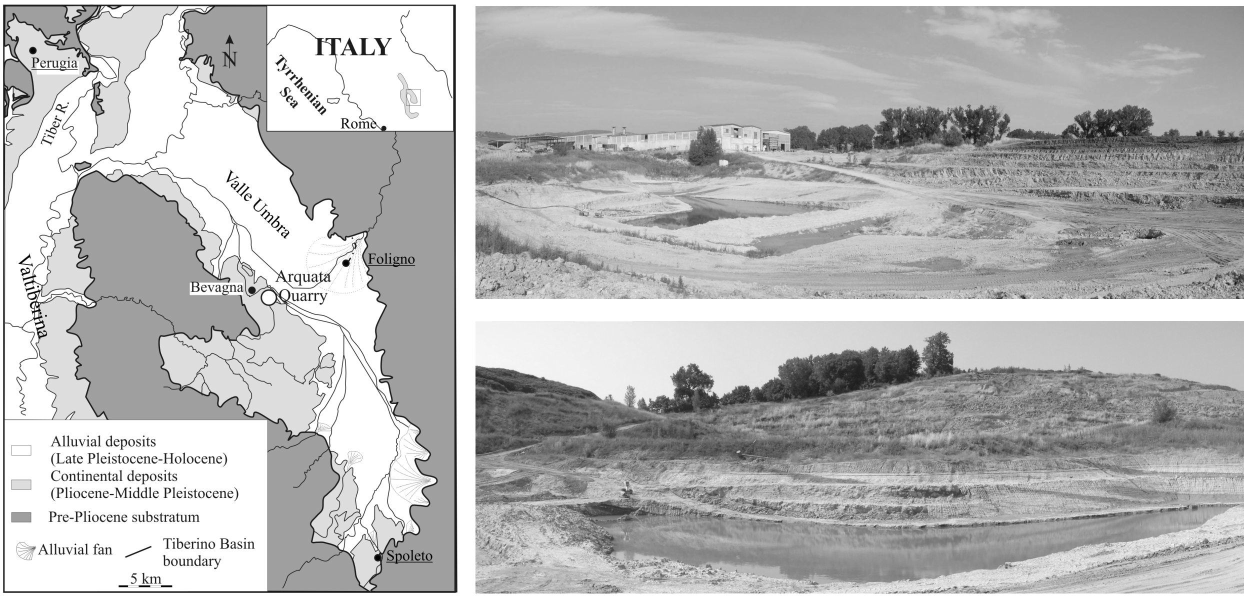

Figure 1. Localization and panoramic views of Arquata Quarry.

The Bevagna-Arquata quarry section (Fig. 1), attributed to the late Early Pleistocene, based on the record of the Matuyama-Jaramillo magnetic inversion [Bizzarri et al., 2011], fits into this scenario. Shallow to relatively deep lacustrine deposits and alluvial plain deposits hold a minor but noteworthy paleofloristic record, made of carpological remains, dispersed throughout the section, and pollen, in the intermediate portion.

Paleocarpological remains prevalently originate from the local (azonal) vegetation of waterlogged environments. The abundant remains of the genus *Schoenoplectus* (Cyperaceae) are particularly interesting for showing a transitional morphology between possibly extinct Pliocene-Pleistocene plants (*S. lacustrioides*) and two modern strictly related forms (*S. lacustris* ssp. *lacustris* and *S. lacustris* ssp. *glaucus*).

A new pollen record from a 4.4 m thick section highlights a conifer-dominated forest phase with abundant *Pinus*, *Cedrus* and *Abies*, showing percentages > 20%, accompanied by *Tsuga* and *Picea*, not exceeding 5%, and discontinuous presence of *Cathaya* type and *Taxodium* type. Among deciduous trees, only *Carya* displays high values (>20%). On the whole, this pollen assemblage points to a temperate-wet interglacial period. However, a significant presence of *Liquidambar* (>5%), together with *Olea* and Ericaceae, highlights increasingly mediterranean conditions towards the end of the record. The abundance of tree taxa that are currently absent from the Italian Peninsula clearly points to pre-Jaramillo late Early Pleistocene biostratigraphical characters, as observed in other sedimentary deposits from Central Italy [Bertini, 2010; Magri and Palombo, 2013], and contributes to a better definition of modes and timing of their disappearance. These new floristic records appreciably improve our knowledge of the paleoenvironmental and climate conditions in central Italy during the late Early Pleistocene.

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The importance of stratigraphic and structural aspects in the mitigations of landslides involving slopes near Aguggia (San Damiano d'Asti)

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The research was performed in order to evaluate the different geological aspects that contributed to the landslides genesis through the importance of the stratigraphic and structural features in the prediction and mitigation of landslides.
This study was conducted using a detailed stratigraphic and structural geological surveys near Aguggia (San Damiano d'Asti) where slopes are involved by landslides. In this sector of the Villafranca d'Asti type-area, the sediments are referred to the villafranchian Lower Complex (Ferrere Unit) that lies on the marine sediments (Asti Sand) [Carraro Ed., 1996].
The Asti Sand consists of not stratified medium-fine grained sand or with horizontal planar lamination, showing local wave structures (symmetrical ripples). It is locally rich in coastal marine molluscs, forming centimetric-decimetric levels. These sediments, of an overall yellow color (2,5YR 8/6 Munsell), appear strongly cemented, particularly where the fossils are abundant. The horizontal planar lamination, the coastal fossils and the local tidal structures indicate a littoral marine environment. The fossil content suggests a reference to the Zanclean [Festa et al., 2009].

Figure 1. Metal mesh containment adhering to the Sabbie di Asti outcrops to mitigate the risk of falls on the viability.

The Ferrere Unit, forming the basal body of the villafranchian Lower Complex, shows a substantial sedimentary continuity with the underlying marine sediments. This unit, 25 m thick, consists of cross bedded coarse grained sand, with laminae in the opposite direction. The laminae are connected to the tidal streams, typically with opposite directions. The textural features and the cross bedding are according to a coarse grained sedimentation in a deltaic front, in which the re-sedimentation of the shells of the Asti Sand often occurs. This unit contains levels rich in centimetric fragments of marine mollusks. Not stratified sand with

sub-horizontal and vertical galleries locally also occurs. These features suggest that these sediments are linked to a shallow depth with a poor deltaic sedimentation and a strong reworking of sediments. The sedimentary and paleontological features define a deltaic front system, in progradation phase, interbedded with beach sediments. The fossil content suggests a reference to the Piacenzian.
This study highlights that the landslides types are linked to the different sedimentological features of the units above described. Moreover, the considerable slopes acclivity, close to 45% in some sectors, is a predisposing factor in the genesis of the landslides.
The presence of a cementation that characterizes the Asti Sand, giving a massive appearance, and the structural features, mainly represented by vertical fractures, give rise to rock fall represented by wedges that are strictly driven by the fractures. The local administration has done with the installation of metal mesh containment adhering to the walls of the outcrops with cable bands, to mitigate the risk of rock falls (Fig. 1).
Instead, the lower consolidation degree and the finer texture of sediments that characterize the Ferrere Unit give rise to landslides characterized with by predominant rotational slip (Fig. 2). In these cases, the best arrangement of the instability is represented by the realization of anthropic terraces in order to reduce the gradient of the slope and channel the water surface runoff.
The study therefore shows the importance of the stratigraphic and structural features in the prediction and mitigation of landslides.

Figure 2. Arrangement of rotational slip with anthropic terraces, underlined by dotted lines, involving Ferrere Unit sediments on the right sector and recent rotational landslide on left sector.

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The history of Late Pliocene-Middle Pleistocene terrestrial settings in Italy: vegetation and palaeoenvironmental changes as a response to Northern Hemisphere insolation forcing and regional tectonics

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Palynology strongly contributes to the reconstruction of the main palaeoenvironmental changes that occurred in intermontane depressions between the Piacenzian and the Middle Pleistocene. The pollen record from the Upper Valdarno (UV, central Italy) is used here as a reference to trace and compare the floristic and vegetational history of other Italian continental settings (e.g. Piedmont basin, Tiberino basin, Colfiorito). The UV is one of the best known basins of the Northern Apennines where lacustrine and fluvial sediments deposited since 3.3 Ma. Pollen data specifically reflect the effects of the astronomical climatic cyclicity of 40 ka and then 100 ka, i.e.: 1) the transition from the uniform, humid, subtropical Piacenzian to the climatically much more unstable Gelasian-Calabrian; 2) the increasingly arid and cool to cold phases dominated by herbaceous vegetation alternated with humid and warmer phases characterized by the expansion of arboreal vegetation progressively depleted of the more thermophilous components, in the course of the Calabrian and Ionian. Both climate and tectonics strongly interplay driving the changes in the structure and floral composition of wetlands associated to successive depositional environments. Since 2.6 Ma swamps notably change in structure, with a large reduction of subtropical taxa, especially *Taxodium*/*Glyptostrobus* type and the progressive expansion of warm temperate forest taxa. At the same time, marshes expanded with plants able to resist in dynamic environments affected by river action. Major global climate changes, i.e., the phase of maximal expansion of the Arctic ice (expressed by the first spread of herbaceous formations) and the Mid-Pleistocene transition (which caused the final disappearance of the subtropical taxa) were rather coincident with the most important tectonic phases in the basin and had in turn serious consequences also on the latest Pliocene to Middle Pleistocene faunal communities. This highlights how the knowledge of the relationship between climatic changes (at global scale) and tectonics (at local to regional scale) is relevant, also for stratigraphical purposes, permitting a comprehensive interpretation of the continental sedimentary records.

First paleoseismological evidence of active deformation along the eastern front of the Southern Alps (NE Italy, Friuli)

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The area under investigation belongs to the Julian Prealps, that represents the easternmost portion of the Plio-Quaternary front of the eastern Southalpine Chain, a south-verging polyphase fold and thrust belt, in evolution since the Middle Miocene and presently active. Here, the WSW-ENE trending, SW-verging thrust system joins the NW-SE trending, right-lateral strike slip Idrija fault system, affecting the Italian-Slovenian boundary.

The area is characterized by medium/high seismicity testified by both large historical and instrumental earthquakes [e.g. Anselmi et al., 2011]. The DBMI11 [Locati et al., 2011] records the 1348 Carinzia earthquake (Mw= 7.02), the 1511 Idrija earthquake (Mw=6.98), and the 1976 Friuli earthquakes on May (Mw=6.46) and September (Mw=5.98).

The structural framework of this sector is characterized by a series of WNW-ESE trending, SSW verging thrusts, that border the hills overlooking the plain or buried under the Upper Pleistocene-Holocene alluvial deposits; these structures are probably linked to the NW-SE trending Borgo Faris dextral strike slip fault that affects the base of the inner Prealps [Zanferrari et al., 2008]. In particular, we studied the shallow deformations induced by the buried Colle Villano thrust near Magredis village: here, surficial geomorphic evidence (drainage anomalies, gentle scarps and back tilted surfaces) of tectonic displacements were identified. The analysis of the industrial seismic lines confirms that the Upper Pleistocene – Holocene deposits are involved in the deformation. In order to characterize the Late Pleistocene-Holocene activity of Colle Villano thrust, paleoseismological investigations were performed. We dug three excavations close to the village of Magredis (~1 km to the north). The analysis of the trench walls allowed to identify the occurrence of recent deformation events induced by faulting (Fig. 1). Two subsequent episodes of deformation were represented by very localised warping (few metres wave length) of the sedimentary sequences exposed by the excavations; secondary extrados faulting was also recognised. One event occurred between 544-646 AD (radiocarbon cal. age, 2σ) and 526-624 AD, the other – probably the last one – occurred close to 1485-1604 AD.

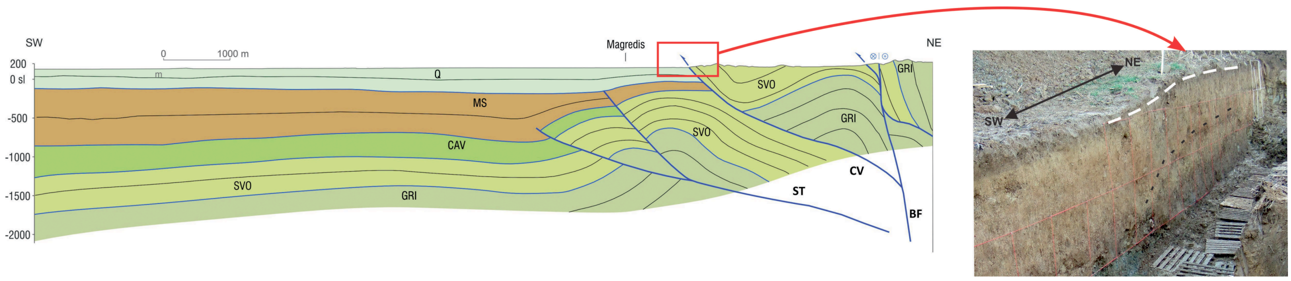

Figure 1. Geological cross-section crossing the Borgo Faris and Colle Villano faults, left panel; Legend: Q: Plio(?)-Quaternary succession; MS: Upper Miocene Molassa; CAV: Lower Miocene Molassa; SVO: Savorgnano marls and sandstones (Ypresian p.p.); GRI: Grivò Flysch (Thanetian? – Ypresian p.p.). ST: Susans-Tricesimo thrust; CV: Colle Villano thrust; BF: Borgo Faris strike slip fault. Northern wall of one of the trenches dug across the Colle Villano fault; white dashed line marks the scarp at surface; black dashed line marks the bending affecting the sedimentary sequence exposed by the trench.

The last event is consistent with the aforementioned 1511 earthquake in terms of both chronology of the deformation and location of the causative fault. This seismic event – one of the largest earthquakes that struck Northern Italy in the past millennium – has been tentatively attributed to the activation of Idrija fault system [Fizko et al., 2005]. Nevertheless, no paleoseismological evidence of this has been provided; moreover, the damage distribution of the event suggests its seismogenic source to be located at the easternmost portion of the Julian Prealps. The results of our investigations therefore indicate that the eastern Southalpine Chain has been probably involved in the seismotectonic framework of the 1511 seismic event.
The present study adds information useful for improving the understanding of the active deformation of the NE sector of the eastern Southalpine Chain and provides geological insights, substantiated by first ever paleoseismological trenches made along the compressive front about one of the most problematic seismotectonic "knots" of Northern Italy, i.e. the 1511 earthquake.

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Sedimentological and mineralogical reconstruction of a Quaternary sequence in Val Rosandra (Trieste, NE Italy)

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The Rosandra torrent is the only surface river in the Trieste karst area. The river springs are located in the Eocenic Flysch (Slovenia); then, it flows at first toward NE, then to SW, carving a gorge in the Cenozoic limestone of the southeastern sector of the Karst of Trieste, up to the Gulf of Trieste (NE Adriatic Sea). At the end of the Rosandra gorge, along the northern side, roughly 12 m high of loose and weakly cemented deposit (Fig. 1) outcrops [Cucchi et al., 2009].
The deposit is composed by a number of alternating silt, sand and gravel levels. The lower part is mainly composed by fine-grained sediments, while the upper part is coarser. Nine samples were collected to determine the sedimentological and mineralogical characteristics of the sequence and to define the related sedimentary processes and the paleo-environmental setting.

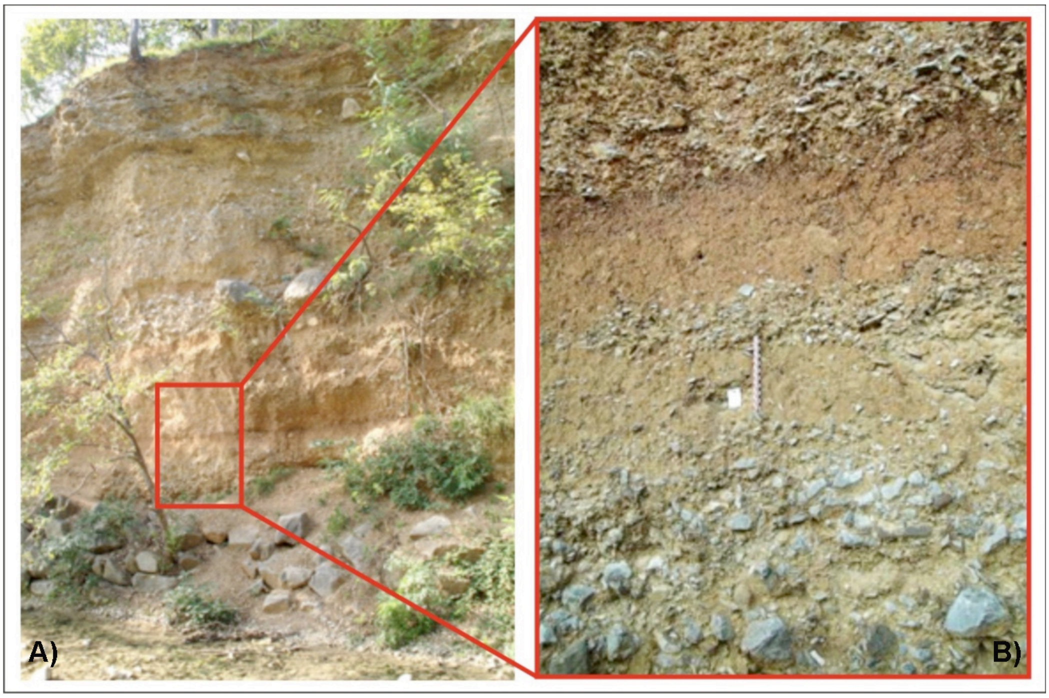

Figure 1. A) general view of the outcrop; B) location of the ^{14}C sample.

Most of the sequence is characterized by alluvial levels which reflect different energy environments. Alluvial levels are characterized by high percentage of gravel together with sandstone and marls clasts. The sand and silty fraction are both characterized by high value of quartz and feldspar; in particular, quartz ranges between 50 and 70 %. The origin of quartz and feldspar could be related to the Flysch related to the Beka – Ocizla sincline, located upstream from the deposit, close to the Rosandra springs.
Level 3.1, which is composed mainly by gravels and sands and is characterized by subangular limestone clasts. This sediment is similar to debris deposits locally outcropping. Some blocks, up to 1 meter in size, are included in the level 7 related to gravitational processes and landslides. In correspondence of the lower part of the sequence, the level 6 is a coarse silt with fine gravel and very high percentage of quartz (93%). The compositional and sedimentological features of the level suggest the occurrence of a loess or reworked loess deposit. Its reddish hue suggests some degree of soil development. In the Trieste karst area, Middle

Pleistocene loess was found, usually reworked by colluvia, in the infilling deposits at the "Riparo di Visogliano" [Falguères et al., 2008], whereas Late Glacial loess commonly occurs in several caves [Boschian 1998; Boschian and Desantis 2011].
From a genetical point of view, the deposit can be roughly divided (Fig. 2) in three parts. I) A basal part, at the cliff toe (Lev. 1 and 2), which is composed by medium and high energy alluvial levels. II) a middle part, which is characterized by fine loess sediments, gravitational deposits (debris and landslides deposits) and, to a lesser extent, alluvial deposits. III) the upper part of the sequence is again alluvial, from middle to high energy.

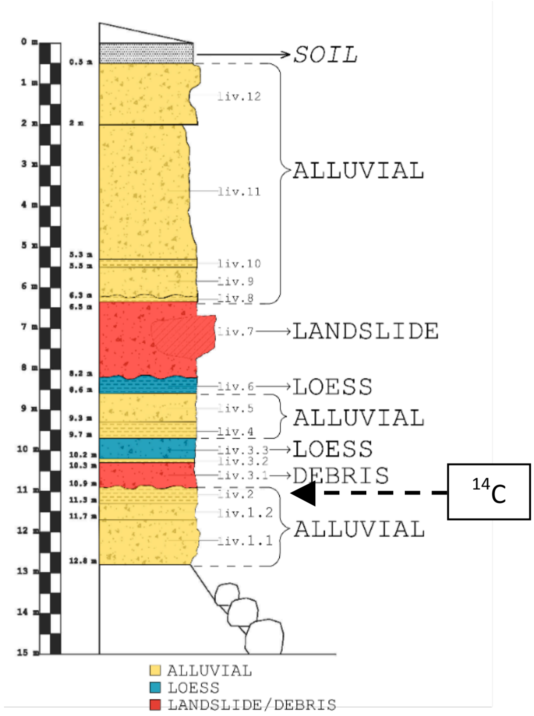

Figure 1. Genetic interpretation of the sequence.

The changes in sedimentary processes and the occurrence of debris and loess indicate a relatively cold and dry environment, which is opposed to the relatively wet and hot environment related to the alluvial deposits.
Further studies are needed to define the absolute age of the sequence. ^{14}C dating on a frustule plant collected on Level 2 (> 45.000 yrs BP) suggested that the lower part of the sequence (alluvial levels and loess) could be related surely pre LGM, while only the upper alluvial sequence could be LGM in age.

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Late Quaternary alluvial megafans in northern Italy

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Large fan-shaped landforms represent most of the northern Po Plain (40,000 km^2) and its eastern continuation, the Venetian-Friulian Plain (10,000 km^2). Major Alpine rivers which feed this Alpine-Apennine foreland basin drain a total catchment of about 100,000 km^2 (70,000 Po R. tributaries, 25,600 Venetian-Friulian rivers).

The main depositional phase occurred during LGM (27-19 ka cal BP), when the glaciers hosted in the Alpine valleys reached the plain and fed the related glaciofluvial and fluvial systems [Fontana et al., 2014]. These latter experienced large and widespread aggradation as fan-shaped distributary systems, that have been described as alluvial megafans when their longitudinal axis is >30 km (i.e., Isonzo, Tagliamento, Piave, Brenta, Adige, Mincio, Chiese, Oglio, Adda, Olona river systems). These large landforms have an extent of 500-3000 km^2.

Pede-Alpine megafans are characterized by steep (1-0,5%) piedmont sectors consisting of amalgamated gravels down to 10-30 km from apex, while the distal sector is fine-dominated and channels are sandy braided. The thickness of LGM sediments in the plain is 30-10 m, thinning to <5 m on the Adriatic Sea shelf, where depositional bodies dating to LGM or previous low-stand units (i.e. MIS 3 and 4) still largely crop out. Following ice decay, after 19-17 ka cal, an erosive phase occurred in the pede-Alpine sector during Lateglacial and early Holocene. This led to river downcutting for tens of meters. Alpine tributaries of the Po River still flow in entrenched valleys down to their junction. In the Venetian-Friulian sector, where distal tract of megafans are directly connected to the Adriatic Sea, incisions have depths of 15-30 m and widths up to 2 km. Post-LGM sedimentation in the valleys consisted of predominant gravels and sands down to the present coastal area. After 8.0 ka cal the sea-level rise triggered the formation of the coastal wedge, the infilling of the valleys and widespread aggradation in the interfluves.

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Evidence of fault inactivity: a multidisciplinary approch integrating Geomorphology, Stratigraphy and Paleontology

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We have here analysed the western flank of the central Apennines, where the calcareous slope is bounded by marine /fluvial deposits. In detail, we studied the Fara in Sabina Mounts, a NW-SE oriented ridge, bordered toward SW by a normal fault. The aim of this work is the reconstruction of the sedimentary, morphological and tectonic quaternary evolution of this sector and the evaluation of the activity of the above mentioned normal fault. A multidisciplinary approach, coupling geological-geomorphological survey, facies analysis and paleontological constrain, has been followed. Moreover, through this analysis we aim to better understand the reliability of geomorphic features, such as the fresh exposure of fault planes along bedrock scarps as certain evidence of active faulting in the Apennines, and to define the Quaternary kinematic history of these tectonic structures. The experience gathered in previous work [Fubelli et al., 2009] suggests that the so-called 'geomorphic signature' of recent fault activity must be supported by wider geomorphologic and geologic investigations, such as the identification of displaced deposits and landforms not older than the Late Pleistocene.

The Fara in Sabina Mts. are made of deformed Mesozoic limestone and marls in transitional facies between the Abruzzi platform and the Umbria-Marche pelagic basin. Along its slope, at elevation ranging between 260 and 277 m a.s.l. several holes of lithodomus mark the uppermost paleoshorelines (UPS) related to a marine transgressive phase of Gelasian age. Paleontological analysis have been made on some boreholes sampling of the related marine and transitional deposits (Chiani-Tevere Formation) [Cosentino et al., 2013]. Above 268 m a.s.l., gastropod-bearing black sandy silts with benthic foraminifera and ostracods define a brackish environment (coastal lagoon) characterized by changes in paleosalinity [Cosentino and Fubelli, 2008]. Anancus arvernensis and Stephanorhinus etruscus, found in lignitiferous deposits north of Fara Sabina [Tuccimei, 1889, 1891; Maxia, 1949], coexisted during the Middle Villafranchian mammal age and characterized the Montopoli, St. Vallier and Costa S. Giacomo faunal units (Late Pliocene-Gelasian) [Gliozzi et al., 1997]. Facies analysis allow to recognize a deltaic system attributable to a shelf-type (Fig. 1) which top depositional surface is recognizable east and northward, at increasing elevation until the Rieti area and correlates the sea level markers of the UPS at 270 m a.s.l. [Cosentino and Fubelli, 2008]. Deposits are made of conglomerate, sand and clay and, eastward, they pass from an alluvial fan to an alluvial braided plain facies attributable to the depositional dynamics of the PaleoFarfa River. The reconstruction of both the basal and top surfaces of the entire alluvial body provides evidence that the activity of Quaternary faults strongly influenced its deposition causing the adjustment of the whole PaleoFarfa drainage system. While upstream top surfaces of the Gelasian alluvial body results strongly affected by an intensive subsequent faults activity, responsible for the formation of the Rieti intermontane basin [Fubelli et al., 2014], in the sector close to Fara Sabina Mounts minor or no significant displacement of the top surface is present (Fig. 2). Actually, top depositional surface is cut by valleys which have been formed after the Middle Pleistocene uplift that involved the whole of central Apennines and caused a post Gelasian marine regression. Due to the interaction between the increase of the incision and climatic variations, during the Middle Pleistocene – Holocene, several orders of alluvial and marine terraces developed respectively along river valleys and Tyrrhenian coast [Centamore et al., 2003].

The geological and geomorphological evidence we collected indicate that the Fara Sabina area is characterized by low significant active faults during the whole Quaternary and that tectonic activity during Gelasian influenced the sedimentary architecture in the coastal portion of the PaleoFarfa River in a lesser way than to the internal sector. Moreover, our observations indicate that the investigated fault planes are exposed mostly because of the occurrence of nontectonic processes, i.e. differential erosion and gravitational phenomena. Trough geomorphological analysis on the younger river terraces and from the Gelasian paleoshoreline at 270 m a.s.l., a quaternary averaged uplift rate of 0.12-0.14 mm/year for this area has been calculated [Fubelli et al., 2014]. The present low seismicity related to these tectonic structures confirms that a fault activation for high magnitude earthquakes able to produce surface faulting can be considered improbable.

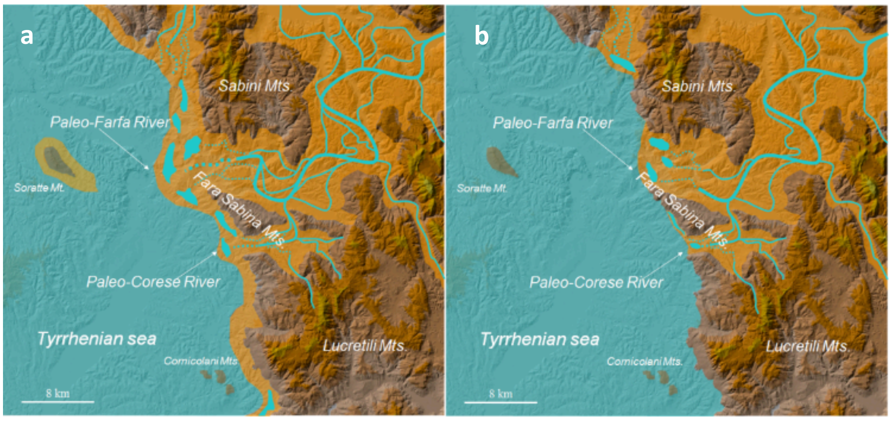

Figure 1. Paleoenvironmental reconstruction of the study area at the beginning (a) and at the end (b) of the Gelasian transgression.

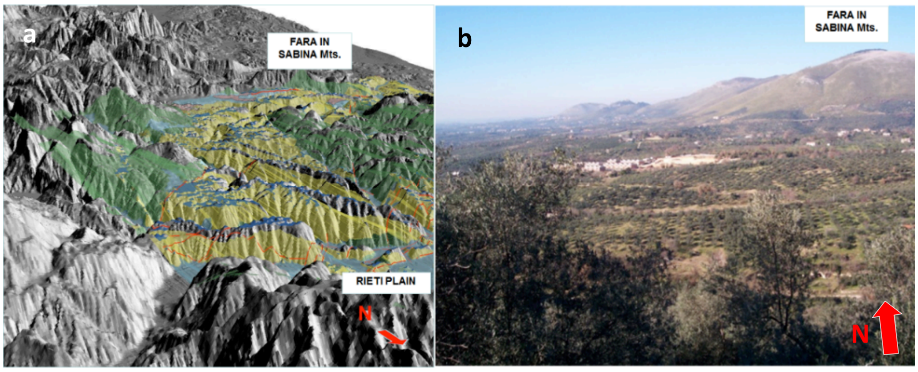

Figure 2. 3D reconstruction of the PaleoFarfa top depositional surface (a); view of the western flank of the Fara Sabina Mts (b).

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Late Quaternary evolution of the eastern sector of the Gulf of Trieste (NE Adriatic Sea)

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The Gulf of Trieste (GOT) is an epicontinental semi-enclosed shallow marine basin in the NE Adriatic Sea, max 25 m deep. Marine sedimentation is strongly affected by local inputs of freshwaters. In particular, the main fresh-water inflow is the river Isonzo and the Timavo in the north and some minor rivers in the southeastern sector [Covelli et al., 2006]. The eastern side of the GOT is bordered by rocky coasts and it is dominated by Cenozoic limestone plunging cliffs and Eocene flysch cliffs and shore platforms.
The neotectonic behaviour of the Gulf was firstly highlighted during the ‘80 by many authors, such as Zanferrari et al. [1982] or Carulli and Cucchi [1991]. Recently, field surveys on geomorphological and archaeological remains stimulated new researches along the whole coastline. In particular, Antonioli et al. [2007] and Furlani et al. [2011] established the tectonic rates using submerged notches and archaeological remains, Melis et al. [2012] using micropaleontological and archaeological markers, while Braitenberg et al. [2005] using short-term data, such as tide gauges and the Grotta Gigante pendulum, suggested that the SE-NW tilting is still active. Busetti et al. [2010] and Carulli [2011] also highlighted the recent activity of some faults in the Gulf.
New geophysical data collected in the southernmost sector of the Gulf allowed to integrate but also to highlight some local discrepancies in previous models. We aim at presenting a review of published and new data on the Late Quaternary evolution of the GOT on the base of geological, geomorphological, sedimentological and archaeological markers.

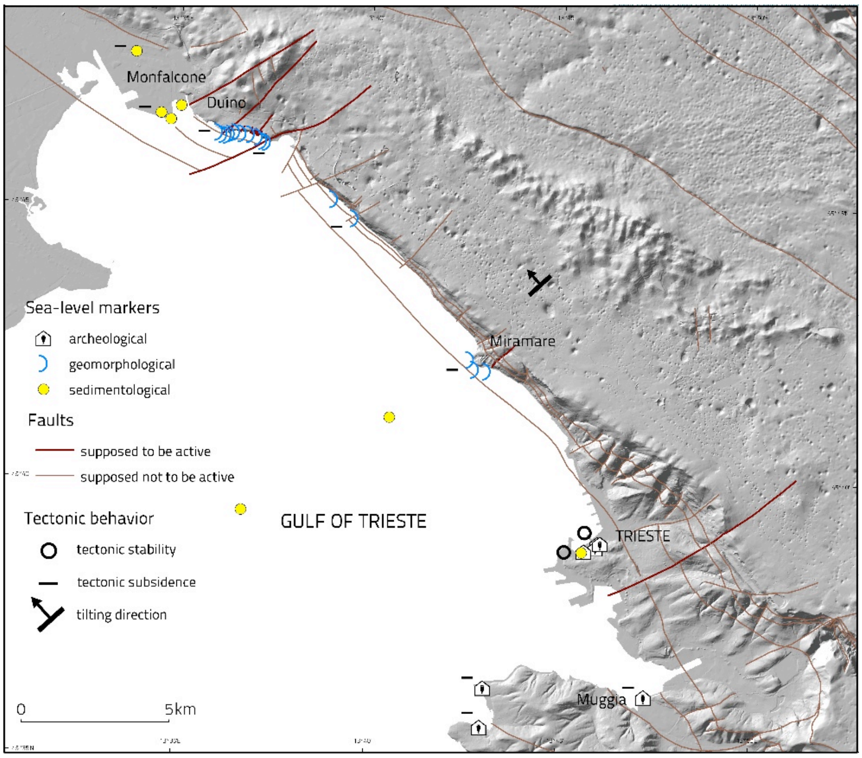

Figure 1. Morphoneotectonic sketch of the Gulf of Trieste.

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Could the low Cerrina Valley (Piedmont – NW Italy) be an Early and Middle Pleistocene trough developed behind the Monferrato thrust front?

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The lower Cerrina valley is located in the northern Monferrato (Fig. 1) and is clearly oversized compared to the stream currently present. Its direction is influenced by tectonics as it corresponds to the axis of a syncline directed first from NW to SE, then WE and finally about SN. Within this valley are extensive and well-preserved Early and Middle Pleistocene alluvial and lacustrine sediments, unique case in the whole Monferrato-Turin hills system. The lithological composition of the alluvial sediments suggests that they were deposited by a river of alpine origin, coming from NW, that flowed into the valley [Giraudi, 1981; Carraro et. al., 1995; Giraudi et al., 2003; Dela Pierre et al., 2003].

Even the Tertiary sediments indicate the peculiarity of the Cerrina Valley: is the only place in the context of the Monferrato and Turin Hills, where the Messinian sediments do not surround older deposits but are entirely surrounded by them, and are not underlying Pliocene marine sediments, but Plio(?)-Quaternary continental deposits. The absence of Pliocene marine sediments implies the emergence of a part of the Monferrato, already hypothesized by Dela Pierre et al., [2003].

Also the thrust front north of the Cerrina Valley appears peculiar because it is formed by two different fronts (Fig. 1A) that extend further north than in the surrounding areas.

As part of the interpretation of the tectonics of the front of the Northern Apennines, Costa [2003] hypothesizes that the front of the Monferrato, to the North of the Cerrina Valley, is advanced because of the presence of two faults, transcurrents or transpressives, that act as ramps. The two faults converge towards the margins NW and NE of the valley (Fig. 1B) and their presence seems to be confirmed by Giraudi [2014].

According to the data [ENEL, 1984] obtained during seismotectonic studies for nuclear power plants, the Lucedio and Cavourrina faults, corresponding to the two thrust fronts shown in Fig. 1A, were active even after the sedimentation of the deposits dated to the late Early Pleistocene. The faults are present, however, only in the area north of the Cerrina Valley, while elsewhere the thrust front corresponds to a flexure.

The thickness of the sediments in the basin north of the faults indicates greater subsidence than in the surrounding areas, lasting at least until the Middle Pleistocene. These data were also confirmed by Giraudi [2014] on areas close to the one investigated by ENEL [1984].

According to Dela Pierre et al. [1995] the Pliocene and Quaternary subsidence of the foredeep basin North of the Monferrato thrust front reflects the reactivation of the front and the uplift of Monferrato and Turin Hills. As a consequence of the northward migration, behind the uplifted area, deep piggyback basins were formed at Saluzzo and Alessandria.

It follows that, because the hills to the north of the Cerrina Valley are those who have suffered the most recent uplift produced by the Monferrato thrust front [Dela Pierre et al., 2003], it is reasonable to assume that the Cerrina Valley syncline evolved, at least from the Early Pleistocene, as a subsiding basin produced by the northward migration of its northern slope lying between the faults hypothesized by Costa [2003], which served as "ramps".

Figure 2 presents the environmental and chronological data related to the sediments lying inside the Cerrina Valley and in the area just north of the thrust front.

The chronology, obtained thanks to paleomagnetic analysis, paleontological studies and dating with the method of the racemization of the amino acids of fossil teeth [Giraudi, 1981; ENEL, 1984; Giraudi et al., 2003], the evaluation of the faults activity and of the degree of deformation and subsidence, allowed to compare the evolution of the two places.

The good chronological correlation between phases of tectonic deformation helps to support the hypothesis that the Cerrina Valley, uplifted after the Messinian and remained emerged during the Pliocene, subsided and expanded during the Quaternary due to the northward migration of the Monferrato thrust front lying below the southern Vercelli plain.

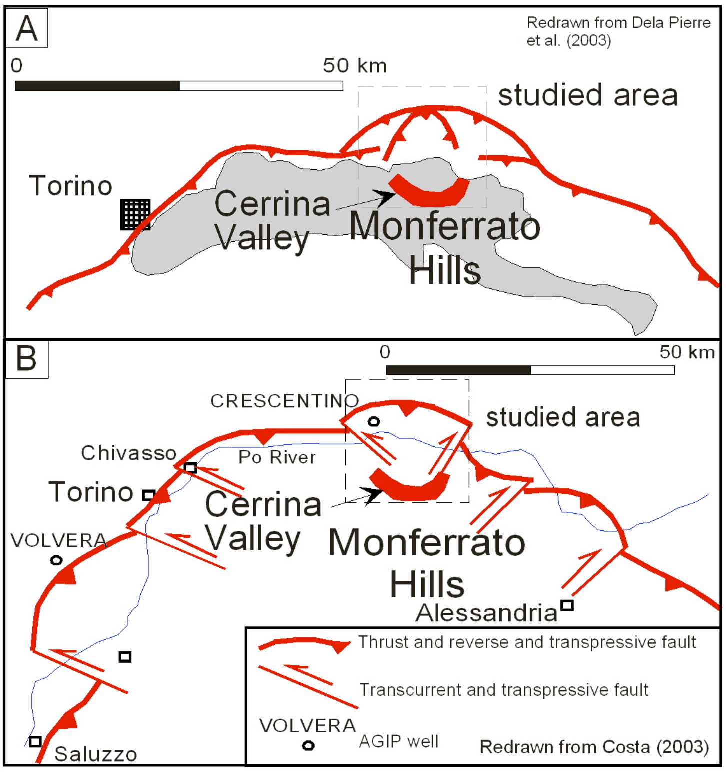

Fig. 1

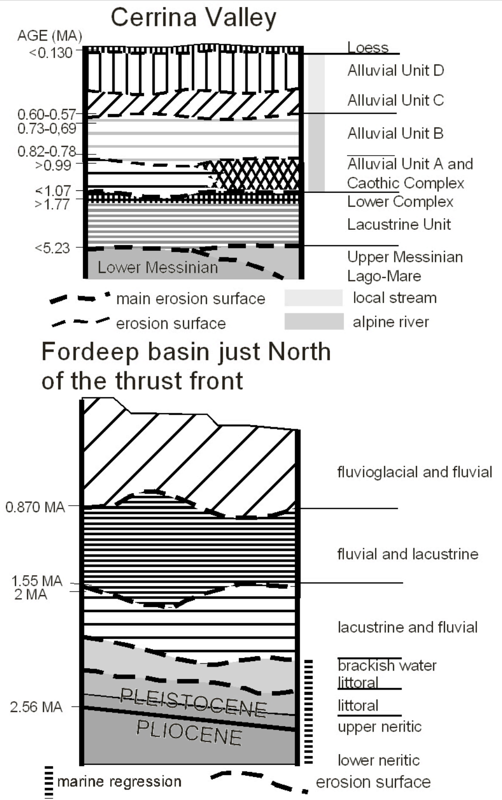

Fig. 2

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Early capture of a central Apennine (Italy) internal basin as a consequence of enhanced regional uplift at the Early-Middle Pleistocene Transition

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Extensional tectonics in the inner portion of the central Apennines began during the Late Pliocene-Early Pleistocene. It resulted in the formation of chain-parallel normal fault systems, whose activity through the Quaternary led to the formation of intermontane tectonic basins; these represented traps for continental sedimentary sequences. In particular, during the Early Pleistocene most of the central Apennine depressions hosted lakes, testifying to endorheic hydrographic networks. Afterwards, lacustrine environment was replaced by fluvial regimes, aged at the Middle Pleistocene, as the hydrographic systems of the basins were captured by headward regressive erosion coming from the outermost sectors of the chain. This is testified by a strong erosional phase that cut into the lake sequences, due to deepening of streams and river incisions, and the subsequent deposition of embedded fluvial deposits. This environmental change is commonly attributed to a regional relief enhancement, as a consequence of the increase of regional uplift of the central Apennines (and geologically seen in many parts of the Apennine chain), generically aged between the upper part of the Early Pleistocene and the lower part of the Middle Pleistocene [e.g. D'Agostino et al., 2001].
The Subequana Valley and Middle Aterno Valley are part of a cluster of Quaternary tectonic depressions distributed along the current course of the Aterno River - here termed the Aterno basin system - which also includes the L'Aquila and Paganica-Castelnuovo-San Demetrio basins to the north, and the Sulmona basin to the south. They are located in the innermost sector of the central Apennines, in correspondence of the chain divide. These basins are hydrographically connected by the Aterno river, one of the moste important fluvial basins of the "Adriatic domain" which runs south-easterly along the eastern side of the Subequana basin and Middle Aterno Valley and flows to the Sulmona basin through the San Venanzio gorges, where it joins to the Pescara river. The depressions are bounded towards the NE by an active normal fault system that led the formation and the tectonic evolution of the basins [Falcucci et al., 2011].
The analysis of the early Quaternary geological evolution of this depression can represent a significant case study to refine the knowledge of the Early-Middle Pleistocene tectonic/environmental transition, especially in terms of timing, taking into account that uplift rate is defined as having been larger along the chain divide.
We integrated geological, geomorphological, paleomagnetic and radiometric dating with the $^{40}Ar/^{39}Ar$ method to reconstruct the morpho-stratigraphic setting of the Subequana Valley-Middle Aterno river system, defining the paleo-environmental features and chronology of the depositional and erosive events that have characterised the Quaternary geological and structural evolution of these basins.
In detail, a synchronous lacustrine depositional phase was recognised in the Subequana basin and the Middle Aterno Valley. Paleomagnetic analysis performed along some sections of these deposits exposed in the Subequana valley attested a reverse magnetisation, reasonably related to the Matuyama Chron. The lacustrine sequence of the Subequana valley passes upwards to sand and gravel, testifying for the infilling of the lake and the onset of a fluvial regime that displays a direction of the drainage towards the north, i.e. opposite to the present Aterno river flow. At the topmost portion of the lake deposits, two subsequent tephra layers were identified and dated by means of $^{40}Ar/^{39}Ar$ method, at ~890ka, for the lower tephra, and ~805ka for the upper one. It is worth noting that a "short" direct magnetisation event occurred just above the lower tephra, whose significance is still under investigation.
This data constraints the infilling of the lake in the Subequana valley very close to the Early-Middle Pleistocene transition. Subsequent to the infilling of the Subequana basin, a fluvial regime, characterised by a northward drainage direction – i.e. opposite to the current one –, was established. Then, after a strong erosional phase, the presence of a new coeval fluvial depositional phase within the Subequana Valley and the Middle Aterno Valley, with flow direction towards the south-east, indicates the formation of a paleo-Aterno.
We identified a further fluvial sequence, embedded within the lacustrine sequence through an evident erosional surface. These deposits are found at the northern part of the Subequana valley, where they laterally

pass to fluvial deposits that crop out at the southern part of the Middle Aterno river valley; this sequence shows a flow direction consistent with the current direction of the Aterno river. This morpho-stratigraphic setting, schematized in Fig. 1, indicates that after an intense erosional phase, which dissected the lake sequence, the Subequana-Middle Aterno river valley system has been hydrographically connected by the course of a paleo-Aterno river; this river flowed southerly, towards the San Venanzio gorges.

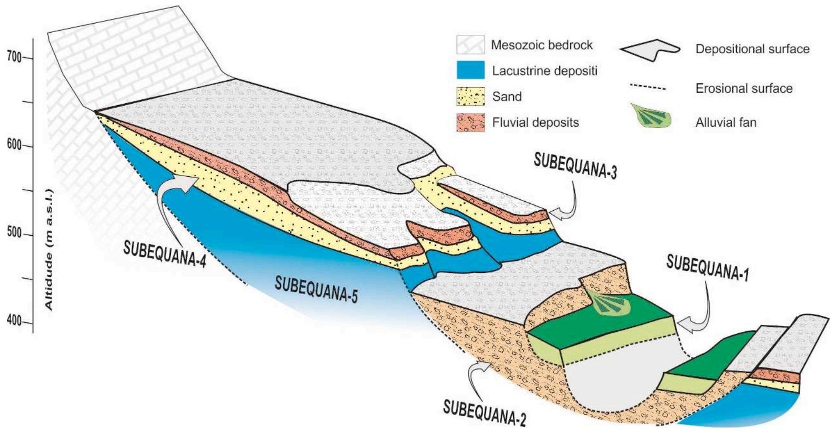

Figure 1. Quaternary morpho-stratigraphic setting of the Subequana Valley.

Such morpho-stratigraphic interpretation is corroborated by geological observations performed in the Sulmona basin. At the outlet of the Aterno river, we found slope derived breccias, commonly attributed to the Early Pleistocene, that lay over the bedrock. Their depositional geometry suggests that the breccias deposited when the Aterno river thalweg was not present yet, that is when the Subequana Valley was hosting a lake and no drainage was hydrographically connecting the valley to the Sulmona basin. Then, an alluvial fan body unconformably overlays the breccias; the fan, suspended over the Aterno river thalweg, was fed by a stream incision coinciding with the paleo-San Venanzio gorges. Lastly, a fluvial deposit is found embedded within the breccias and the alluvial fan, sourcing from the San Venanzio gorges as well. A tephra layer was found interbedded to the sedimentary body. The volcanic deposit was related to the “Pozzolane Rosse” eruption of the Colli Albani district, dated at 456±4 ka BP [Galli et al., 2010]. This fluvial deposit indicates the presence a paleo-Aterno river flowing from the Subequana valley.
Therefore, the described morpho-stratigraphic framework, and the obtained chronological elements constrain the capture of the endorheic hydrographic network of the Subequana valley-Middle Aterno Valley during a time span comprised between ~800ka and ~450ka. In this perspective, it is worth noting that endorheic hydrographic networks of other basins (e.g. the Leonessa basins) located along the innermost portion of the central Apennine chain were captured during the same time span by headward erosion of streams and rivers related to the “Tyrrhenian hydrographic system” [e.g. Fubelli et al., 2009]. This provides new elements for unravelling coupling between river incision potential and capability, and the Apennine chain uplift.

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The first latest Piacenzian-Gelasian fluvial record in northern Italy: insights from the Alessandria Basin

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The continental record of the late Piacenzian-Gelasian in northern Italy is poorly documented by field-based studies, mainly because of the incompleteness and/or coarseness of the studied sections [e.g., Carraro, 1996; Boano and Forno, 1999; Vigna et al., 2010]. New integrated stratigraphic analyses (i.e.: sedimentary facies, gravel petrography, palaeomagnetic record, plant and fresh-water molluscs assemblages) in the southern margin of the Alessandria Basin, a large scale satellite syn-orogenic basin, located at the junction between the Alps and the Apennines, offer first insights into a late Piacenzian - Gelasian fluvial record, which appeared virtually undatable for the coarseness of most of the succession. In order to overcome this difficulty, we took the chance of the exceptional exposure of the lower part of the fluvial succession in a gravel pit and for the first time in northern Italy we relied on detailed bio-magnetostratigraphic analyses of fine-grained abandoned channel fills, included in the fluvial deposits.

During the Pliocene-Pleistocene transition the Alessandria Basin experienced N-S shortening and was overthrusted to the north onto the Po Foreland Basin along the Apennine/Padane thrust front [Biella et al., 1997; Piana, 2000]. In this contractional scenario, the sedimentary evolution of the basin was controlled by progressive tilting of the margins, related to the Alps and Apennine uplift, and ongoing subsidence in the depocenter. The sinsedimentary deformation produced an overall growth-syncline basin architecture, and progressive unconformities, punctuated by onlap terminations, at the basin margins [Bertotti and Mosca, 2009; Irace et al., 2010].

In the southern margin of the basin, the studied fluvial succession is gently inclined toward the N-NE. It is 25-30 m thick and is split by smooth basal angular unconformities (S1, S2 and S3) into three units (MRZ1, 2 and 3), which show internal decreasing dip values from the bottom (5°) to the top (1-2°), consistent with the growth strata geometry depicted by subsurface interpretations. MRZ1 and MRZ2 (shallow to confined braided systems) are restricted between 2.8 and 2.6 Ma from bio-magnetostratigraphic analyses. The overall stratigraphic framework indicates syntectonic deposition and erosion during the progressive uplift of the Alps and Apennines. However, the frequency of unconformities and sedimentary changes suggest the superposition of orbitally forced glacio-eustatic cycles to the tectonic deformation, which has its climax in the Gelasian, as revealed by the 450 ka to 600 ka long hiatus associated to S3. The subsequent deposition of MRZ3 (meandering systems), including a Gelasian magnetic reversal, points to the fading of tectonic activity.

In conclusion:

- multidisciplinary analyses document for the first time that in the Alessandria Basin coarse fluvial sedimentation started in the latest Piacenzian, after the climatic deterioration recorded at ca. 2.80 Ma (G10 in [Lisiecki and Raymo, 2005]).
- the late Piacenzian-Gelasian time bracket was interested by a long-lasting regional deformation phase related to the Alps-Apennine tectonics, that shaped an unconformity-bounded stratigraphy in the interposed Alessandria basin. The contribution of the contemporary global climate change can be even detected within the mainly coarse grained fluvial stack of this basin, but only in the late Piacenzian, while the tectonic climax had been overwhelming during the Gelasian. In this perspective, the tectono-sedimentary framework depicted for the Alessandria Basin shares good similarities with those of other synorogenic basins of the northern Apennine system: the hinterland Valdarno [Ghinassi et al., 2013] and Valdelsa Basin [Benvenuti et al., 2014] and the piggy-back Castell'Arquato Basin [Roveri and Taviani, 2003].
- the stratigraphic reconstruction marks important improvements on the knowledge of European continental biota: the carpoflora assemblage reflects the cooling after 2.8 Ma with persistent lack of

humid thermophilous plant taxa of East Asian affinity and occurrence of several cool-tolerant extra-European taxa (e.g. *Ampelopsis* cf. *ludwigii*, *Boehmeria lithuanica*, *Cryptomeria rhenana*); the fresh-water mollusc assemblage shows the occurrence of *Pomatias elegans* and *Tournouerina belnensis*, identified for the first time in the Pliocene of northern Italy.

- the present work provides a case study for the palaeoenvironmental reconstruction of the margins of continental basins, which correspond to highly dynamic belts connecting the drainage networks of orogenic systems to the depocenters.

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An updated overview of the distribution of biochronologically relevant fruit and seed taxa in the Plio-Pleistocene of Italy

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The analysis of fruit and seed assemblages in Pliocene and Early Pleistocene successions of northern-central Italy provides an interesting record of the terrestrial palaeoflora, which complements the information derived from the extensive pollen records available in this area. Recently, several carpoflora-bearing layers, spanning from 5.1 to 0.9 Ma, have been inserted in a more accurate stratigraphic framework, sometimes with a precision of ca. 100 ka. The new data have been incorporated into a database named CENOFITA, whose analysis showed that the fossil record of several species was often limited to one to three chronostratigraphic stages of the Pliocene (Zanclean, Piacenzian) and Early Pleistocene (Gelasian, Calabrian). The analysis of the northern-Italian fossil record of such species allowed us to obtain an overview of the distribution of carpological taxa in the Pliocene and Early Pleistocene and to elaborate a new distribution chart. In this new chart the carpological species were clustered in six groups of species with similar chronologic distributions. We suggest that the analysis of such groups, in undated or poorly dated carpological assemblages, would be useful for their biochronological interpretation: the Zanclean floras can be distinguished by the Piacenzian ones in case of occurrence of Group 1 species, whereas the simultaneous occurrence of several species of Groups 2 and 3, without species of Groups 1 and 5, could be used to suggest a Piacenzian affinity for undated assemblages. The occurrence of several species of Groups 5 and 6, without species of Groups 1-3, may just point to a generic Gelasian or Calabrian affinity. The palaeoclimatic characterisation of the individual species, but also of the plant assemblages, suggests that a temperature decrease is one of the causes of the palaeofloral changes. In fact the most apparent events are represented by the disappearance of thermophilous species. The appearance of new species in the studied fossil record is mostly due to the establishment of favourable local environmental conditions, rather than to evolutionary events.
In this respect, our study revealed that it is necessary to separate northern from central Italy in the biochronological analysis of fruit and seed assemblages. In fact in central Italy, considered as a refuge area in the Early Pleistocene [Martinetto, 2001], some thermophilous plants of East Asian affinity (*Sinomenium cantalense, Symplocos casparyi, Toddalia rhenana*) occur in the Gelasian, whereas the north Italian data would point to a disappearance in the Piacenzian.

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The Sulmona Basin Lake during the early Last Glacial: Palaeoclimate vs Palaeohydrology

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The carbonate lacustrine deposits of the Sulmona basin represent a unique archive of palaeoclimatic and palaeoenvironmental data related to the Pleistocene. In fact, three main alluvial-fluvial-lacustrine units compose the Sulmona Pleistocene succession. Each unit is chronologically constrained by magnetostratigraphy, $^{40}Ar/^{39}Ar$ ages and tephrocronology [Giaccio et al., 2012; 2013a; 2013b; Sagnotti et al., 2014]. The section here investigated (POP section) consists of about 19 m of greyish to whitish, faintly to well stratified calcareous mud, with occasional dark-grey organic rich layers up to a millimetres thick. An erosion surface truncates the section, which is covered by fluvial sand and gravels of the Last Glacial [Giaccio et al., 2012]. The section has been studied and sampled both excavating a trench and drilling a core.
Along the section, four tephras (POP1, POP2a and POP2b, POP3) were recognised [Giaccio et al., 2012]. 2012]. POP1 and POP 3 have been dated by $^{40}Ar/^{39}Ar$ to 92.4±4.6 and 106.2±1.3 ka, and correlated to marine C22 and X-5 layer, respectively. During recent fieldwork, two additional tephras (POP2 and POP4) has have been uncovered. In particular the POP4 tephra 3.25 m below the POP3 tephra has been correlated to the X-6 marker [Regattieri et al., 2014], and now directly dated by $^{40}Ar/^{39}Ar$ to 109.5±0.9 ka.
Stable isotopes analyses have been carried out on the whole succession, with a resolution of ca. 10 cm corresponding to ca. 65 yrs for each sample [Regattieri et al., 2014]. The $\delta^{18}O$ values of the POP carbonate are relatively low (average - 9.32 ‰) implying that the input from karst springs with higher recharge areas, and thus lighter isotopic signal, overprints the signal of local precipitation in the lake water $\delta^{18}O$. In fact, most of the recharge area of the Sulmona basin karst springs lies between 1200 and 1500 m asl [Barbieri et al., 2005; Desiderio et al., 2005a; 2005b]. The $\delta^{13}C$ record decreases progressively towards the top of the section, indicating that the input from karst springs was less important than the oxidation processes of lake organic matter [Regattieri et al., 2014].
The interval between the POP3/X-5 and POP4/X-6 tephras records the cold event C24 and the Greenland Interstadial GI24. To better understand the evolution of the Sulmona Lake during this crucial climatic period, that also comprises the deposition of the Tyrrhenian sapropel S4, ostracod analyses have been performed on ca 20 samples. The ostracod associations provide relevant information about the changes occurring in the water body in terms of temperature, depth and aquatic vegetation.
Just above the POP4/X-6 tephra and for about 1 m of thickness, *Cytherissa lacustris*, *Cypria lacustris* and *Candona neglecta* (Assemblage 1=A1) occur in all samples with variable densities. *C. lacustris* lives nowadays in northern and central Europe in areas, which have cold-water conditions and oxygen content higher than 3 mg/l [Carbonel et al., 1988]. The same assemblage has been found living in the deep zone of the Geneva Lake, at a range depth of 13-70 m [Decruy and Venneman, 2014]. In the above two metres, *Cp. lacustris* and *C. lacustris* disappear and are replaced by *Pseudocandona marchica*, *Candona candida, C. neglecta, Isocypris* sp., *Cypridopsis vidua* and *Herpetocypris reptans* (Assemblage 2 =A2). A2 indicates shallow waters (littoral environment, depth range 2-13), characterised by macrophytes and high organic matter content made of degraded macrophytes and old macroalgae [Decruy and Venneman, 2014].
The drastic change in ostracod assemblage is not contemporaneous with the shift in d18O values, but occurs about 100 years later. This must be linked to the resilience of the lake ecosystem to the climatic change, i.e. the time required to return to an equilibrium or steady state after a perturbation.
Using the mutual ostracod range method (MOTR), a GIS-based method linking the occurrence of 75

European non-marine ostracod species to air temperature ranges, it has been possible to reconstruct the average July and June air temperatures for the two different assemblages [Horne et al., 2012]. Nowadays, the average temperature recorded in July is 23.5°C and in January is 3.9°C. In our fossil record, the air temperature ranges recorded by A1 are lower than the actual ones, both in July and January whereas the air temperature ranges recorded by A2 include the modern July and January temperatures.
The ostracod assemblages well record the differences in temperature between the cold event C24 and the Greenland Interstadial GI24, although affected by the buffering effect of the water body. Such effect could depend from the large inflow of water from karst springs, confirming that the very low values of $\delta^{18}O$ are linked to spring water recharge from higher altitudes and not to higher temperatures.
It is still unclear whether the disappearance of A1 could be a symptom of the onset of meromixis, as occurred in many Alpine lakes when major climatic changes took place during the Late Pleistocene [Carbonel et al., 1988], or a progressive shallowing of the water body as suggested by the isotope signal.

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Aggradation of the Montebelluna Megafan (NE Italy) at the MIS 3-2 transition, problems and perspectives

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The Alps hosted a complex glacial system during the Last Glacial Maximum (LGM) and the previous glaciations. While landscape dynamics in the Alpine area and foreland alluvial plains during the LGM have been largely investigated, the evolution during preceding glacial-interglacial cycles is much less known. Some late Middle Pleistocene reconstructions, supported by independent age control, are available in the Northern [e.g. Dehnert et al., 2010; Preusser et al., 2011] and Southern Alpine sectors [e.g. Monegato et al., 2010; Rossato et al., 2013]. The sedimentary setting of the SE foreland of the Alps is strictly connected to the evolution of alluvial megafans with size up to 2600 km^2 (Fig. 1) [Fontana et al., 2014]. These large distributary fluvial systems achieved their maximum extent during LGM, burying older sediments under 20-30 m of deposits. Thus, pre-LGM successions are poorly exposed and can be investigated mainly through relatively deep coring. A noteworthy exception is represented by the Montebelluna megafan (D in Fig. 1), a pre-LGM sedimentary body of the Piave River which is covered by Brenta and Piave LGM sediments only in its distal portion [Mozzi, 2005; Fontana et al., 2008; Fontana et al., 2014].
The Montebelluna megafan has a double apex in the Caerano and Biadene valleys, West of the Montello Hill (inset map in Fig. 1), and is now detached from the present Piave channel belt by a W-E fluvial scarp, about 25 m high. It consists of gravels with thin and isolated sandy lenses. The top geomorphic surface has a steep gradient around 0.6% and shows well-preserved and dense braided channels. The top of the gravels can be traced underground until about 40 km downstream of the apexes, North of the town of Mogliano, at ca. 30 m depth. Tectonic activity of outermost Southalpine thrusts locally displaced the Montebelluna megafan at the southern foot of the Montello Hill [Mozzi, 2005].

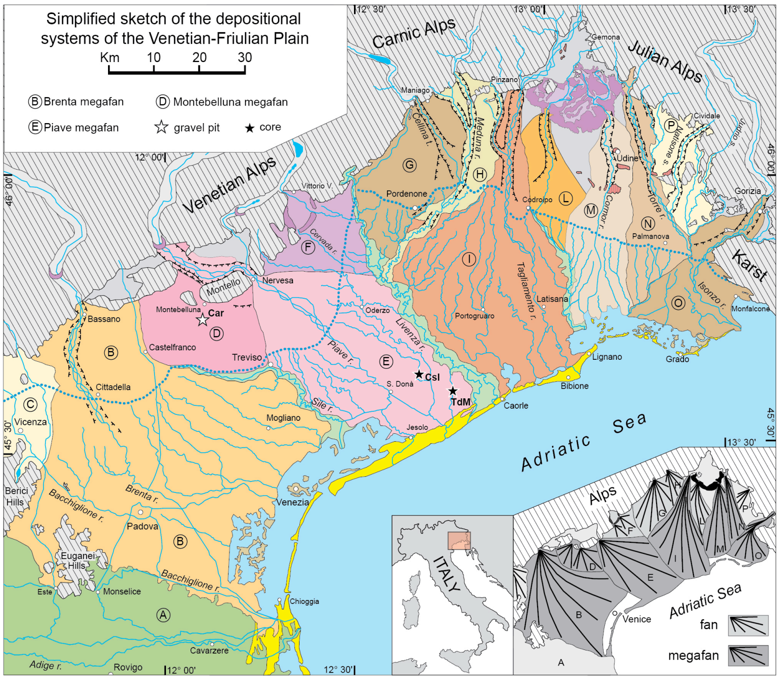

Figure 1. Simplified sketch of the Late Quaternary depositional systems of the Venetian-Friulian Plain. In the bottom-right corner, a scheme of the alluvial megafans and fans is presented (modified from [Fontana et al., 2008]).

New stratigraphic data have been recently acquired in the "Caravaggio" gravel pit, located 10 km downstream of the apex near Montebelluna (Fig. 1), where a section 200 m wide and 37 m high (41 m to 78 m a.s.l.) is visible. The succession consists of well-organized gravels (fine-to-coarse), with thin channel bodies and few decimetric lenses of sand. These latter have been sampled along the section for petrographic analysis (5 samples) and OSL dating (3 samples).
The preliminary results evidence a major change in the sand petrography. The uppermost sample presents a petrographic signature typical of the Piave R. catchment. The four lower samples are characterized by a higher content in metamorphic and volcanic rocks, which points to a contribution from the Cismon R., presently a tributary of the Brenta R.
OSL age estimates bracket the deposition of the uppermost 35 m between 37 and 26 kyr BP, a much younger chronology than the MIS 6 age suggested in previous interpretations [Carton et al., 2009]. The Montebelluna megafan apparently developed during the late MIS 3 and deactivated in the early MIS 2, due to the shift of the Piave R. to the North and East of the Montello Hill, possibly in response to the first major advance of the Piave glacier in the Prealpine valley reach.
In the distal sector of the megafan of present Piave R. (Nervesa megafan, E in Fig. 1), peaty and organic layers frequently occur in the alluvial sequences, allowing to build a detailed radiocarbon chronostratigraphy. In this area sedimentation was almost lacking during MIS 3, with thick peat accumulation documented in cores around 30-35 m of depth [Fontana et al., 2010]. On the contrary, since about 32-27 kyr cal BP, fast and widespread aggradation started in the area, supplied by the path of Piave River flowing eastern of Montello Hill. This sedimentation phase took place, with some discontinuities, until about 22-20 kyr cal BP, with a total thickness of about 30 m. Thus, the comparison between geochronological data from the Montebelluna and Nervesa megafans allows to discuss the interplay between these two large alluvial systems.

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Dispersal bioevents of large mammals in SW Europe during the Early Pleistocene: implications for biochronology and faunal dynamics

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Dispersal (species movement away from an existing population or away from the parent organism) is one of the fundamental processes in biogeography, crucial for understanding the evolutionary dynamics of organism distribution over time and across space [Colbert et al., 2012]. Dispersal events likely modify the structure of the pre-existing mammalian faunas and contribute to regulating both regional and local faunal renewals and diversity trends by leading to new dynamic equilibriums and promoting faunal turnovers through time.

As is often observed in secular models, Pleistocene mammals did not generally moved in multi-species waves of dispersal, rather each species changed its range depending on the suitability of environmental conditions in respect to its own environmental tolerances and ecological flexibility. In particular, the presence of important physical/ecological barriers may have prevented some taxa from reaching some territories or cause long delays in their dispersal, and the resilience of already established species might have slowed the spread of new taxa into some areas, leading to some diachronicity/asynchronicity in local first appearances.

Data available for SW Europe (Figs. 1 and 2), indeed, would show that factors driving the remodelling of the range of a species, and time and mode of its dispersal and diffusion into a given region often differed from species to species as from one territory to another [Palombo, 2014]. Nonetheless, numbers and characteristics of SW European LFAs (e.g. depositional context and taphonomical signatures, richness, evenness, and number of ecological groups) greatly differ from one geographic area to another, making any comparison between single LFAs difficult and scarcely informative. As a result, correlations and biochronological assessments of LFAS may be difficult especially when firm chronological constraints are unavailable. To group LFAs into Faunal Complexes (FCs), may help in reducing biases. Although FCs regarded as a proxy of a "biochronological unit" (see Palombo [2009] for a discussion) are unlikely to capture attributes arising from processes operating at small spatial scales, they should do well at summarizing the average structure and characteristics of a mammal fauna living during the biochron's time slice and comparing local versus regional long-term faunal dynamics.

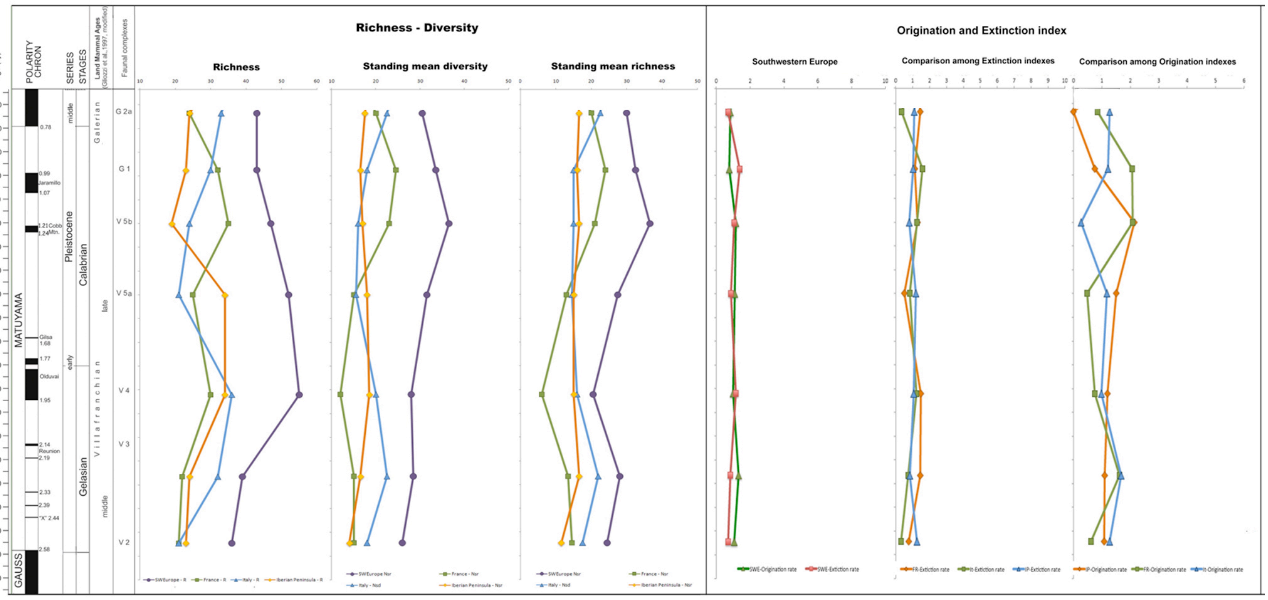

Figure 1. Comparison among trends of Richness, Diversity and Origination and Extiction Rates in the studied SW European faunal complexes (FCs) during the Early Pleistocene.

This research aims to investigate the relationship between climate change and ecosystem dynamics, disentangling the asynchronous and diachronous dispersal bioevents of large mammals across geographical and ecological boundaries, analysing functional diversity and its changes through time. Data on first/last appearances and chronological range of large mammals in SW Europe point out on one hand that per-dispersal first appearances generally outnumbered the per-in-loco-origination ones, on the other the asynchrony in several local appearances of taxa that dispersed from both Asia and Africa and, rarely, from Central Europe. During the Middle Villafranchian ELMA (V2 and V3 FCs), most of the newcomers spread across all of the SW European studied area, while from the time of the Olduvai palaeomagnetic event, inter-regional dispersals of multiple, potentially interacting species affected each region differently. The functional diversity (= relative abundance of ecological groups) changed across geographic gradients through the Pleistocene in a somehow unpredictable way, though species inhabiting open environments clearly dominated in SW Europe at the time of the Mid-Pleistocene-Revolution. In addition, the ecological structure of FCs suggests an overall prevalence of open environments on the Iberian Peninsula. In France forests and woodlands were on average more widespread, while a variety of habitats characterised the Alpine and Peninsular Italy. All in all, available evidence suggests that during the Early Pleistocene, the main global climate changes (particularly changes in periodicity) activated significant faunal dispersals and taxonomical turnovers. Some other gradual faunal changes developed during periods exceeding Milankovitch's cycles as the cumulative result of the responses of individual species to climate change, contraction and expansion of species range, and reassessment of biotic interactions. Diachronicity in local turnover across the focal territories probably relied on differences in local dynamic patterns of competition/coevolution, though different manifestations of global climate changes in different geographic settings would have contributed to scale local bioevents.

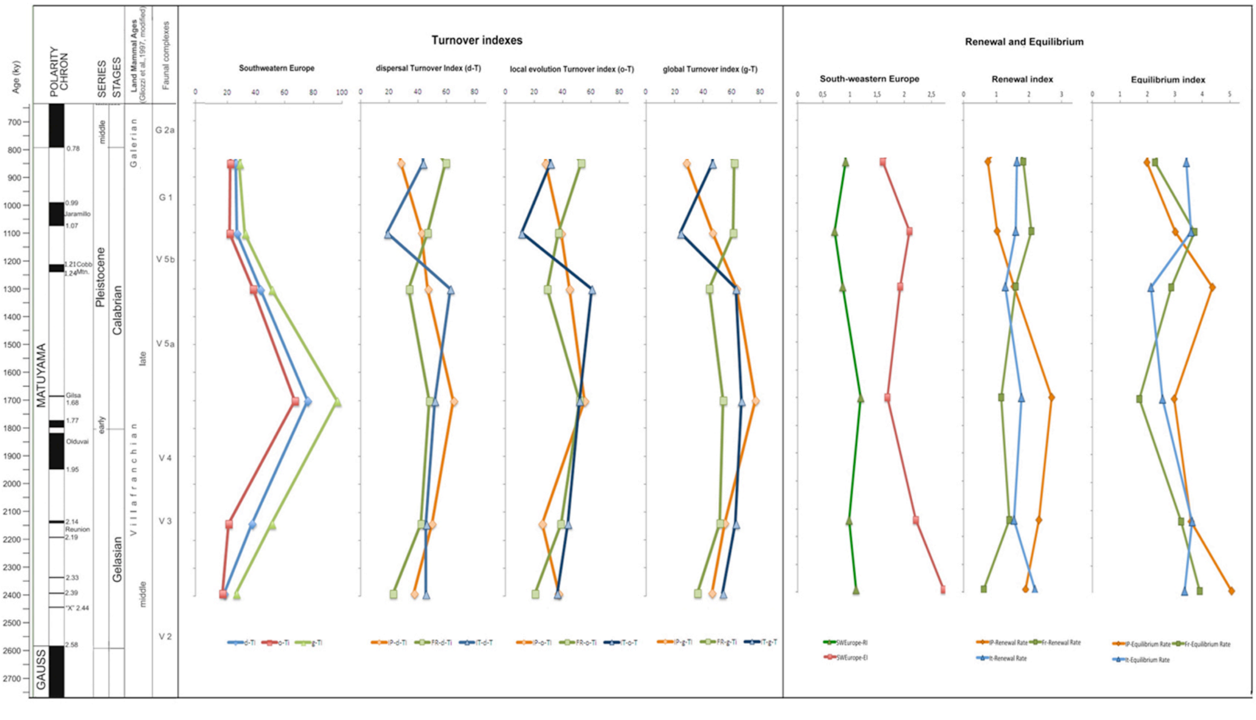

Figure 2. Comparison among trends of Turnover, Renewal and Equilibrium Indexes in the studied SW European faunal complexes (FCs) during the Early Pleistocene.

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Neotectonic evidence of the Plio-Pleistocene activity of the eastern Southalpine thrust front in western Friuli

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The last two decades of geological studies yielded new evidence for unravelling the activity of the Plio-Quaternary front of the eastern Southalpine Chain (ESC) in Friuli region. The ESC is a SSE verging, about WSW-ENE striking fold and thrust belt in evolution from the Middle Miocene to the Present. At present the ESC thrust-system accommodates about 2-3 mm/y shortening [Serpelloni et al., 2005, Bechtold et al., 2009] and crustal thickening and propagates towards the Friulian piedmont Plain. The Friulian prealpine area is characterized by medium/high seismicity both instrumental and historical. According the DBMI11 [Locati et al., 2011] some M>6 historical earthquakes hit the Prealpine area: 1348 (Carnia), 1873 (Bellunese), 1936 (Bosco del Cansiglio) and 1976 (Friuli). In the western sector of the ESC we investigated three main segments of the ESC front: 1) the Maniago-M. Jouf, 2) the Arba-Ragogna and 3) the Polcenigo-Maniago thrust systems.

Morphotectonic and stratigraphic analyses along the ESC front show many evidence of Plio-Quaternary deformation in correspondence to these major faults. Along the Maniago-M. Jouf system, at the Cellina valley outlet, the middle Pleistocene succession of Maniago Libero is thrust over the upper Pleistocene fan [Zanferrari et al., 2008]. At the Meduna valley outlet, the study of the terrace staircase [Monegato and Poli, 2015] illustrates a long lasting deformation in four different phases since the Pliocene. In particular, the deformation of alluvial unit related to the last aggradation of the Meduna fan (30 to 11 cal ky BP) points to a slip rate of 0.6 mm/y for the Maniago thrust.

The Arba-Ragogna thrust system shows morphotectonic evidence along the piedmont plain, built by the Cellina, Meduna and Tagliamento fans, such as anomalies of the fluvial drainage and an about 3 m high tectonic scarp between Valeriano and Lestans localities. Moreover the stratigraphic reconstructions along the fluvial scarps of the Valeriano and Gercia creeks and the Tagliamento River show a progressive unconformity stack involving the succession from the Pliocene to the late Pleistocene [Paiero and Monegato, 2003; Poli et al., 2009]. The LGM surface of the Tagliamento outwash fan is displaced of about 4 m on the tip line of the fault, showing an upper Pleistocene to Present slip rate of about 0.2 mm/y.

The Polcenigo-Maniago system cuts the alluvial fans interfingering with the major Cellina fan along the eastern piedmont area of the Cansiglio-Cavallo massif. The uplift produced a series of telescopic fans; those related to the LGM aggradation show surficial deformation corresponding to the faults of the thrust system. Locally the deposits related to the LGM Cellina fan [Avigliano et al., 2002] are displaced of about 10 m, suggesting also for this sector a recent slip rate of about 0.6 mm/y.

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Pleistocene large mammals and pollen from the Mercure Basin (southern Italy)

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The Mercure basin is an intramontane depression of the Southern Apennines, located in the central sector of the Pollino ridge along the Calabria-Lucania boundary. The basin separates the sedimentary terrains of the Southern Apennines from the metamorphic units of the Calabrian Arc and is filled in with Pleistocene fluvial, deltaic and lacustrine sediments [Monaco, 1993; Monaco et al., 1998; Schiattarella, 1998; Catalano et al., 2004]. Lacustrine sediments, made up of homogeneous laminated whitish clayey silts, containing tephra layers, represent the final phase of the basin infill and partly crop out because of river dissection (Fig. 1; [Robustelli et al., 2014]). These sediments were ascribed to a general Middle-Late Pleistocene age according to large mammal biochronology [Cavinato et al., 2001].

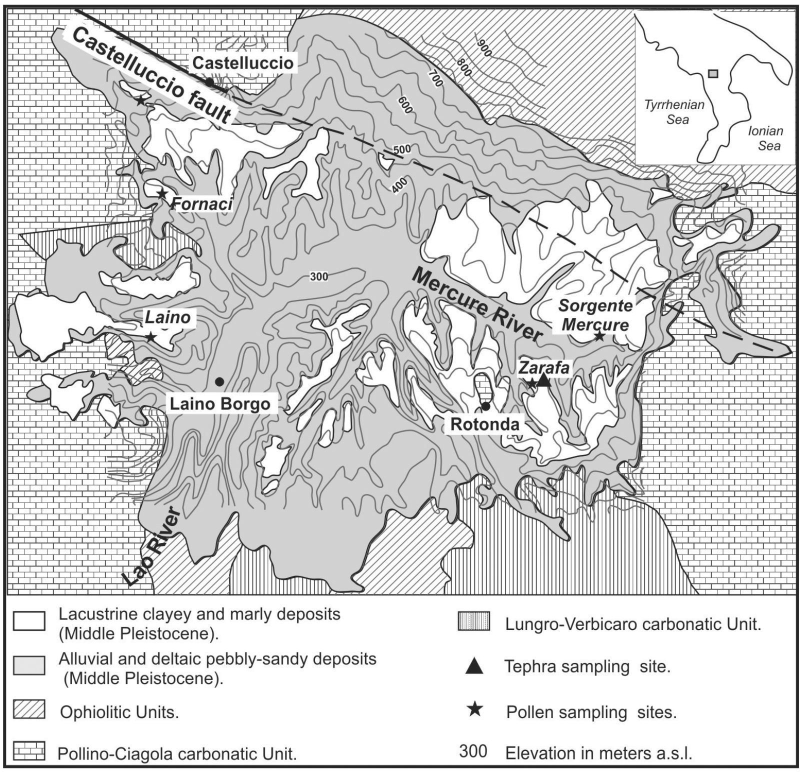

Figure 1. Geological map of the Mercure basin (after [Petrosino et al., 2014]).

Large mammal fossil bones were found in different localities within the Mercure basin. The most complete record comes from the fluvial deposits, underlying the outcropping lacustrine silts, excavated at Calorie (Rotonda), where an almost complete skeleton of *Palaeoloxodon antiquus* was unearthed together with *Stephanorhinus hundsheimensis*, *Hippopotamus antiquus* and a large mustelid [Cavinato et al., 2001; Cherin et al., 2013]. This faunal assemblage can be referred to the early Middle Pleistocene (Galerian mammal age). A Galerian faunal assemblage was also found at Fornaci (Fondo Pagano, Castelluccio Inferiore): fragmentary remains of a large megacerine deer, possibly referable to *Praemegaceros* ex gr. *P. verticornis*, *Dama* cf. *D. clactoniana* and *Bison* sp. [Cavinato et al., 2001]. From the same locality and also at Scaldacane, near Rotonda, fragmentary remains of *Dama dama*, *Cervus elaphus* and *Equus hydruntinus*, were collected but their stratigraphic position is unknown, and all the taxa can be generally referred to the late Middle-Late Pleistocene (Aurelian Mammal Age).

Recently, a preliminary tephrochronologic investigation and pollen analyses were carried out on the infilling succession exposed along V-shaped tributary valleys of the Mercure river [Petrosino et al., 2014]. Lithological and chemical features of the thickest and best preserved tephra layer were fully characterised, and single crystal $^{40}Ar/^{39}Ar$ dating was performed yielding an age of 514±16 ka [Petrosino et al., 2014]. Pollen analyses revealed the occurrence of warm and humid interglacial conditions that were correlated to MIS 13 on the basis of the age determination (Fig. 2).

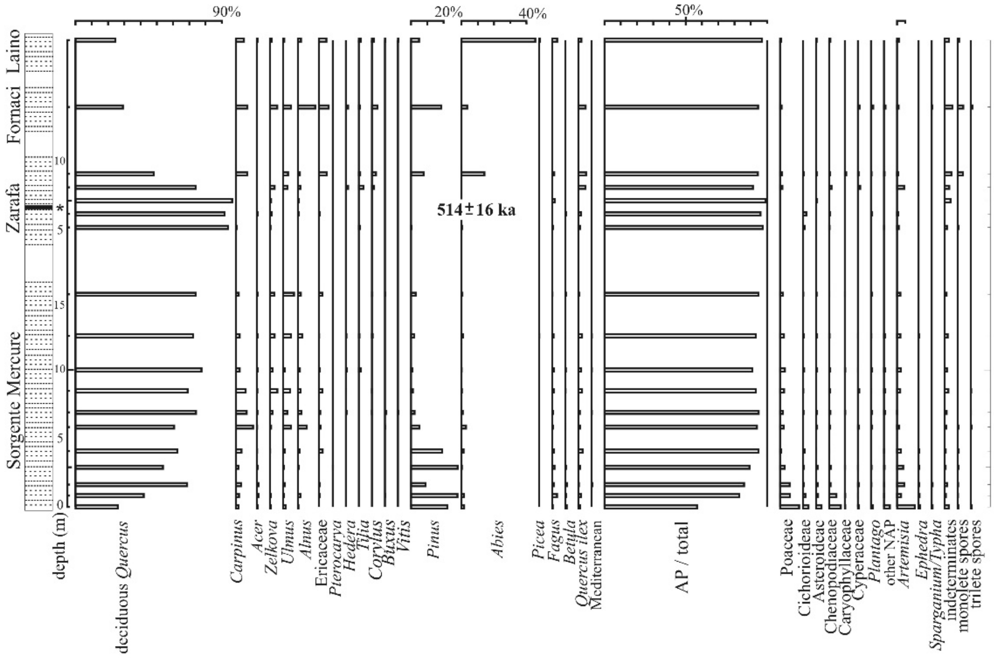

Figure 2. Composite pollen diagram of the Mercure lacustrine succession (after [Petrosino et al., 2014]).

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Strutture recenti nord-vergenti a basso angolo in Val Cerrina (Monferrato Casalese): nuove segnalazioni

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Vengono segnalati i rinvenimenti avvenuti tra il 2005 ed il 2010 di nuove strutture di sovrascorrimento a direzione nordvergenti paragonabili a quelle segnalate da Giraudi nel 1981 in affioramenti artificiali temporanei, prossimi alle ex cave di argilla di Castagnone di Pontestura (AL), note per il rinvenimento di faune tardopleistoceniche in terreni fagliati. In occasione di scavi per interventi edilizi urbanistici e di sistemazione idrogeologica, sono stati individuati, censiti e cartografati alcuni interessanti casi di piani di sovrascorrimento a basso angolo, non necessariamente coevi, che interessano formazioni del substrato e coperture superficiali, con età verosimilmente attribuibili al Pleistocene superiore. La localizzazione dei siti, in ordine di rinvenimento, è corrispondente all'area industriale di Cereseto, ad uno scavo per un laghetto artificiale in Comune di Ozzano M.to (Figure 1 e 2) e ad uno scavo sul fronte di frana attivatasi a monte della Cappella I di S. Eusebio a Serralunga di Crea, presso il Sacro Monte di Crea, siti localizzati a distanze chilometriche dall'affioramento di Castagnone.

Figura 1. Piani di sovrascorrimento a basso angolo in Marne di S. Agata Fossili sovrastanti a paleosuolo.

Il quadro che emerge, alla luce di possibili approfondimenti proponibili, consente di riaprire il dibattito tecnico-scientifico inerente la tematica dell'evoluzione neotettonica e geomorfologica del fronte collinare Casalese e segnatamente della Val Cerrina, con il relativo spettro di nuove valutazioni e possibili aggiornamenti del quadro neotettonico alla scala locale e regionale, con particolare riferimento agli studi condotti negli Anni '80 dal gruppo di ricerca del Prof. Geol. Francesco Carraro, per l'insediamento di nuovi siti nucleari nella vicina zona di Trino Vercellese. L'attuale presenza di vicini depositi nucleari e le ipotesi aperte per l'individuazione del deposito unico delle scorie nucleari rendono sempre attuale l'argomento.

Figura 2. Sovrascorrimenti a basso angolo in Marne di S. Agata Fossili su paleosuolo, fronte di scavo a direzione N-S.

The early evolutive stages of the L'Aquila Basin (central Italy) inferred from paleontological and stratigraphical analyses

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The L'Aquila Basin is a large intermontane sedimentary basin of tectonic origin located in central Apennines. Its sedimentary filling is composed of a thick succession of Upper Pliocene-Quaternary deposits, which overlie with an angular unconformity the pre-Pliocene substratum. The basin is divided into two sub-basins: the L'Aquila-Scoppito sub-basin (ASB), to the west, and the Paganica-S. Demetrio-Castelnuovo sub-basin (PSC), to the east.

In the ASB sub-basin, the most ancient sediments are included into two different synthems, the Colle Cantaro-Cave Synthem, mainly recognizable in boreholes, made of slope-derived breccias and debris flow deposits or clayey-sandy conglomerates, and the Madonna della Strada Synthem, which consists mainly of clayey silts, sandy silts, and sands, containing up to five intercalations of lignite beds. The two synthems are divided by a well-developed 1-3 m thick paleosol [Centamore and Dramis, 2010]. The Colle Cantaro-Cave Synthem has been referred by different authors to Piacenzian-Gelasian [Centamore and Dramis, 2010], Gelasian [Mancini et al., 2012] or early Calabrian [Messina et al., 2001]. The uppermost portion of the Madonna della Strada Synthem, due to the presence of large mammal assemblages, corresponds to the Pirro Nord FU, about 1.3 Ma [Cosentino et al., submitted]. Within the Madonna della Strada Synthem a freshwater ostracod assemblage made of *Candona (Neglecandona) neglecta* Sars, *Pseudocandona marchica* (Hartwig), *Ilyocypris bradyi* Sars, *Eucypris pigra* (Fischer), *Potamocypris zschokkei* (Kaufmann), and *Paralimnocythere messanai* (Martens) has been recovered, including the cold- stenothermal fossil species *Eucypris dulcifrons* Diebel and Pietrzeniuk. This assemblage points to a palustrine environment.

The oldest continental deposits in the PSC sub-basin pertain to the San Demetrio Synthem that includes several formations deposited in different environments. At the bottom, the San Nicandro Fm. consists of laminated to massive whitish calcareous silts bearing freshwater ostracods, sponges spicules and molluscs. The ostracod assemblage is very different from the Madonna della Strada one and is characterised by a *Caspiocypris* species flock [Spadi et al., submitted], with the presence of *Caspiocypris* sp. 1 Spadi and Gliozzi, *Caspiocypris* sp. 2 Spadi and Gliozzi, *Caspiocypris* sp. 3 Spadi and Gliozzi, *Caspiocypris* sp. 4 Spadi and Gliozzi, *Cypria* sp. nov. Spadi and Gliozzi, *Ilyocypris* sp. nov. Spadi and Gliozzi, *Amnicythere* ex gr. *stanchevae* Krstić, and *Paralimnocythere* cf. *P. dictyonalis* Medici, Ceci and Gliozzi. This assemblage points to a relatively deep-water and low energy lacustrine environment. The Prata di Ansidonia Fm., Valle Orsa Fm., and Valle dell'Inferno Fm., crop out in the central portion of the sub-basin and are partially heteropic to the S. Nicandro Fm. or gradually overlain it. They are related to the deposition of a Gilbert-type delta system prograding into the lake from N or NW. Ostracod assemblages recovered in the silty intercalations of those formations show compositional changes, including assemblages in which the four *Caspiocypris* species are progressively replaced by assemblages made of *Candona (Neglecandona)* cf. *C. (N.) neglecta* Sars, *Candona* (*Neglecandona*) ex gr. *paludinica* Krstić, *Fabaeformiscandona* aff. *F. alexandri* (Sywula), *Potamocypris fallax* Fox, *Cypria ophtalmica* (Jurine) and *Cavernocypris* aff. *C. subterranea* (Wolf). On the NE margin of the PSC sub-basin, the Valle Valiano Fm., Fonte Vedice Fm. and Madonna della Neve Fm. crop out, representing alluvial fan and slope deposits with alluvial fan conglomerates [Giaccio et al., 2012]. The San Demetrio Synthem is cut at the top by an erosional surface that, in the central portion is at 855 m a.s.l., carved into the Gilbert-type delta deposits. Reverse polarity and the presence of tephra layers in the S. Nicandro Fm. lead Giaccio et al. [2012] to refer this synthem mainly to Calabrian, which is in contrast with the results of our paleontological analyses. The ostracod assemblage of the San Nicandro Fm. can be compared with the ostracod assemblages of the Fosso Bianco Fm. in the Tiberino Basin, which bears a similar *Caspiocypris* species flock [Medici and Gliozzi, 2008]. For this reason, we suggest a correlation between the lake deposits of the San Demetrio Synthem (L'Aquila Basin) and the upper Piacenzian-Gelasian lacustrine succession of the Fosso Bianco Fm. (Tiberino Basin).

Several data suggest that the Colle Cantaro-Cave and San Demetrio synthems could be considered coeval:

1) according to different seismic-reflection profiles they both deposited in a syn-rift stage [Cosentino et al., submitted];
2) the erosional surface that cut the San Demetrio Synthem could be correlated with the angular unconformity between the Colle Cantaro-Cave and the Madonna della Strada synthems. Furthermore, both surfaces could be correlated with the angular unconformity which separate the Piacenzian-Gelasian Fosso Bianco Fm. and the Calabrian S. Maria di Ciciliano Fm in the Tiberino Basin, linked to the 260 m relative sea-level drop (mainly due to tectonic uplift), which occurred at the Tyrrhenian margin of the central-northern Apennines close to the Gelasian/Calabrian transition [Cosentino et al., 2009, submitted].

Based on the paleontological and stratigraphical analyses carried out on the basal filling deposits of the L'Aquila Basin, it is possible to state that the basin set up since Late Piacenzian. During the first filling phase (Late Piacenzian-Gelasian), the ASB sub-basin acted as a source-to-sink system that accommodated high volume of debris-flow and slope-derived deposits, while in the PSC sub-basin a huge and deep lake was settled. Around the Gelasian-Calabrian boundary, a tectonic uplift phase that affected the central Apennines chain caused the unconformity between the Colle Cantaro-Cave and Madonna della Strada synthems in the ASB sub-basin, and the erosional surface that cut the San Demetrio Synthem in the PSC sub-basin. In the second filling phase (Calabrian), the L'Aquila Basin hosted a braided plain characterised by extended swamplands in the ASB sub-basin.
In conclusion, during its early evolutionary stages, the L'Aquila Basin was represented by two separated sub-basins, divided by a basement threshold possibly located in correspondence with the Bazzano-Monticchio Ridge.

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