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THE SEDIMENTATION ALONG THE ROMAN COAST BETWEEN MIDDLE AND UPPER PLEISTOCENE: THE INTERPLAY OF EUSTATISM, TECTONICS AND VOLCANISM – NEW DATA AND REVIEW

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ABSTRACT
The Quaternary stratigraphy of the Roman coastal area is one of the most studied for the excellent exposures of the sedimentary succession, which offer the opportunity to analyse the interplay between eustatism, tectonics and volcanism. We present an updated interpretation based on new stratigraphic and geomorphologic data. Sedimentary successions have been organised as Unconformity-bounded Stratigraphic Units, based on the hierarchy of the bounding unconformities. Major regional unconformities are related to eustatic sea level changes and regional uplift, whereas tectonic uplift and subsidence produced high relief but localised unconformities. Major regional unconformities are related to eustatic sea level changes and regional uplift, whereas tectonic uplift and subsidence produced high relief but localised unconformities. The sedimentary record is best preserved during high stands of the sea level, as constrained by the several available age determinations of volcanic deposits. The transition from marine to continental environments occurred between approximately 850 and 700 ka, when the Roman area hosted the deltaic sedimentation from a paleo-Tiber river (Ponte Galeria Synthem). The uplift of the NW-trending Mt. Mario rise, isolated the deltaic sedimentary wedge and forced the paleo-Tiber toward the SE, inside a subsiding valley wherein a thick succession of fluvial conglomerates was deposited. As a consequence of the river diversion, a large lake or swamp probably developed in the area, bearing an influence upon the early phreatoplinian activity of the Colli Albani volcano which started at about 600 ka (Santa Cecilia Synthem; ca. 700-550 ka). The growth of the volcano progressively shifted the river back northward, across the Monte Mario rise (after ca. 550 ka) approximately where the present day river has its course. The Valle Giulia Synthem (ca. 550-450 ka) is made up of clastic and volcaniclastic fluvial deposits, as well as travertine related to both active tectonics (up to 20 m of local uplift) and hydrothermal activity. The subsequent Torrino Synthem (ca. 450-350 ka) is mostly made up of large volume ignimbrites and lavas erupted both from the Colli Albani volcano to the S and the Sabatini volcanoes to the N. Regional and local tectonics was relatively quiescent. This synthem is cut by the erosional unconformity formed during the low stand of the sea level relative to the oxygen isotopic stage 10. The overlying succession has been named Quartaccio Synthem, characterised at the base by the Villa Senni eruption unit (ca. 350 ka), a complex ignimbrite succession erupted from the Colli Albani volcano, which caused the last and largest collapse of its caldera. The following rise of the sea level produced an abrasion surface at the top of the ignimbrite overlain by dune sand (Nuova California subsynthem, i.e. Duna Rossa antica auct.). These deposits are cut by NE-trending faults between Pomezia and Castelporziano and uplifted by 140+/-5 m during ca. 70 ka, at the rate of 2 mm/y. The uplift produced a local high relief unconformity wherein the Aurelia and the Vitinia subsynthems were deposited until ca. 280 ka. The top of the Quartaccio Synthem is presently at elevations comprised between 40 m and 60 m a.s.l. Successively, along with the waning of the volcanic activity, regional uplift resumed at a rate of approximately 0.2 mm/y. This allowed the preservation of terraced deposits, along the coastal belt both to the N and S of the Tiber delta and along the Tiber Valley, referred to two different isotopic stages. Those related to the oxygen isotopic stage 7 (Campo Selva Synthem), are today preserved between 30 and 40 m a.s.l. whereas those related to the oxygen isotopic stage 5 (Saccopastore Synthem), occur between 15 and 30 m a.s.l. The computed regional uplift rate is well in agreement with known data for the Tyrrhenian terrace along the Italian coast.

RIASSUNTO
*I*l litorale romano è uno degli ambienti più studiati per capire le relazioni tra tettonica, vulcanismo ed eustatismo nel corso del Pleistocene*. Questo lavoro propone una nuova sintesi delle complesse relazioni stratigrafiche e geomorfologiche di quest’area. I corpi rocciosi sono stati organizzati in unità stratigrafiche a limiti inconformi, in base alla gerarchia delle superfici che li delimitano. Per il Pleistocene medio-superiore dell'area romana, le superfici di grado gerarchico maggiore e correlabili a scala regionale, sono legate alle variazioni eustatiche del livello marino, mentre l'azione della tettonica sviluppa superfici ad alto rilievo ma localizzate alle aree di deformazione. Le successioni sedimentarie sono da correlare, in genere, agli alti stazionamenti del livello del mare, come suggerito dalle datazioni dei livelli vulcanici intercalati. L’emersione dell’area romana avviene con la deposizione, tra la dorsale di M. Mario e la costa, dell’unità di Ponte Galeria (ca. 850-700 ka) in facies di delta, alimentata da un paleoTevere proveniente da N. L’isolamento di questo cuneo deposizionale avviene per l’innalzamento dell’alto di M. Mario a direzione NW-SE. Il Tevere è forzato a scorrere ad est di questo cuneo, parallelamente alla costa verso SE, lungo una fascia in continua subsidenza con la deposizione di diverse decine di metri di conglomerati, probabilmente determinando una vasta area palustre che condizionerà il carattere freatomagmatico delle prime eruzioni dei Colli Albani, note come Tufi pisolitici. Queste unità costituiscono il Sintema Santa Cecilia, depostosi tra 700 e 550 ka ovvero tra lo stadio 17 ed il 15. A partire da questo momento, la crescita del vulcano dei Colli Albani risospinge il Tevere verso nord dove trova un varco verso la costa vicino al suo corso attuale. Il successivo Sintema Valle Giulia (stadio 13) accoglie, oltre alla sedimentazione del Tevere e quella vulcanoclastica, anche ingenti volumi di travertini a testimonianza di una tettonica attiva con dislocazioni dell’ordine dei 20 m, e di un importante sistema idrotermale legato all’inizio del vulcanismo. Nel successivo Sintema Torrino (stadio 11) sono inclusi i maggiori volumi di prodotti vulcanici, con la messa in posto di vaste coltri ignimbritiche ed espandimenti lavici sia dai Colli Albani (Lave di Vallerano, Pozzolane Rosse, Lave di Fosso Tre Rami, Pozzolane Nere) che dai vulcani Sabatini (Tufo Rosso a Scorie Nere). Durante questo periodo la tettonica regionale è relativamente quiescente. Il sintema è tagliato dalla superficie relativa all’abbassamento del livello del mare, durante lo stadio 10, entro cui si depone il Sintema Aurelia, con alla base l’unità ignimbritica del Villa Senni (350 ka), cui si deve il collasso della caldera Tuscolano-Artemisia al centro dei Colli Albani. Subito dopo la messa in posto del Villa Senni si ha l’ingressione marina relativa allo stadio 9 che porta alla formazione di una superficie di abrasione al tetto dell’ignimbrite, coperta da sabbie di spiaggia, duna e retroduna (Subsintema Nuova California), ovvero la Duna Rossa antica auct. Questa superficie è dislocata da faglie ad andamento NE tra Pomezia e Castelporziano ed oggi si trova a quote comprese tra +60 m s.l.m.e +100 m s.l.m. Il sollevamento determina la formazione di una superficie erosiva tra la costa e la bassa valle del Tevere, che ospiterà fino ai 280 ka la deposi-*

zione dei subsintemi Aurelia e Vitinia la cui quota di tetto è compresa tra i 40 m ed i 60 m s.l.m. Questo terrazzo sutura, o quasi, le dislocazioni tra Pomezia e Castelporziano, che dunque determinarono un innalzamento relativo di 140+/-5 m in circa 70 ka, al tasso di circa 2 mm/a. Successivamente la regione va incontro a sollevamento generalizzato che, in concomitanza con le oscillazioni del mare, ha consentito la conservazione di terrazzi incassati sia lungo la costa che lungo la valle del Tevere, dove i sedimenti relativi allo stadio 7 formano il Sintema Campo Selva oggi posti tra 30 m e 40 m s.l.m., mentre i depositi relativi allo stadio 5 formano il Sintema Saccopastore, oggi riconoscibili tra quota 15 m e 30 m s.l.m. Il tasso calcolato regionale di sollevamento è di 0.2 mm/a in accordo con quanto noto per il litorale laziale a nord ed i dati noti del Tirreniano.

Key-words: sedimentation, volcanism, tectonics, eustatism, Quaternary

Parole chiave:, sedimentazione, vulcanismo, tettonica, eustatismo, Quaternario

1. INTRODUCTION

The Roman coastal area extends between the Sabatini volcanoes to the North and the Colli Albani volcano to the South, along the Tyrrhenian coast of Central Italy (Fig. 1). Excellent exposures of Quaternary sedimentary successions occur in the area and offer the opportunity to analyse the interplay between eustatism, tectonics and volcanism. Since the early fifties, many different interpretations have been proposed on the number and significance of the sedimentary successions, based each time on new exposures and new age determinations. Table 1 is a synoptic scheme of the main stratigraphic interpretations. Open questions concern the hierarchy of the unconformities and their relationship to glacial periods (Blanc, 1957; Ambrosetti & Bonadonna, 1967; Manfredini, 1990; Karner & Renne, 1998; Karner *et al*., 2001a, b), and the internal architecture of the sedimentary successions in relationship with sea level changes and tectonic uplift (e.g., Conato *et al*., 1980; Malatesta & Zarlenga, 1986; Milli, 1997). Some workers have pointed out the contribution of volcanism to sedimentary processes (e.g. Cavinato *et al*., 1992; Marra & Rosa, 1995), while others analysed the geometry of coastal terraces related to the Pleistocene sea level oscillations (e.g. Basili & Bosi,1996). Several Faunal Units have been based on the well preserved vertebrate fossil remains occurring within the Pleistocene Roman sedimentary successions and, together with archeological findings, they have been used for detailed paleoenvironmental reconstructions (Cavarretta *et al.* 2001 and references therein).

This paper focuses on the Middle to Upper Pleistocene sedimentary succession of the Roman area and syntethises data from more than two thousand stratigraphic sections, measured in an area of approximately 1500 km^2. The proposed hierarchy of the unconformities is based on their lateral extension and morphologic relief, and on the facies associations of the enclosed rock bodies.

2. METHODOLOGY

Starting from 0.6 Ma, the Roman coastal area has received volcaniclastic sedimentation from the two volcanic areas of the Sabatini to the North and of the Colli Albani to the South. The presence of volcaniclastic deposits transitional to volcanic deposits and to coastal sediments has allowed the correlation of volcanic activity and coastal sedimentation and the understanding of how volcanism, eustatism and tectonics acted in the evolution of the area. Some of the large erupted volume pyroclastic flows reached the coastal area and the deposits are interbedded with the coastal sediments. The geochronologically dated volcanic units have been used to constrain the time range of deposition of the hosting sedimentary successions.

Lithostratigraphic units have been organised as Unconformity -bounded Stratigraphic Units (UBSU). The most widespread erosional surfaces in the Roman area during Middle to Upper Pleistocene are related to the low stands of the sea level. These unconformities bound the Synthems, i.e. the fundamental UBSU in respect to which the hierarchy of the other unconformities is referred (Salvador, 1987). Vertical tectonic displacements may locally enhance or reduce the field evidence of unconformities.

The correlation of the synthem to glacio-eustatic variations of the sea level is important, as the hierarchy of unconformities is referred to a geological process. Each recognised synthem has been correlated to the oxygen isotope scale (Pisias *et al.*1994; Shackleton 2000) on the basis of available geochronological and /or paleontological data.

Lateral facies relationships between volcanic units and volcaniclastic sediments have allowed the distinction of syn-eruption and inter-eruption successions related to the volcanic activity of the Colli Albani and of the Sabatini volcanoes (cf. Smith, 1987; Giordano *et al*., 2002a).

Where historical formational or unit names are not misleading, we have retained the traditional name for the synthem (for example our Ponte Galeria Synthem coincides with the Ponte Galeria Formation *auct.*), whereas we have changed it where names may induce confusion (for example the S. Cosimato Formation auct. has been interpreted in many different ways, and means different things to different authors.).

3. MIDDLE TO UPPER PLEISTOCENE, STRATIGRAPHIC AND TECTONIC EVOLUTION OF THE ROMAN AREA

The transition from marine to continental environments in the Roman area occurred with the deposition of the Ponte Galeria synthem between approximately 850 and 700 ka (cf. the Ponte Galeria Formation by Conato et al., 1980;. Table 1). The Ponte Galeria Synthem represents the sedimentation of a paleo-Tiber river delta (e.g. Marra & Rosa, 1995; Milli, 1997) fed from the north. The deposits of this unit are described in a number of papers (Table 1) and range from fluvial conglomerate and sand to lagoonal clay and beach sand and gravel. The Ponte Galeria synthem encompasses several sea level oscillations (at least from stage 20 to stage 17; Marra *et al.*, 1998), although compensated by subsidence. The synthem forms an aggradational wedge up to 80 m thick.

Between ca. 700 and 600 ka, the uplift of the NW-trending Mt. Mario rise tilted the block by few degrees toward the W-SW, and caused the diversion of the paleo-Tiber river toward the southeast (Giordano *et al.*, 2002b), along the Crescenza-Torrenova paleovalley (Fig. 1). The former Ponte Galeria delta was therefore isolated from the river system and formed a plateau sloping toward the sea (Fig. 1).

As a consequence of the uplift, a high relief erosion surface formed, preserved today to the W and the S of the plateau. The unconformity is mostly represented by V-shaped paleo-gullies. The overlying sedimentary succession is made up by an aggradational and fining upward succession of fluvial to lacustrine sediments, mainly derived from the underlying Ponte Galeria synthem, with increasing upward volcaniclastic sediments derived from the early explosive eruptions from the Sabatini and Colli Albani volcanoes. This succession is named “S.Cecilia Synthem” (cf. Marra & Rosa, 1995) and can be correlated with the isotopic stage 15 (Fig. 1), on the basis of interbedded ignimbrites dated between $561^{+}_{-}1$ ka and 548 $^{+}_{-}$ 4 ka (Karner *et al.*, 2001b). The largest of those volcanic deposits are the Trigoria eruption unit and the Tor de Cenci eruption unit from Colli Albani (De Rita *et al.*, 2002a), and the Tufo Giallo della Via Tiberina eruption unit from the Sabatini (De Rita *et al.*, 1993; Karner et al. 2001a). The Mt. Mario rise prevented ignimbrites from the Sabatini volcanoes (namely the Tufo Giallo della Via Tiberina) to reach the area to the south and west of Rome, and diverted the pyroclastic flows along the paleo-Tiber river, where the ignimbrites occur with remarkable thickness. The river diversion gave also rise to lacustrine environments, influencing the phreatomagmatic character of the early volcanic activity of the Colli Albani volcano (De Rita

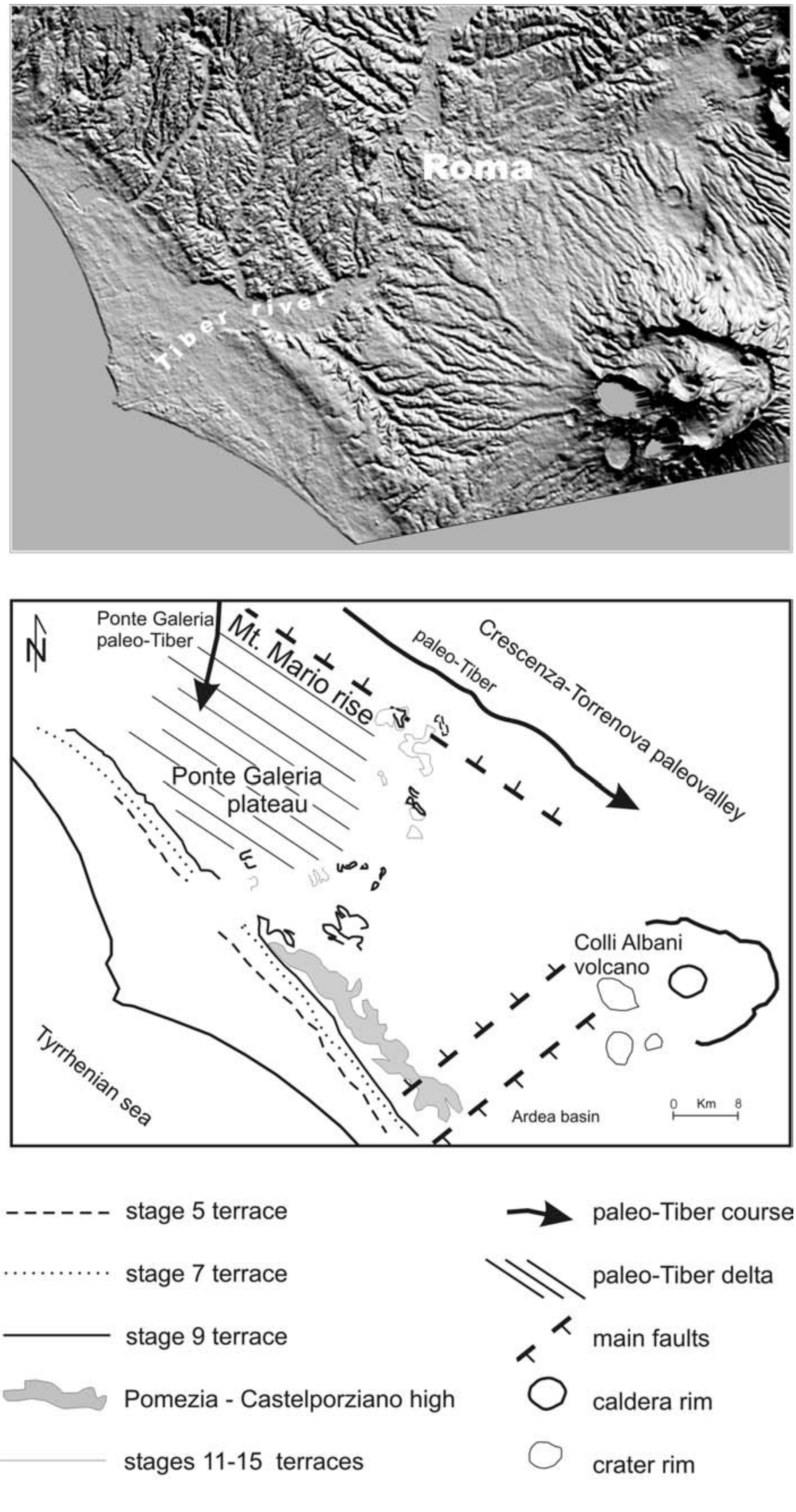

FIGURE 1 - DEM of the study area (courtesy of ESRIN) and schematic interpretation of the main structural, volcanic and geomorphologic features (see text for explanation).

et al., 2002a).

The lowest elevation of the basal unconformity of the Santa Cecilia Synthem occurs at 18 m a.s.l. in the Ponte Galeria area where the succession is maximum 32 m thick in outcrop. The same unconformity is located at – 80 m in respect to sea level (r.s.l.) to the east of the Mt. Mario rise, where the succession is more than 45 m thick, as inferred from borehole data. These data indicate that vertical tectonic displacements occurred during and after the deposition of the Santa Cecilia Synthem.

The growth of the Colli Albani volcano caused the progressive shift of the paleo-Tiber back northward, where the river crossed the Mt. Mario rise in a position similar to present day. From then onwards, all river terraces relative to the following aggradational periods are found both along the right and the left river banks of the present course of the Tiber river, testifying that little shifts have occurred ever since.

The following synthem, named "Valle Giulia" (cf. Marra and Rosa, 1995), comprises an aggradational and fining upward succession of fluvial deposits, volcanic units and several travertine plates, related to the presence of hydrothermal system. The thickness of the fluvial succession is up to 30 m. The most widespread volcanic units present within this synthem, the Palatino phreatomagmatic unit, the Casale del Cavaliere eruption unit (De Rita *et al.*, 2002a) and the Tufo Giallo di Prima Porta (Karner *et al.*, 2001b) are dated at around $528^{+}_{-}1$ and $514^{+}_{-}3$ ka (Karner *et al.*, 2001b), which constrain the synthem to the isotopic stage 13 (Table 1).

The lowest elevation of the basal unconformity of the Valle Giulia Synthem is presently at approximately 10 m a.s.l., whereas it is downthrown by some tens of metres to the east of the Mt Mario rise. Vertical tectonic displacements during and after the Valle Giulia emplacement determined the development of subsiding sectors mostly along NE-trending and NW-trending faults.

The successive synthem, named "Torrino" encompasses an aggradational and fining upward succession of mostly volcaniclastic sediments and volcanic deposits relative to large lava flows (Vallerano lava flows; Fosso Tre Rami lava flows; cf. De Rita *et al.*, 1995) and large volume, caldera forming explosive eruptions (Pozzolane Rosse and Pozzolane Nere eruption units) from the Colli Albani, as well as from the Sabatini (Tufo Rosso a Scorie Nere eruption unit). This synthem is constrained at the stages 12 and 11 (Tab. 1), on account of the available age determinations on the volcanic units which span from the $460^{+}_{-}4$ ka for the Vallerano lava flow at the base of the synthem, to the $407^{+}_{-}4$ ka for the Pozzolane Nere at the top (data from Karner et al., 2001b to be compared with Voltaggio and Barbieri, 1995 and reference therein). The basal unconformity of this synthem is today at 10 m a.s.l., and the maximum thickness in outcrop of the fluvial succession is 30 m.

The synthem does not appear to record the occur-

TABLE 1 - Comparison between the stratigraphy proposed in this paper and previous interpretations.

LITHOSTRATIGRAPHY from Conato et al.,1980 Malatesta e Zarlenga,1986	LITHOSTRATIGRAPHY from Marra e Rosa, 1995 Karner et al., 2001	SEQUENCE STRATIGRAPHY FROM Milli, 1992;1994; 1997 depositional sequences III° order	IV° order	Present paper UBSU		chronostratigraphic constraints (data from Karner et al., 2001b)	δ¹⁸O Curve Shackleton, 1995	Absolute Age		
YOUNGER DUNE NEOTYRRHENIAN	TYRRHENIAN FORMATION	PONTE GALERIA SEQUENCE	PG8	Saccopastore Synthem	GALERIA SUPERSYNTHEM		2, 5	Ma 0.1	UPPER	PLEISTOCENE
OLDER DUNE VITINIAN FORMATION EUTYRRHENIAN	VITINIA FORMATION		PG7	Campo Selva Synthem			6, 7	0.2	MIDDLE	
AURELIAN FORMATION	AURELIA FORMATION		PG6	Quartaccio Synthem (Vitinia unit; Aurelia unit; Nuova California unit)		Tufo Giallo di Sacrofano (285±1ka)	8, 9	0.3		
SAN COSIMATO FORMATION	SAN PAOLO FORMATION		PG5	Torrino Synthem		Tufo Villa Senni (355±2ka); Pozzolane Nere (407±4ka)	10, 11	0.4		
	VALLE GIULIA FORMATION		PG4	Valle Giulia Synthem		Tufo Rosso a Scorie Nere (449±1ka); Pozzolane Rosse (457±4ka); Tufo Giallo di Prima Porta (514±3ka); Tufo del Palatino (528±1ka)	12, 13	0.5		
	SANTA CECILIA FORMATION		PG3	Santa Cecilia Synthem		Tufo Giallo Via Tiberina (561±1ka); Tufo di Tor de Cenci (561±1ka)	14, 15	0.6		
PONTE GALERIA FORMATION	PG 2 (PONTE GALERIA FORMATION)		PG2	Ponte Galeria Synthem			16, 17	0.7		
	PG 1 (PONTE GALERIA FORMATION); MONTE DELLE PICHE UNIT, MONTE CIOCCI UNIT (MONTE CIOCCI FORMATION)		PG1				18, 19, 20, 21, 22	0.8		

rence of important vertical tectonic displacements.

The Torrino Synthem is cut by an erosion surface which is the basal unconformity of the successive synthem, named “Quartaccio”. The formation of the erosion surface is chronologically well constrained at the low stand of stage 10 by the presence on top of the surface of the large volume and caldera-forming Tufo Lionato-Villa Senni ignimbrites from the Colli Albani. These ignimbrites have been dated several times with different techniques at around 350 ka (e.g. Bernardi et al., 1982; Radicati di Brozolo et al., 1981; Karner and Renne, 1998). The Tufo Lionato-Villa Senni (TL-VS) ignimbrites locally rest on beach-sand and marine sediments (Nuova California unit) which record the sea level at ca. 350 ka (Fig. 2), evaluated, according to Wealbroeck et al. (2002), at –120 m r.s.l. (cfr. Fig. 4).

In the Pomezia-Castelporziano area, several sedimentary units at different elevations are related to the subsequent marine ingression relative to the isotopic stage 9. This probably records the contemporaneous uplift of the Pomezia-Castelporziano rise with respect to the Ardea-basin along NE-trending faults (Figs. 1, 2 and 3). In this area, an abrasion surface at the top of the TL-VS ignimbrites, is covered by dunal- to retro-dunal-sand (the Castelporziano unit; i.e. “Duna Rossa antica” or “Older Dune” *auct.*), which is presently uplifted to up to 100 m a.s.l. (Figs. 2 and 3), and which can be related to any moment between the low stand 10 and the following high stand 9. The uplift isolated the Pomezia-Castelporziano block, against which the Aurelia unit was deposited. The Aurelia unit forms a fluvial to marine terrace, presently visible along the Tiber river valley (Figs. 1, 2 and 3). The lowest elevation of the basal unconformity of the Aurelia unit is at 10 m a.s.l. whereas the top reaches 50 m a.s.l. The Aurelia unit is generally overlain by the Vitinia unit, a sedimentary aggradational succession, rich in volcaniclastic sediments mostly derived from the contemporaneous activity of the Faete epoch of the Colli Albani volcano (ca 350-270 ka; De Rita *et al.*, 1995). The Aurelia and the Vitinia units are separated by a low relief unconformity surface, which never cuts lower than the Aurelia basal unconformity (Fig. 2), and which outcrops at 30 m a.s.l. at the lowest. The top of the Vitinia unit reaches 55-60 m. At the top of the Vitinia unit, the scatter presence of a pumice fallout deposit related with the Tufo Giallo di Sacrofano from the Sabatini volcanoes (De Rita *et al.*, 1993) dated at 285 ± 1 (Karner *et al.*, 2001b), constrains the Vitinia unit to the stage 8.5, i.e. a secondary warm peak occurred during the cooling that led to the low stand relative to the isotopic stage 8 (Fig. 4 and Table 1). The 55-60 m surface, which corresponds to the top of the Vitinia unit can also be recognised along the seaside margin, facing west, as a continuous surface which sutures the displacements of the Pomezia-Castelporziano high. This surface constrains the Pomezia- Castelporziano uplift to a time span comprised between the deposition of the TL-VS ignimbrites (at 350 ka) and the Vitinia unit (at 280 ka) (Figs. 1, 2 and 3).

The more recent terraces are preserved at progressively lower elevations (Figs. 1 and 3) indicating that regional uplift re-started after the deposition of the Vitinia unit at the top of the Quartaccio Synthem. Two marine terraces are preserved along the coast at 30-40 m a.s.l. (“Campo Selva” Synthem) and 15-30 m a.s.l. respectively (Saccopastore” Synthem) (Fig. 3). The sediments relative to the Campo Selva Synthem are visible in a number of quarries (e.g. Tacconi quarry) but bear no datable volcanics or fossils, so that the age constrain is not well defined although it appears logical to

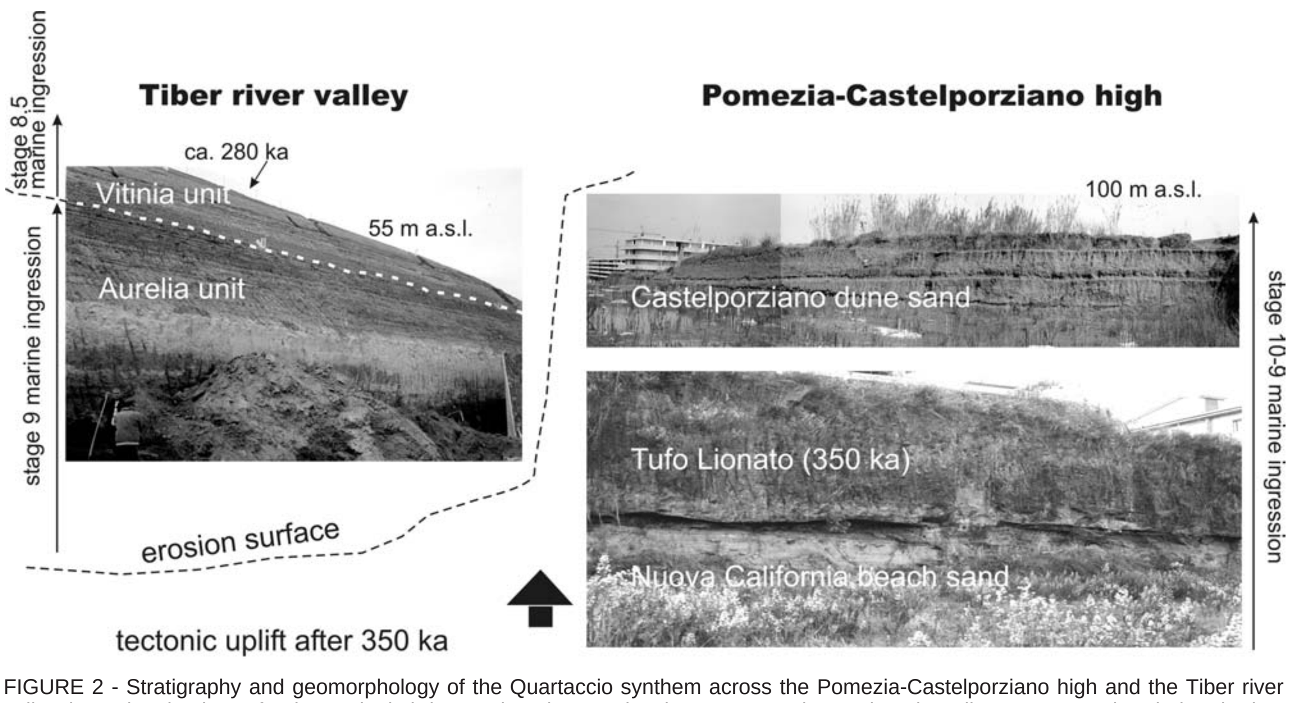

FIGURE 2 - Stratigraphy and geomorphology of the Quartaccio synthem across the Pomezia-Castelporziano high and the Tiber river valley (see Fig. 1). The Tufo Lionato ignimbrite emplaced at sea level over wet marine- to beach-sediments, at 350 ka, during the low stand 10 of the sea level, and was then overlain by dune sand before it was uplifted to form the erosion surface (dashed line) inside which the Aurelia and Vitinia subsynthems are infilled.

relate it to the stage 7. Along the Tiber river no fluvial terrace that can be safely correlated with this stage. The age of the Saccopastore Synthem, the lowest terrace (Figs. 1 and 3), is constrained at the stage 5a by the presence of *Strombus bubonius* fauna reported by Blanc (1936) from the north of the Tiber river (Casal di Statua, 19 m a.s.l.). In the city of Rome, along the course of the Tiber river, several fluvial terraces occurring at an average elevation of 35 m a.s.l, can be related to this stage. In this deposits the "Man of Saccopastore", a Neanderthal man dated at about 100 ka, was found (Blanc, 1942).

4. DISCUSSION AND CONCLUSIONS

Regional uplift, local tectonics, eustatism and volcanism, acted during the Middle to Upper Pleistocene geologic evolution of the Roman area.

The correlation of the basal unconformity of synthems to periods of low standing of the sea level has, as constrained by tephrachonologic data, allowed the evaluation of the relative role of regional uplift versus local tectonics.

In Table 2 we have computed the amount and the rate of vertical uplift for several stratigraphic surfaces. The error bar for each computed value, is given by the maximum and minimum elevations of the top or the base of the terrace, on the time span of deposition. This time span is taken conservatively to encompass the peaks of the oxygen isotopic stage on the curve of Waelbroek *et al.*, (2002). The present day elevation of the top of the marine terraces related to the stages 5a (15-30 m a.s.l. for the Saccopastore Synthem), 7 (35-45 m a.s.l. for the Campo Selva Synthem) and 9-8.5 (55-60 m a.s.l. for the Quartaccio Synthem) are similar along the whole Roman coast, both to the north and to the south of the Tiber river delta and therefore are related to regional uplift. The computed uplift rate averages at 0,2 mm/y, and appears to be constant since the Vitinia unit emplacement, i.e. approximately since 280 ka (Tab. 2 and Fig. 4). This value is well comparable with the regional uplift rate computed for the 125 ka marine terrace by Bordoni and Valensise (1998), as well as with stratigraphic and geomorphologic data from the coast of northern Latium, where, similarly, three orders of terraces related to stages 9, 7 and 5 are present at comparable elevations (De Rita *et al.*, 2002b). It must be underlined that similar values are also known from geoarchaeological studies of Roman times remains (Anzidei *et al.*, 2002).

On the contrary, the uplift of the Pomezia-Castelporziano high along NE-trending faults, which most likely re-activated the Pliocene-Lower Pleistocene masterfaults of the adjacent Ardea basin (Faccenna *et al.*, 1994) (Fig. 1 and Fig. 3) is a localised tectonic process, that occurred shortly after the eruption of the Tufo Lionato-Villa Senni ignimbrites and the collapse of the Colli Albani caldera at 350 ka. The computed uplift rate is high, at 2 mm/y, which implies a fast and discrete event, possibly related to volcano-tectonic processes. Today, the area is still affected by intense hydrothermal activity (e.g. Chiodini & Frondini, 2001; Quattrocchi *et al.*, 2001) aligned along the main NE-trending faults.

The older Santa Cecilia Synthem (stage 15), Valle Giulia Synthem (stage 13) and Torrino Synthem (stage 11), do not show important intervening regional uplift, except for localised m- to 10 m-scale faulting. Taking into consideration that the deposition of the three synthems hosted the largest volume of erupted products

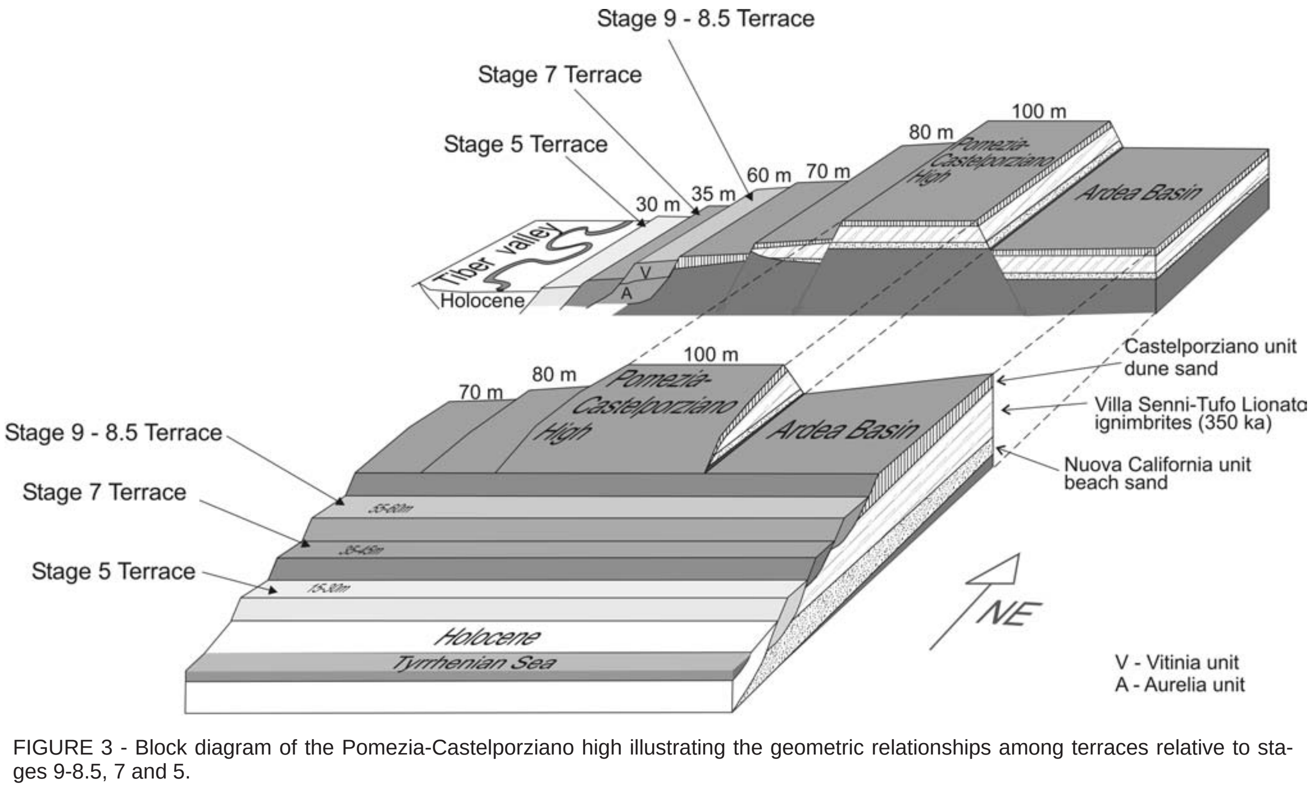

FIGURE 3 - Block diagram of the Pomezia-Castelporziano high illustrating the geometric relationships among terraces relative to stages 9-8.5, 7 and 5.

TABLE 2 - Computed uplift rates for different stratigraphic surfaces. The base of the Quartaccio synthem is taken as representing the sea level during the low stand 10, whereas the successive surfaces as sea levels during high stands 8.5, 7 and 5 respectively.

SYNTHEM	UNIT	SURFACE ELEVATION (m asl)	AGE (ka)	UPLIFT (m)		UPLIFT RATE (mm/y)	COMMENT
				min	max		
Saccopastore		Top (15-30)	130 - 80 *	15	30	0,22 +/- 0,13	Regional uplift
Campo Selva		Top (35-45)	230-190 *	5	30	0,20 +/- 0,2	Regional uplift
Quartaccio	Vitinia	Top (55-60)	284 +/- 3 **	10	25	0,23 +/- 0,15	Regional uplift
Quartaccio	Nuova California	Base (80)	351 +/- 3 ***	135	145	2,0 +/- 0,2	Local uplift

* Corresponding to sea level high stands from Waelbroeck et al., 2002
** Karner *et al*., 2001a
*** Villa, 1992

both from the Sabatini volcanoes and the Colli Albani volcano (Tuscolano-Artemisio Epoch, 600-350 ka; cf. De Rita *et al.*, 1995) it may be proposed that high eruption rates likely associated with high heat flow are favourable conditions for compensating isostatic uplift at regional scale. Small scale faults also indicate a relative tectonic quiescence, whereas the development of large caldera complexes at the Colli Albani and Sabatini volcanoes indicates the prevailing of volcano-tectonics.

The localised and fast uplift of the NW-trending Mt. Mario rise occurred instead between 700 and 600 ka (Giordano *et al.,* 2002b) and has characteristics very similar to the uplift of the Pomezia-Castelporziano high. The unconformity generated by the Mt. Mario uplift has high relief but it is only present at the margins of the Ponte Galeria plateau (Fig. 1) and bears no regional significance. Instead, it could be related to volcano-tectonic processes which occurred just before the beginning of the volcanism in the area.

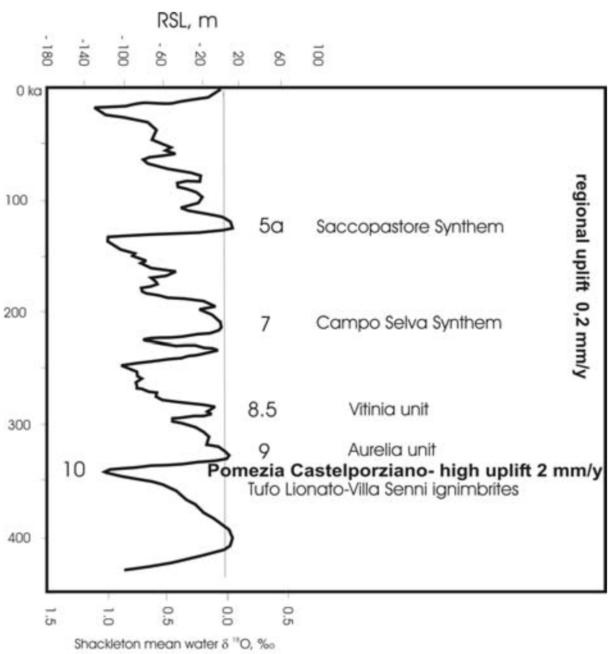

FIGURE 4 - Sea level oscillation according to Waelbroeck et al., 2002 and succession of sedimentary and tectonic events in the Roman coastal area after the emplacement of the Tufo Lionato- Villa Senni ignimbrites.

With respect to previous interpretations, this reconstruction implies:

1. The recognition of eustatism as the main factor able to produce, in this area, regionally widespread unconformity surfaces, as sea level oscillated by over 100 m with a cyclicity of approximately 100 ka. These unconformities bound synthems. Instead, local tectonics is responsible for the formation of high relief although localised unconformities. The best example of these two processes is the Quartaccio Synthem (Figs. 2 and 3). This synthem is regionally represented by a terrace deposited during the oxygen isotopic stage 9, with the top at approximately 60 m a.s.l. (cf. De Rita *et al*., 2002b). On the other hand, in the Pomezia-Castelporziano area, the synthem is made of several units because the area uplifted during the rise of the sea level which occurred between the low stand relative to stage 10 and the high stand relative to stage 9. As a consequence, the “Older Dune *auct.*” (Table 1), which corresponds to our Castelporziano dune sand, was not deposited during the “Tyrrhenian” (<125 ka), but it is older, with obvious implications, as discussed above, in respect to the timing and the rate of uplift required to attain the present day elavation (max. 100 m a.s.l.; Figs. 1 and 2).
2. The Aurelia and the Vitinia units are two distinct subsynthems, although part of the same Quartaccio Synthem. They can be respectively correlated to sea level high stand peaks attained during stages 9 and 8.5 (Fig. 4). This new interpretation implies the chronologic constrain of the deposition of the Vitinia unit at >280 ka, making the Vitinia unit older than commonly thought, with large implications for the bio-stratigraphy of the area (e.g. Gliozzi *et al*., 1997; Di Stefano *et al*., 1998; Cavarretta *et al*., 2001 and references therein). This interpretation easily justifies several lines of evidence, such as the very low relief erosion surface at the base of the Vitinia unit, which never cuts lower than the basal unconformity to the Aurelia unit, the evident morphologic unity of the two units forming a single terrace with its top at 55-60 m, easily recognisable from the coast to the fluvial environment (Fig. 1), and the age determinations on the interbedded of volcanic horizons, which are always older than 250 ka (cf. Karner and Marra, 1998).
3. The presence of a larger volcaniclastic component in the Vitinia unit in respect to the underlying Aurelia

unit is also well in agreement with the datation of the first products (e.g. the Capo di Bove Lava flow dated at 277 ka; Voltaggio & Barbieri, 1995 and references therein; Karner et al., 2001a), which overflowed the caldera rim relative to the Villa Senni eruption. Similarly to many other calderas, such as the Campi Flegrei and Taupo (N.Z.), volcanic activity immediately after the collapse of the caldera, and usually for several thousands of years, is confined within the collapsed area, so that outside the volcaniclastic sedimentation is greaty reduced. This time-gap therefore just represents the time necessary to the caldera to be filled by deposits, and is recorded by the marked increase in volcaniclastic sediments in the Vitinia unit in respect to the Aurelia unit.

4. During the Middle-Upper Pleistocene in the Roman area deformation processes result from the competition among regional uplift, localised tectonics, likely related to volcano-tectonic processes, and eruption rates (i.e. heat flow rate). The whole region, since Lower Pleistocene, has experienced a general tendency to regional uplift, which appears to be less significant during the climax of volcanic activity (between 600 and 300 ka ;cf. Cavinato *et al*., 1994). The uplift resumed later (stages 9, 7 and 5) at a rate of 0.2 mm/y, suggesting that volcanism in the area, although still affected by an important hydrothermal activity (e.g. Funiciello *et al*., 2002) is coming to an end. This is also evident by the generalised reduction of eruption rates of the latian volcanoes during the Upper Pliestocene (DeRita *et al.,* 1995). This interpretation is substantially different from that proposed in a recent paper by Karner *et al.* (2001b), who, based on the analyses of one stratigraphic section located in the Ponte Galeria area, attributed the uplift occurring after stage 9 to a refill of the magma chamber of the Colli Albani volcano and therefore claimed possible volcanic hazard. Our data indicate instead that the resumption of uplift is a regional process occurring along the whole latian coast, not at all exclusive to the Colli Albani area, and well in agreement with the waning of the volcanism.

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