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THE GROWTH OF THE CHIANTI RIDGE: PROGRESSIVE UNCONFORMITIES AND DEPOSITIONAL SEQUENCES IN THE S. BARBARA BASIN (UPPER VALDARNO, ITALY)

****Mauro Coltorti[1], Silvia Ravani[1] & Federico Verrazzani[2]**
[1]Dipartimento di Scienze della Terra, Università di Siena, Via di Laterina, 8 – 53100 Siena;
-coltorti@unisi.it, ravani@unisi.it
[2]Libero Professionista: kfeldspato@inwind.it

ABSTRACT: M. Coltorti et al., *The growth of the Chianti Ridge: progressive unconformities and depositional sequences in the S. Barbara Basin (Upper Valdarno, Italy)*. (IT ISSN 0394-3356, 2007).
The Chianti Ridge, elongated in a NW-SE direction, separates the Upper Valdarno from the Siena Basins. It is made of Macigno and Scaglia Toscana Fms. belonging to the Tuscan Nappe that underlies the Ligurian Units. Inside the Upper Valdarno basin three main synthems have been identified, separated by major unconformities; from the bottom: 1. Castelnuovo synthem, subdivided into Spedalino and Meleto subsynthems, 2. Montevarchi synthem and 3. Bucine synthem. The Spedalino subsynthem, that unconformably lies over the pre-Pliocene bedrock, is made up of thin and laterally discontinuous coarse gravels. The Meleto subsynthem, commonly referred to a lacustrine environment, is made of alluvial plain lithofacies, including channel, crevasse splay and swamp depositional systems where a *Taxodium* forest developed and peat accumulated. Close to the western margin of the basin these subsynthems are tilted up to 60°. The Montevarchi synthem, mainly made of sands and gravels accumulated inside a wide braidplain, and lies unconformably over the previous units. This synthem is tilted eastward up to 20°. Finally, the Bucine synthem lies unconformably over the previuos synthems generating a fluvial terrace of the Arno River. The two lower units date back to the Early Pliocene. In fact the Meleto clays contain mammal remains that can be found in the Triversa Faunal Unit (Early Villafranchian, late Early - Middle Pliocene) as well as in the Ruscinian (Early Pliocene). They are also negatively magnetized and could correspond to the Gilbert Chron. Palaeomagnetic investigations and the presence of aeolian sediments in the Montevarchi synthem and cold pollen flora allowed its attribution to the Middle and Late Pliocene. The relationships between the different synthems and the dominant unconformities coupled with thermochronological data recently obtained in the Apennine ridge to the east (Balestrieri *et al.*, 2003) allow us to establish that the Chianti Ridge, after a major planation, became the eastern edge of a moderate relief (Spedalino subsynthem) that was later transformed into a wide alluvial plain (Meleto subsynthem). Updoming tilted the previous units before the modelling of a second major unconformity that preceed the deposition of the Montevarchi synthem. It is possible that during this period the Valdarno was still connected to the Siena Basin to the west. A third major unconformity followed finally separating the two basins. These deformations occurred almost at sea level. During the Early and Middle Pliocene, the Apennine Ridge to the east did not exist and the Upper Valdarno represented the western part of the peri-Adriatic Basin. The deepening of the drainage network is due to the generalised uplift that in the nearby areas started during the Early Pleistocene. Finally the creation of the present-day Apennine watershed was not gradual but very rapid in the geological time scale and started mostly during the Early Pleistocene.

RIASSUNTO: M. Coltorti et al., Il sollevamento della dorsale del Chianti: discordanze progressive e sequenze deposizionali nel bacino della S. Barbara (Valdarno superiore, Italia*). (IT ISSN 0394-3356, 2007).*
*La dorsale dei Monti del Chianti, orientata in direzione NO-SE, separa il bacino della Valdarno Superiore dal bacino di Siena. Essa è costituita dai termini più recenti della Serie Toscana (Macigno e Scaglia Toscana) che sovrascorrono le Unità Liguri. Nel bacino della Valdarno superiore sono stati riconosciuti tre sintemi delimitati da importanti superfici di discordanza, dal basso verso l'alto: 1, sintema di Castelnuovo, suddiviso nei subsintemi di Spedalino e di Meleto; 2, sintema di Montevarchi; 3, sintema di Bucine. Il subsintema di Spedalino, che giace in discordanza sul substrato pre-pliocenico, è costituito da ghiaie grossolane di modesto spessore e lateralmente discontinue. Il subsintema di Meleto, generalmente interpretato come un sistema deposizionale lacustre, è caratterizzato da litofacies di pianura alluvionale, differenziate in vari sistemi deposizionali (canali, tracimazioni, paludi, ecc.) dove si depositavano torbe e si sviluppava una foresta a Taxodium. Nei pressi del margine occidentale del bacino entrambi questi subsintemi sono piegati fino a 60°. Il sintema di Montevarchi, costituito prevalentemente da sabbie e ghiaie deposte in un'ampia pianura a canali intrecciati, giace in discordanza sulle unità precedenti. Questo sintema è piegato verso est fino a 20°. Infine, il sintema di Bucine giace in discordanza sui precendenti sintemi generando un terrazzo fluviale del fiume Arno. Le due unità inferiori sono datate al Pliocene Inferiore. Infatti le argille di Meleto contengono faune a mammiferi che possono essere attribuite sia al Villafranchiano Inferiore (tardo Pliocene Inferiore – Pliocene Medio, Unità di Triversa), sia al Rusciniano (Pliocene Inferiore). Questi subsintemi sono magnetizzati negativamente e sono attribuiti all'evento di Gilbert. Le indagini paleomagnetiche, la presenza di depositi eolici e le associazioni polliniche fredde hanno permesso di attribuire il sintema di Montevarchi al Pliocene Medio e Superiore. Le relazioni esistenti tra i sintemi individuati e le varie discordanze, unitamente ai dati termocronologici, ottenuti recentemente nella dorsale appenninica a Est (*Balestrieri *et al.*, 2003) *hanno permesso di stabilire che la dorsale del Chianti, dopo un importante spianamento è diventata il margine orientale di un modesto rilievo (subsintema di Spedalino) e più tardi un'ampia pianura alluvionale (subsintema di Meleto). Il sollevamento della dorsale ha piegato le unità precedenti prima del modellamento di una seconda discordanza che ha preceduto la deposizione del sintema di Montevarchi. È possibile che durante questo periodo la Valdarno fosse ancora connessa con l'adiacente bacino di Siena posto più a ovest. Successivamente si modella una terza principale discordanza che separa nettamente i due bacini. Queste deformazioni avvenivano all'incirca al livello del mare. Durante il Pliocene inferiore e medio la dorsale appenninica ad est non emergeva e il Valdarno superiore rappresentava il settore occidentale del bacino peri-adriatico. L'approfondimento del reticolo di drenaggio è dovuto al sollevamento generalizzato che, nelle aree limitrofe, è iniziato durante il Pleistocene inferiore. Infine, la creazione dell'attuale spartiacque appenninico non è stata graduale ma molto rapida, a scala dei tempi geologici, ed è iniziata soprattutto durante il Pleistocene inferiore.*

Keywords: Progressive unconformity, Synthem, Stratigraphy, Facies Analysis, Chianti Ridge, Valdarno, Apennines, Italy.

Parole chiave: Progressive unconformity, Sintema, Stratigrafia, Analisi di facies, Dorsale del Chianti, Valdarno, Appennino, Italia.

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1. INTRODUCTION

The basins on the Tyrrhenian side of the Italian Peninsula are the site of a major controversy because their origin has been associated to ongoing tectonics during the Miocene and Pliocene. In the past, research was mostly concentrated on the general setting of the basins and their main subdivisions; few investigations were devoted to facies analysis or to their relationship with the nearby ridges that represent the results of the same dynamics. This is probably due to the fact that at the summit of the ridges only erosional features are still preserved. In this paper, we investigate the western side of the Upper Valdarno Basin, one of the most famous Neogene-Quaternary basins in the Northern Apennines, because it contains a large number of sites with Villafranchian mammal fauna (Azzaroli, 1977; Gliozzi *et al.*, 1997). In this area, inside the Santa Barbara peat quarry, the oldest sediments of the basin crop out. There are extensive outcrops and a series of boreholes[1] that reach the bedrock evidencing the geometry of the erosional surface at the base of the filling and that of the peat layers. We also investigated the different unconformity bounded stratigraphic units (UBSU) and their sedimentological characteristics and the architectural elements. This allowed us to establish the modifications that occurred in relation with the ongoing tectonics. Using all the scarce chronological elements, we tried to associate the changes that affected the basin with the uplift of the ridge, that was one of our main goals. We use a multidisciplinary approach involving geology, geomorphology and facies analysis which gives the best possibilities of understanding how and when the basin and nearby ridge were generated, the dynamics that affected the area and the changes that led to the creation of the present-day landscape.

We are going to demonstrate that, contrary to what was previously hypothesised these ridges are the result of folding and not of normal faulting. Moreover these movements did not create topography during the Pliocene, and the present day setting is mostly the result of differential erosion activated after the movement of generalised uplift that affected the Apennines coupled with high angle normal faulting along the Tyrrhenian side since the late Early Pleistocene.

2. THE GEOLOGIC AND STRATIGRAPHIC BACKGROUND

The Upper Valdarno, situated approximately 30 Km to the SE of Florence, was considered a graben or half-graben (Trevisan, 1952; Nardi, 1961; Elter *et al.*, 1975; Eva *et al.*, 1978; Mariani & Prato, 1988; Patacca *et al.*, 1990; Bertini *et al.*, 1991; Lazzarotto & Liotta, 1991; Sagri 1991; Billi *et al.*, 1991; Martini & Sagri, 1993; Bossio *et al.*, 1995). It is characterised by a relatively gently SW margin (Chianti Ridge) and by a steep NE side (Pratomagno Ridge) where the main fault system is located. To the W the Chianti Mountains separate it from the Siena Basin. It is elongated about 35 Km in a NW-SE direction with a maximum width of 15 Km (Fig. 1, 2).

[1] Thanks to ENEL

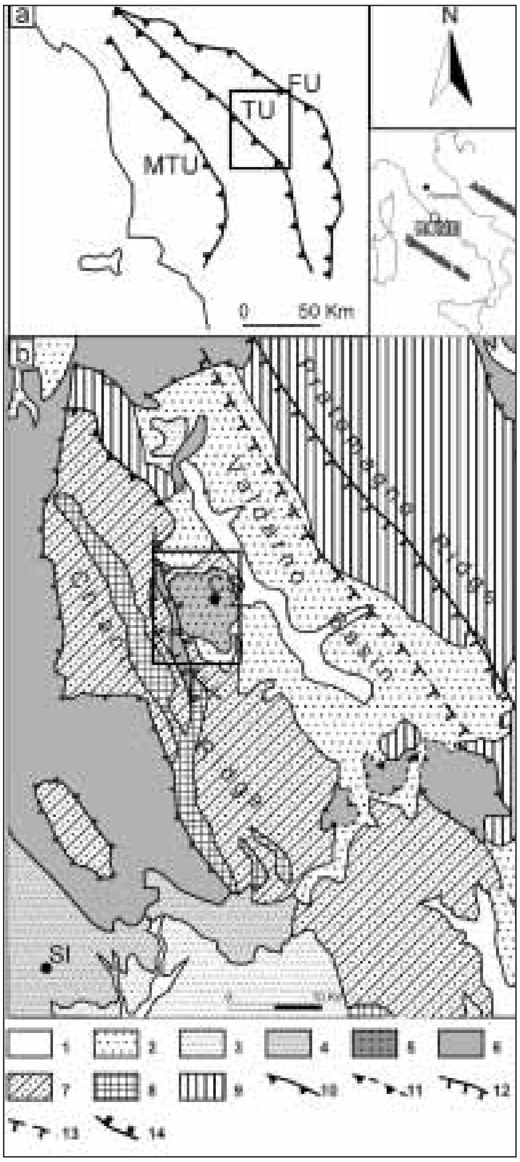

Fig. 1 - a. Schematic structural map of the main thrust fronts in the area (from AAVV, 1982 modified), FU: Cervarola-Falterona Unit Front; TU: Tuscan Unit Front; MTU: Mid-Tuscany Metamorphic Unit. b. Geological sketch map of the Siena Basin, Chianti Mountains, Upper Valdarno Basin and Pratomagno Ridge. 1: Alluvial Holocene deposits, 2: Pleistocene deposits, 3: Marine clay, silty-marly clays of the Siena Basin (Pliocene), 4: Marine conglomerates and sandstones of the Siena Basin (Pliocene), 5: Santa Barbara Basin (Early-Middle Pliocene), 6: Ligurian Units, 7: Macigno Fm., 8: Scaglia Toscana Fm., 9: Cervarola - Falterona Fm., 10: thrust and reverse faults; 11: buried thrust and reverse faults; 12: high-angle normal faults; 13: buried normal faults; 14: low-angle normal faults; CS: Castelnuovo dei Sabbioni, SI: Siena. The rectangle shows the studied area.

a. Schema strutturale dei principali thrust nell'area in esame (AAVV, 1982 modificato), FU: Unità Cervarola-Falterona; TU: Unità Toscane; MTU: Unità Metamorfiche medio-toscane. b. Carta geologica del Bacino di Siena, Monti del Chianti, bacino del Valdarno Superiore e dorsale del Pratomagno. 1: Depositi alluvionali olocenici, 2. Depositi pleistocenici, 3. Argille, argille siltoso-marnose marine del bacino di Siena (Pliocene), 4. Conglomerati e sabbie marine del bacino di Siena (Pliocene), 5. Bacino della S. Barbara (Pliocene Inferiore-Medio), 6. Unità Liguri, 7. Macigno, 8. Scaglia Toscana, 9. Unità Cervarola-Falterona, 10. Thrust e faglie inverse, 11. Thrust e faglie inverse sepolte, 12. Faglie normali ad alto angolo, 13. Faglie normali sepolte, 14. Faglie normali a basso angolo; CS: Castelnuovo dei Sabbioni, SI: Siena. Il rettangolo indica l'area studiata.

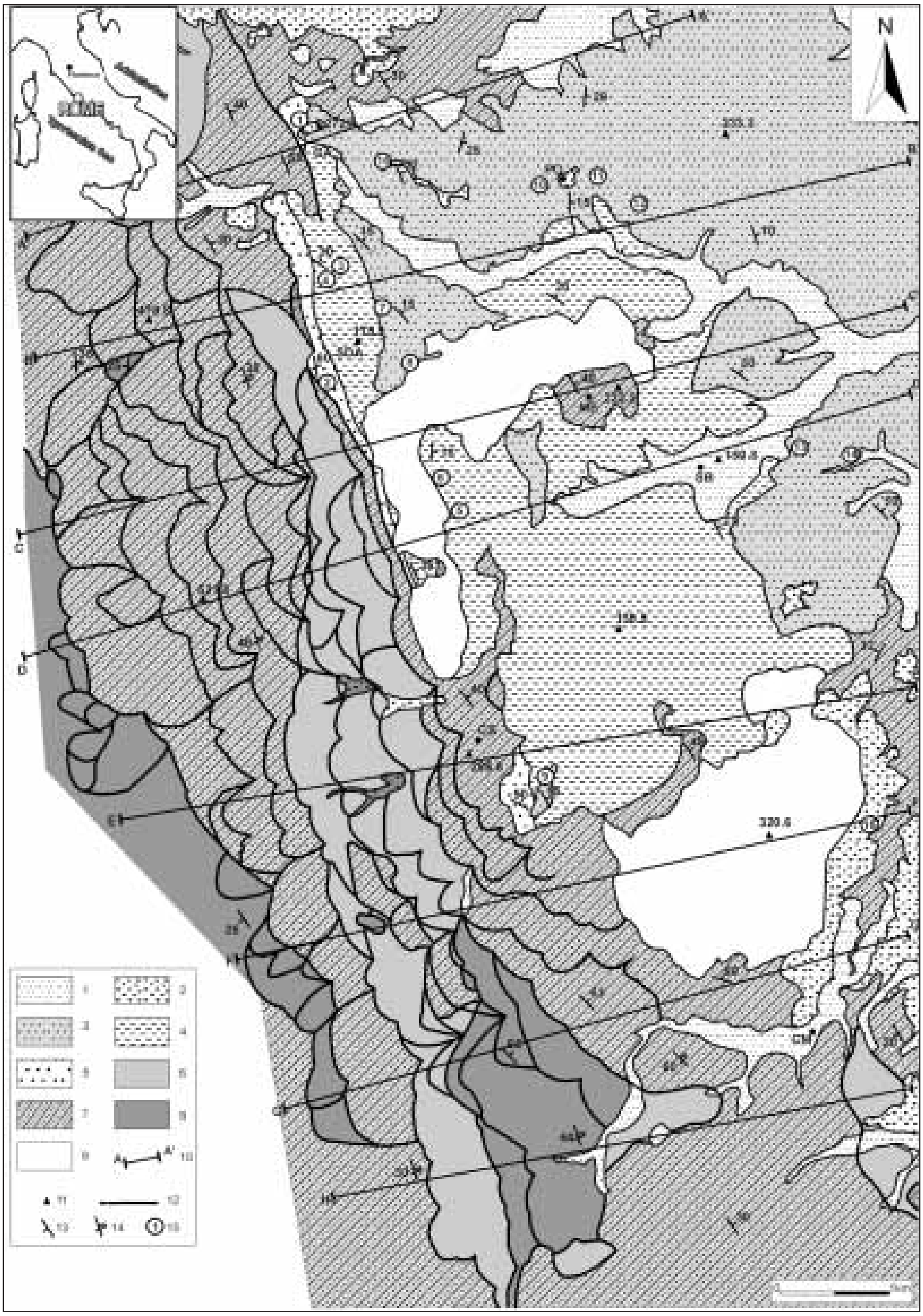

Fig. 2 - Geological sketch map of the studied area. 1: Holocene fluvial deposits, 2: Bucine synthem (Late Pleistocene), 3: Montevarchi synthem (Early Pliocene-Early Pleistocene), 4: Meleto subsynthem (Early-Middle Pliocene), 5 Spedalino subsynthem (Early-Middle Pliocene). Bedrock:6: Ligurian Units (claystones, limestones and marls), 7: Macigno Fm., 8: Scaglia Toscana Fm., 9: Mine Area, 10: Section tracks; 11: reference topographic points; 12: fault; 13: normal strike and slip; 14: reverse strike and slip; 15: stratigraphic section tracks. CS: Castelnuovo dei Sabbioni, ME: Meleto, SB: Santa Barbara, SDA: San Donato in Avane, GA: Gaville, CM: Cavriglia Monastero, PO: Poggio Secco.

Schema geologico dell'area studiata. 1: Depositi fluviali (Olocene), 2: sintema di Bucine (Pleistocene superiore), 3: sintema di Montevarchi (Pliocene superiore-Pleistocene inferiore), 4: subsintema di Meleto (Pliocene inferiore-medio), 5: subsintema di Spedalino (Pliocene inferiore-medio). Substrato: 6: Unità liguri (argille, calcari e marne), 7: Macigno, 8: Scaglia Toscana, 9: Area miniera, 10: Traccia sezioni, 11: punti quotati, 12: faglie, 13: strati diritti, 14: strati rovesci; 15: tracce delle sezioni stratigrafiche. CS: Castelnuovo dei Sabbioni, ME: Meleto, SB: Santa Barbara, SDA: San Donato in Avane, GA: Gaville, CM: Cavriglia Monastero, PO: Poggio Secco.

The Chianti Ridge is made by a stack of different tectonic units (Elter & Sandrelli, 1995; Bonini, 1999). The non-metamorphic Tuscan Nappe is the lowest and it is represented by folded rocks of the Macigno Sandstones (Late Oligocene – Early Miocene) and the Scaglia Toscana calcarenites, shales and marly limestones (Middle Cretaceous - Oligocene). In the eastern side of the Chianti Ridge, large olistostromes coming from the Ligurian and Sub-ligurian Units (Complesso di Canetolo, M. Morello Unit) were deposited inside the Macigno Fm. (Merla,1969; Castellucci & Cornaggia, 1980; Lazzarotto & Liotta, 1991; Bonini, 1999). Similar olistostromes, dispersed in the turbiditic series of the Northern Apennines, would indicate submarine landslides connected with the progressive migration of the tectonic units towards the foredeep (Abbate & Sagri, 1981; Pini, 1999 and ref. therein). However, to explain the geometry of the different lithological units Castellucci & Cornaggia (1980) inferred the presence of a series of overturned folds.

In the NE margin of the basin, the Tuscan Unit tectonically overlies, along W-dipping thrust fronts, a thick turbiditic sandstone succession belonging to the Cervarola-Falterona Unit (Merla & Abbate, 1967; Abbate, 1983; Albianelli *et al.*, 1995; Bonini, 1999). The various tectono-sedimentary units are the result of the eastward overthrusting of the terrains belonging to the westernmost palaeogeographic domains (Elter *et al*., 1975; Ricci Lucchi, 1986; Bertini *et al*., 1991; Patacca *et al*., 1990; Barchi *et al*., 1998; Finetti *et al*., 2001). Later on, the Tuscan and Cervarola Units were overlain along low angle E-dipping faults by the allochthonous Ligurian Units, mostly made up of clays, limestones and marls (M. Morello Unit, Complesso Caotico) (Merla & Abbate, 1967; Abbate, 1983; Boccaletti & Coli, 1983; Decandia *et al*., 1993). This rootless tectonic unit (Locardi, 1982) was detached in correspondence to the less resistant formations and, at least the more external part is generally considered the result of gravity tectonics known locally as "gravitational flows" (i.e. Marecchia Valley; Ruggieri, 1970; Veneri, 1986). In fact, the thrusting along the fronts was compensated by a series of detachments in the area now occupied by the Ligurian Sea.

Today, the Chianti Ridge constitutes an antiform with the Tuscan Unit at the core and Ligurian Units cropping out in the SW and NE side of the basin. The western margin of the Valdarno Basin corresponds to the eastern side of this antiform.

The evolution of the intermontane basins, including the Upper Valdarno, is actually very debated. A group of authors interpreted them as graben-like features, created on the rear of the thrust fronts (Elter *et al*., 1975; Martini & Sagri, 1993; Barberi *et al*., 1995). Their origin should be linked to the migration of the Apennine chain-foredeep system and therefore their activation and filling should be progressively more recent moving from W to E. Many authors associated this migration to a typical subductional model (Malinverno & Ryan, 1986; Patacca *et al*., 1990; Doglioni, 1991). In this model, the extensional movements controlled the fluvial-lacustrine sedimentation. The older extensional basins in the onshore Tyrrhenian side would be generated during Tortonian-Messinian times (Azzaroli & Lazzeri, 1977; Abbate, 1983; Bernini *et al*., 1990 see ref. therein; Billi *et al*., 1991; Sagri, 1991; Bossio *et al*., 1995; Sagri & Magi, 1992; Benvenuti, 1993; Martini & Sagri, 1993; Albianelli *et al*., 1995).

More recently, at least four main regional unconformities (Messinian, Early Pliocene, Late Pliocene, Early-Middle Pleistocene), related to syndepositional events, have been documented (Bernini *et al*., 1990, Boccaletti & Sani, 1998, Boccaletti *et al*., 1999) and associated by the same Authors to the "compressional" style of basin genesis (Boccaletti *et al*., 1995; Coltorti & Pieruccini, 1997A; 1997B; Calamita *et al*., 1999). Lazzarotto & Liotta (1991) had already documented the presence of folds inside the fluvial-lacustrine deposits but it was supposed to have only a local significance in an extensional context. Finetti *et al*. (2001, and ref. therein) considered these basins as "perched basins", quite synonymous of "thrust-top" and "piggy back basins" (Grasso & Butler, 1991). On the other hand, Coltorti & Pieruccini (1997A; 1997B), Calamita *et al*. (1999) and, more recently, Argnani *et al*. (2004) attributed these deformations to the surface response of the activity of low-angle E-dipping normal faults. The latter authors agree that the high angle normal faults that today delimit the eastern border of the basin are the result of extensional movements active since the end of the Early Pleistocene.

During our field work, we recognised a series of abrupt contacts between different lithologies that are difficult to explain except with the occurrence of a fault zone with various fault planes that mark the contact between different terrains (Figs. 2, 3). In our interpretation, all the tectonic contacts represent E-dipping low angle faults that affected both the Tuscany and Ligurian terrains. This wide fault zone (Fig. 3) is located on the northern continuation of one of more important detachments of the Apennine area: the Alto-Tiberina Fault (Barchi *et al*.,1998; Boncio *et al*., 1998; Boncio & Lavecchia, 2000). Although Bonini (1999) attributed the evolution of the Valdarno basin to the activity of the thrust front along the western side of the Chianti Ridge, and especially at the contact between Tuscan and Ligurian Units, we collected any evidences that could confirm this hypothesis.

3. THE PLIO-PLEISTOCENE DEPOSITS

The sedimentary filling of the Upper Valdarno Basin is made up of continental sequences attributed to the Middle Pliocene up to the Pleistocene (Merla, 1949; Abbate, 1983; Albianelli *et al*., 1997; Albianelli *et al*., 2002; Napoleone *et al*., 2003). The contact between the pre-Pliocene bedrock and the Plio-Pleistocene deposits is an abrupt unconformity. Inside the filling three stratigraphic units separated by angular unconformities have been recognised by the previous authors (Sestini, 1936; Azzaroli & Lazzeri, 1977; Abbate, 1983; Billi *et al*., 1991; Bertini *et al*., 1991; Lazzarotto & Liotta, 1991; Martini & Sagri, 1993). More recently, they have been grouped in synthems (Sagri & Magi, 1992; Benvenuti, 1993) and supersynthems (Boccaletti *et al*., 1995; Ghinassi & Magi, 2004) indicative of three depositional cycles (Fig. 4).

From the oldest they are: 1, Castelnuovo; 2, Montevarchi and 3, Monticello-Ciuffenna. The

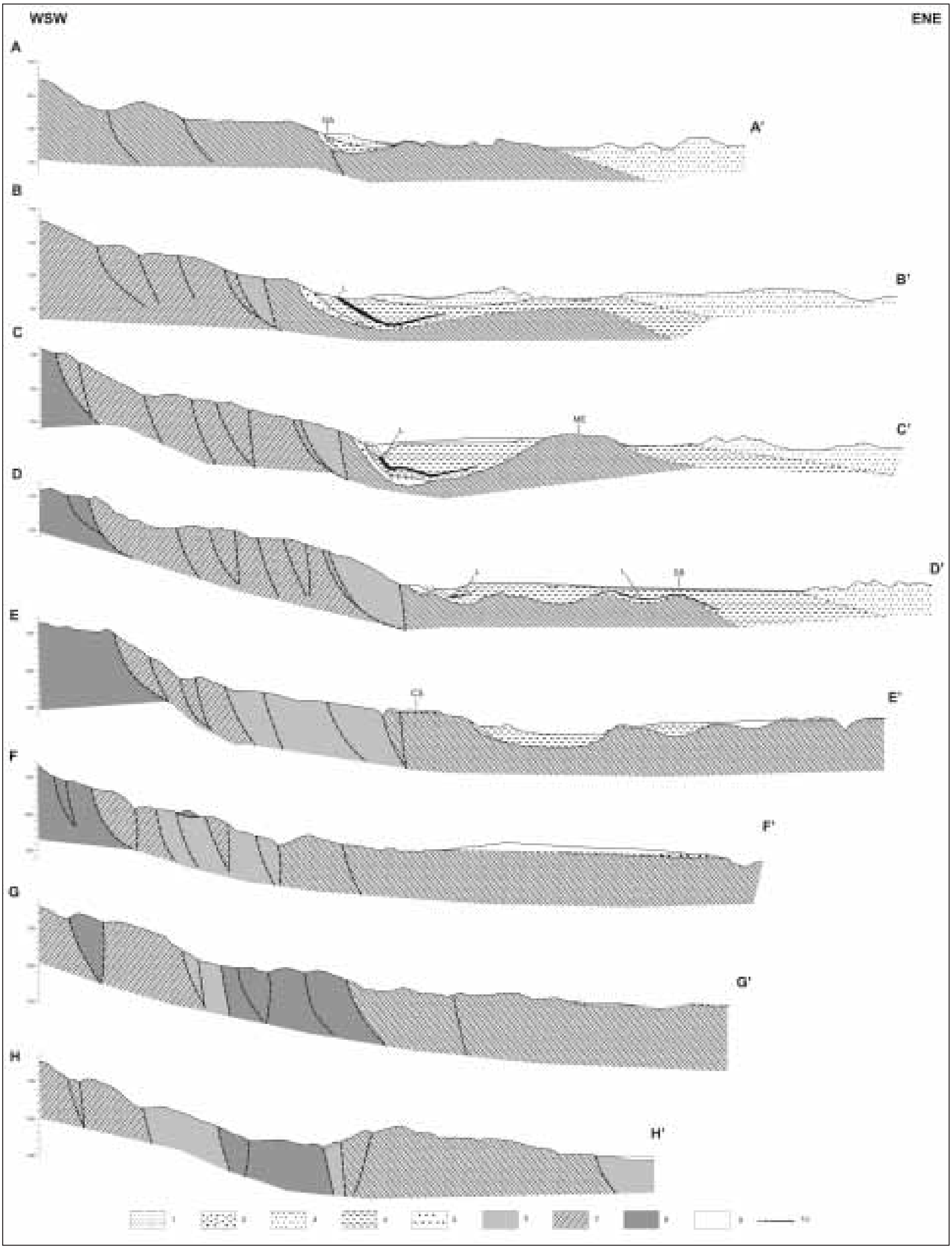

Fig. 3 - Geologic sections through the S. Barbara basin as mapped in Fig.2. 1: Holocene fluvial deposits, 2: Bucine synthem, 3: Montevarchi synthem, 4: Meleto subsynthem, 5 Spedalino subsynthem, 6: Claystones, limestones and marls (Ligurian Units), 7: Macigno Fm., 8: Scaglia Toscana Fm., 9: Mine Area, 10: fault, GA: Gaville; ME: Meleto, SB: Santa Barbara, CS: Castelnuovo dei Sabbioni, L: lignite bank.

Sezioni geologiche attraverso il bacino della S. Barbara così come indicate in Fig.2. 1: depositi fluviali olocenici, 2: sintema di Bucine, 3: sintema di Montevarchi, 4: subsintema di Meleto, 5: subsintema di Spedalino, 6: Argille, calcari e marne (Unità Liguri), 7: Macigno Fm., 8: Scaglia Toscana Fm., 9: Miniera, 10: faglia, GA: Gaville; ME: Meleto, SB: Santa Barbara, CS: Castelnuovo dei Sabbioni, L: banco di lignite.

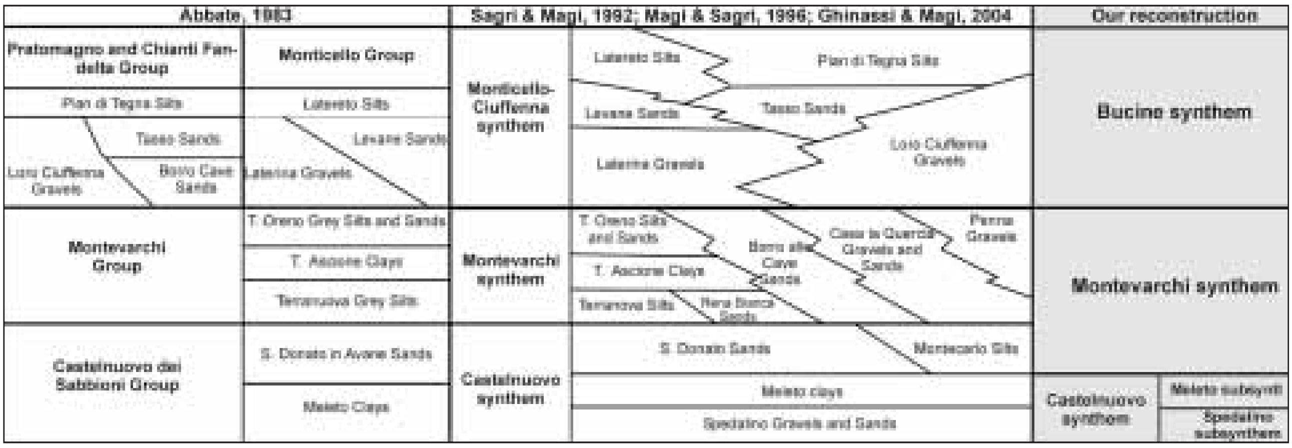

Fig. 4 - Synthesis of the stratigraphic reconstruction of various authors.
Sintesi della stratigrafia ricostruita da vari autori.

Castelnuovo synthem was further subdivided into three units, from the bottom: Spedalino Gravels and Sands, Meleto Clays and S. Donato Sands, while the Montevarchi synthem includes the Terranuova Silts, Ascione Clays and Oreno Silts and Sands (Lazzarotto & Liotta, 1991; Magi & Sagri, 1996; Bertini, 2001; Napoleone *et al*., 2003; Ghinassi & Magi, 2004). We continued to use this name for the Montevarchi synthem (Fig. 4) because we prefer not to proliferate names in the scientific literature. However, it must be stated that this unit has never been described in detail and a type sequence does not exist. Moreover we changed the base of the sequence that, after our investigation, is marked by a major unconformity not recognised in the other areas. It separates the Castelnuovo from the Montevarchi synthem and the S. Donato Sands belongs to the latter (Fig. 4). These last sediments should be interlayered with coarser sediments interpreted as fan delta deposits fed from the east (Penna Gravels, Casa Quercia Gravels and Sands and Borro Cave Sands). Along the SW margin of the basin this synthem also includes the Montecarlo Sands and Silts and white aeolian sands (Rena Bianca Sands) interlayered with fluvial sands in the areas close to the alluvial systems located to the west (Magi & Sagri, 1996; Bertini, 2001; Ghinassi & Magi, 2004). The aeolian sands seem to overlie discontinuously with the S. Donato Sands (Bertini, 2001; Ghinassi & Magi, 2004; Ghinassi *et al*., 2004). Finally the Monticello-Ciuffenna synthem is made of fluvial deposits (Laterina Gravels, Levane Sands and Latereto Silts) and alluvial fan deposits (Loro Ciuffenna Gravels, Tasso Sands and Pian di Tegna Silts) (Benvenuti, 1993; Albianelli *et al*., 1995). This synthem corresponds with Bucine synthem (Fig. 4) but this name is here preferred because it was used first in literature (Merla & Abbate, 1967; Azzaroli & Lazzeri, 1977; Lazzarotto & Lotta, 1991).

The relationships between the erosional boundary surfaces located: 1. at the base of the sequence; 2. at the base of the Montevarchi synthem; 3 at the base of the Bucine synthem, generate a progressive unconformity that testifies that the Chianti Ridge underwent uplift movements while the basin was sinking, hosting a "fluvial-lacustrine sedimentation" (Boccaletti *et al*., 1995; Bonini, 1999).

A detailed sedimentological analysis of the Neogene-Quaternary deposits outcropping in the Upper Valdarno Basin was carried out to identify: 1, the facies associations and the architectural elements and, 2, the depositional paleo-environment. In fact, except for some general observations on the main lithological units (Abbate, 1983; Billi *et al*., 1991; Benvenuti, 1993; Martini & Sagri, 1993), an exhaustive sedimentological study was made only for the Late Pliocene aeolian sediments (Ghinassi & Magi, 2004). Our sedimentological analyses were made adopting the Miall (1985; 1996) classification. The facies analysis and the different lithofacies associations led to the recognition of many architectural elements used to distinguish between the depositional systems. In the present work three synthems have been recognised, bounded by unconformities partially not consistent with those identified by the previous authors. In fact the Castelnuovo synthem corresponds only in part with the basal sequence recognised by the previous authors (Fig. 4) because it is made only by the two basal units (Spedalino Gravels and Sands, Meleto Clays). Nevertheless we decided not to create new names in order to avoid a proliferation of new synthems in the geological literature. The contact between the two units is never visible in outcrop and a clear unconformity between the two basal units is not recognisable although we cannot exclude it. However, the facies association changes abruptly. The sediments cropping out in the Meleto area (Meleto Clays of previous Authors) have been here considered a subsynthem. It must be pointed out that the textural description is wrong because the clays are subordinate to the sands. The Castelnuovo synthem is unconformably overlapped by the Montevarchi synthem, that is overlaid by the Bucine synthem. At least in the study area there are no facies variations, inside the Montevarchi synthem, that should be used for a further subdivision as the previous authors have done in the Montevarchi area (Sagri & Magi, 1992; Ghinassi & Magi, 2004).

In particular, the sediments belonging to each synthem can also lie directly on the bedrock (Figs. 2, 3).

3.1 Castelnuovo synthem

As mentioned above it is difficult to establish the relationships between the older deposits and if they should be considered a synthem or a subsynthem. In fact, the older is very thin and only locally preserved and the contact with the overlying sediments is never visible in the field. Moreover, they are continental deposits where erosional boundaries are common.

3.1.1 Spedalino subsynthem

The subsynthem is mostly made up of gravels and sands. Short stratigraphic sections have been observed at the contact with the Macigno Fm. The most important sections are located to the north of Gaville and near San Donato in Avane (Figs. 2, 7, 8). In the western sector of the basin, close to the Chianti Ridge, the unconformity at the base of the gravels as well as the overlying layers dip ca. 40°-70° to the NE while to the E they become sub-horizontal (Fig. 3).

Albianelli *et al*. (2002) mentioned a negative magnetic field of layers inside the Spedalino subsynthem but does not show where the sequence was made. On the other hand, Albianelli *et al*. (1997) and Napoleone *et al*. (2003) have clearly shown that a magnetic signal was found in the lower part of the Meleto Clays. The dating of the base of the unit was therefore obtained extrapolating a constant sedimentological rate. These circular arguments could hide a much older age for the Spedalino gravels especially if a major unconformity was to be located at the top of the sequence.

Facies analysis

Two stratigraphic sections have been investigated in detail (S1 and S2; Figs. 2, 7). The deposits are made up of clast-supported cross-bedded or massive rounded gravels and pebbles (Gt and Gm) well sorted in places. They generate massive layers up to 3 m thick (Fig. 7). The gravels are medium to coarse-grained up to 100 cm in size (S2). The matrix is scarce. The composition is exclusively arenaceous coming from Macigno Fm. Occasionally soft clasts are present. Rare lenses of cross-bedded stratified sands are also present (St) (S1; Fig. 7).

Interpretation

Similar sediments are found in coarse gravelly depositional systems such as a pedemountain stream, braided channels or in proximal alluvial fan deposits. The good sorting of some coarse Gm layers suggests the presence of armoured beds that favours a pedemountain stream environment. The Gt and thin lenses of St lithofacies are consistent with the same environment. The lateral absence of this unit could suggest that it fills a palaeo-valley cut into the bedrock. The river was located close to a relief and fed by rocks belonging to the Macigno Fm.

3.1.2 Meleto subsynthem

It is made by fine sediments, rich in lignite layers. In boreholes, the clays are up to 250 m thick. The most extensive outcrops are located close to the San Donato quarry where ca. 15÷20 m thick sequences have been described (Figs. 2, 7, 8). These sediments contain remains of mammal bones of *Tapirus arvernensis, Ursus minimus, Dicerorhinus* sp., *Leptobos* sp. and *Anancus arvernensis*, related to the Triversa Faunal Unit (Borselli *et al*., 1980; De Giuli *et al*., 1983; Benvenuti *et al*., 1995; Albianelli *et al*., 1997), attributed to the Early Villafranchian. However, a similar association is also found in the Ruscinian (Early Pliocene) (Fejfar, 2001). The palinological analyses recognised an association of tropical (Taxodiaceae, Lauraceae, *Nyssa, Engelhardia, Symplocos*, ecc.) and temperate taxa (*Quercus, Carpinus, Liquidambar, Carya, Zelkova, Populus, Acer, Betulla, Fagus*, etc.) (Bertini & Roiron, 1997) that indicate warm humid climatic conditions favourable to the development of forests and swamps.

Albianelli *et al*. (2002) and Napoleone *et al*. (2003) established a reverse polarity for the lowermost part of the sequence and attribute it to the k-interval Gauss (C2An.1r) suggesting an age of 3.1 Ma for a lignite layer close to the base of the sequence. However, the chronostratigraphic setting is based on the supposed Middle Pliocene age of the Triversa Unit, that as previously stated is uncertain. It is also based on the assumption of a constant sedimentation rate and does not consider that the sequence, as we describe in the following paragraphs, is not continuous and is split in two by a major unconformity located between the Castelnuovo and the Montevarchi synthems. Therefore, there is no base for the application of the “count from the top” method as utilised by *Napoleone et al*. (2003). Moreover, the whole sequence is clastic and contains a large number of channels that constitute further discontinuities at a local scale. Therefore, paleomagnetic investigations can only be used to state that this unit is older than 3.1 Ma.

Facies analysis

Four stratigraphic sections crop out in the S. Barbara and in the S. Donato quarries (S3-S6; Figs. 2, 7). The Meleto subsynthem is mainly made up of grey massive or slightly laminated silty clays (Fm, Fl), containing wood remains, branches, leaves and pine-cones. These lithofacies are interlayered with thin layers of fine to coarse trough or planar cross bedded sands (St and Sp lithofacies respectively), up to 30 cm thick (S5; Fig. 7). Rarely coarse and medium-grained sands (St, Sp), up to 180 cm thick, are present and contain wood fragments (branches and leaves) (S4; Fig. 7). In particular, in S4 section a 6 m thick lignite bed has been observed containing thin layers (up to 20÷30 cm thick) of fine to medium grained trough cross bedded sands (St). The rooted parts of many tree trunks in a standing position have also been observed (S3; Fig. 7). Thicker lignite beds are also well known at depth and were extensively quarried. Smaller cascade folds have been observed close to the bedrock. Boreholes for lignite exploitation revealed the existence of a narrow synform close to the mountain slope bordered to the east by a minor antiform (Fig. 3). The latter is made up of folded sandstones and has been named Meleto anticline by *Bonini* (1999).

Interpretation

Most of the fine-grained sediments (Fm and Fl lithofacies association) are overbank deposits (architectural element FF), developed from overbank sheet flow into a large alluvial plain characterised by different subenvironments (channels, crevasse, swamps, etc.). The peat represents the accumulation of the vegetation in the floodplain where a *Taxodium* forest developed from time to time. The thinner sandy lithofacies (St, Sp) represents a crevasse channel (architectural element CR) breaking the main channel margin. The progradation from crevasse channel into floodplain creates crevasse splay deposits (CS) that periodically affected the floodplain. These deposits are characterised by St and Fl lithofacies associations. The architecture is coherent with the Model 6 (sandy, mixed load meandering rivers) of Miall (1985).

Fig. 5 - S. Donato sands belonging to the Montevarchi synthem.
Sabbie di S. Donato appartenenti al sintema di Montevarchi.

3.2 Montevarchi synthem

The main sections are located inside the S. Donato quarry, next to Village of Meleto, and inside the Santa Barbara area (Figs. 2, 5, 7, 8). Close to the study area, in the SW sector of the Valdarno Basin, at the top of the supposed coheval Montevarchi succession, fine-grained levels rich in pollen assemblages have been encountered interlayered with aeolian deposits (Rena Bianca Sands, Fig. 4). The basal part of the Rena Bianca sequence is characterised by cold and humid climatic conditions with dry moderate oscillations (Bertini, 1994; Albianelli *et al*., 1995). The progressive cooling is testified to by the increase of Fagus and Picea (Bertini & Roiron, 1997).

The previous authors did not notice the unconformity and included this unit inside the Montevarchi synthem. It is related to the Late Pliocene – Early Pleistocene interval (Billi *et al*. 1991; Bossio *et al*., 1992; Albianelli *et al*.,1995), because of the finds of Late Villafranchian faunas (Azzaroli, 1977; De Giuli, 1983; Azzaroli, 1984; Benvenuti, 1993). In particular, the base of the Rena Bianca Sands is attributed to ca. 2,58 Ma (Gelasian) based on paleomagnetic investigations (Albianelli *et al*., 2002; Napoleone *et al*., 2003). The deposition of the aeolian sands occurred during an arid event inside the global climatic deterioration of this period (Bertini & Roinor, 1997; Ghinassi *et al*, 2004). Again, Albianelli *et al*. (2002) and Napoleone *et al*. (2003) suggested an age of 2.64 Ma for the top of the Meleto subsynthem, but as previosuly stated, they used a constant sedimentation rate between two paleomagnetic intervals the lowermost being located below a major unconformity.

Facies analysis

Eight sections (S7-S14) have been investigated (Figs. 2, 7). The bottom part of the synthem is mainly characterised by fine to coarse trough or planar crossbeds (St and Sp respectively) that show a marked lateral facies variation. Load-cast structures are sometimes present. The sands are generally alternated with rich organic matter, grey massive or slightly laminated silty clays, a few cm thick (Fm, Fl). The lack of sedimentary structures is probably due to strong bioturbation. Wood remains are common. Moving upwards, there are trough crossbedded gravels (Gt) interlayered with fine to coarse trough crossbeds (St) and horizontal laminated sands (Sh). Rarely ripple cross-lamination is present (Sr). Moreover rich organic centimetric beds are common (C), although wood remains are generally also scattered inside the sandy lens. The base of the gravels is erosional and marked by pebbles in a scarce sandy matrix. The clasts are generally well rounded and up to 10 cm in diameter. They are mainly derived from the Macigno sandstones. However, near Poggio Secco, some clasts with an orthogneiss composition (F. Talarico, pers. com.) have been recognised. The finding of metamorphic clasts, and in particular of "porphiric aplite" whose easternmost outcrop is actually the Elba Island, is noticed in numerous peri-Tyrrhenian basins (Tongiorgi & Tongiorgi, 1964; Bossio *et al*., 1995). Orthogneiss clasts have also been recognised inside the Macigno Fm. in the Chianti Mts. (Ferrini & Pandeli, 1983).

Interpretation

Gravelly (Gt) and sandy lithofacies (St, Sh, Sr) are typical of a fluvial channel (CH architectural element; Miall, 1985). The tabular gravelly layers identify gravel bars or bedforms (GB architectural element) that are commonly interbedded with sandy bedforms (SB architectural element). The fine-grained lithofacies associations are deposited into the alluvial plain from overbank sheet flows (FF architectural element) and can also fill abandoned channels. These elements are commonly interbedded with SB architectural elements. Fine organic sediments are also commonly deposited in the ponds and swamps inside the alluvial plain. Sometimes crevasse splays (CS) can spread from crevasse channels into floodplains, interrupting the sedimentation of overbank fines (FF). The sedimentary architecture is typical of a wide alluvial plain with meander belts that turn upwards into a braidplain. The fluvial style suggests a gravel-sand or a gravelly meandering river (Model 5 and Model 6; Miall,1985).

The orthogneiss clasts come from the erosion of the Macigno Fm. located to the W. A main provenance from SW for the S. Donato Sands was also obtained with paleocurrent measurements by ALBIANELLI *et al*. (1995) and GHINASSI & MAGI (2004).

3.3 Bucine synthem

The sections investigated (S15 and S16) are located near the village of Gaville (Fig. 2, 6, 7, 8). These are mainly gravels up to 15÷20 m in thickness (Fig. 7). They constitute the top of a terrace and there are vertical escarpments (locally named "balze") that represent the rim of the terrace. The summit of the terrace ranges between 290 m upstream in the Castelnuovo dei Sabbioni area to 240÷250 m near Cavriglia, downstream. The longitudinal slope of the terrace was ca. 0,7%.

These deposits contain faunas attributed to the Middle-Late Pleistocene or to the end of the Early Pleistocene (BORSELLI *et al*., 1980; DE GIULI, 1983; BENVENUTI, 1993; ALBIANELLI *et al*., 1995). In this work we suggest a Late Pleistocene age for the topmost unit because of its morpho-pedostratigraphic characteristics. In fact, the unit is: 1, the last deposit before the post-glacial incision that led to the present-day setting of the valley and there are no other wide terraces located at minor elevations; 2, the top of the terrace is not weathered by rubified soils with Bt or Bts profiles, typical of the MIS 5 Interglacial (COLTORTI & PIERUCCINI, 2006). This synthem is apparently not deformed.

Facies analysis

The deposits are characterised by clast-supported trough and planar cross-bedded gravels (Gt and Gp respectively), with a scarce sandy matrix. The clasts are well-rounded or sub-rounded and a sandstone composition predominates. Their dimensions range from a few cm up to 20 cm. Rarely fine to coarse trough cross-bedded or massive sands (St and Sm respectively) and silts (Fm) up to 30 cm thick are present. The contact with gravels is clearly erosive. In the S15 section the unconformity between the Castelnuovo and Bucine synthems can be observed. In this sector of the basin the Bucine gravels overlie the Castelnuovo synthem made up of massive sand (Sm) and massive organic rich silts (Fm).

Interpretation

The association of the Gt and Gm lithofacies and the tabular layers characterise gravel bars and bedforms (GB architectural elements: Miall, 1985) generating a multilayer infilling. Both lithologic, and textural features and lithofacies association are typical of a gravelly braidplain that could belong to the fluvial depositional system of the Palaeo-Arno river and its tributaries (Model 2; Miall, 1985). Migrating channels and lateral-accretion macroforms (LA architectural element) suggest the local onset of a wandering system (Model 4; Miall, 1985). The gradient of the top depositional surface gently dipping towards the central part of the valley in the area closer to the slope suggests the existence of a series of coalescent alluvial fans.

Fig. 6 - Gravel deposits belonging to the Bucine synthem cropping out north-east of Poggio Secco (see also Fig.2).

Depositi ghiaiosi appartenenti al Sintema di Bucine affioranti a nord-est di Poggio Secco (cfr. Fig.2).

4. THE EVOLUTION OF THE WESTERN SIDE OF THE VALDARNO BASIN

The beginning of the evolutionary history of the basin is marked by a major unconformity (Fig. 9A). It allows us to separate pre-Pliocene from Plio-Quaternary tectonic movements. This unconformity cuts the thrust of the Tuscan Unit over the Cervarola Unit as well as the detachment at the base of the Ligurian Units. In fact, the Early Pliocene sediments lie unconformably over all these tectonic units. This confirms that a large amount of shortening and the later collapse of the Ligurian Units occurred previous to the Early Pliocene.

It is worth mentioning that, around 5 Ma an important rock uplift is recorded with thermochronologic analysis in the Apennines to the E of the Valdarno Basin (ABBATE *et al*., 1994; BALESTRIERI *et al*., 2003).

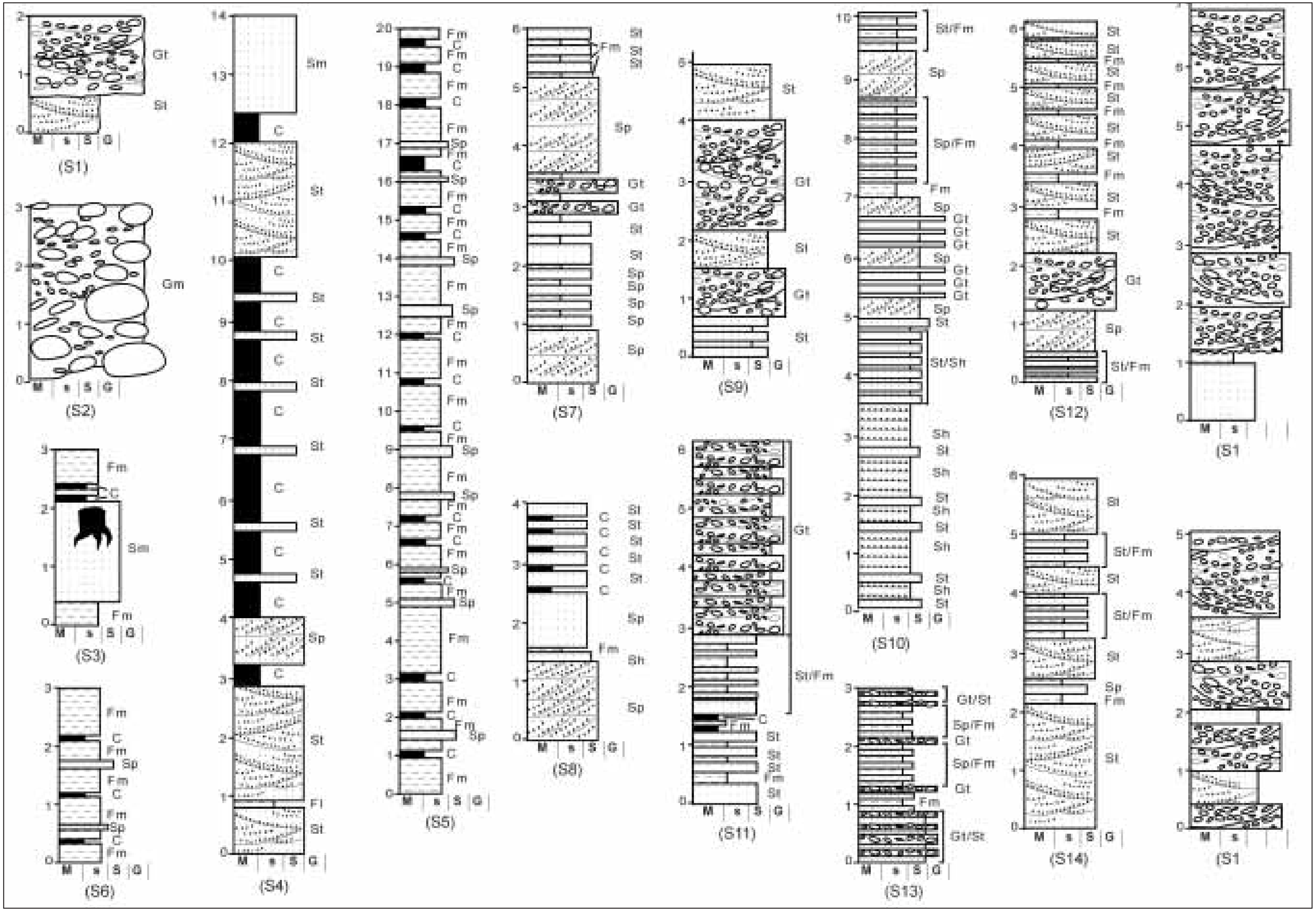

Fig. 7 – Stratigraphic sections related to portions of the recognised synthems inside the S. Barbara Basin: Spedalino subsynthem (S1 and S2); Meleto subsynthem (S3 to S6); Montevarchi synthem (S7 to S14) and Bucine synthem (S15 and S16). The thickness of the sections is in meter. M: mud, s: silt, S: sand and G: gravel. The lithofacies codes are related to facies classification of Miall (1996).

Sezioni stratigrafiche relative a porzioni dei intemi riconosciuti nel bacino della S. Barbara: subsintema di Spedalino (S1; S2); subsintema di Meleto (S3 - S6); sintema di Montevarchi (S7 - S14) e sintema di Bucine (S15; S16). Lo spessore delle sezioni è espresso in metri. M: fango, s: limo, S: sabbia e G: ghiaia. I codici delle litofacies sono relativi allo schema classificativo di Miall (1996).

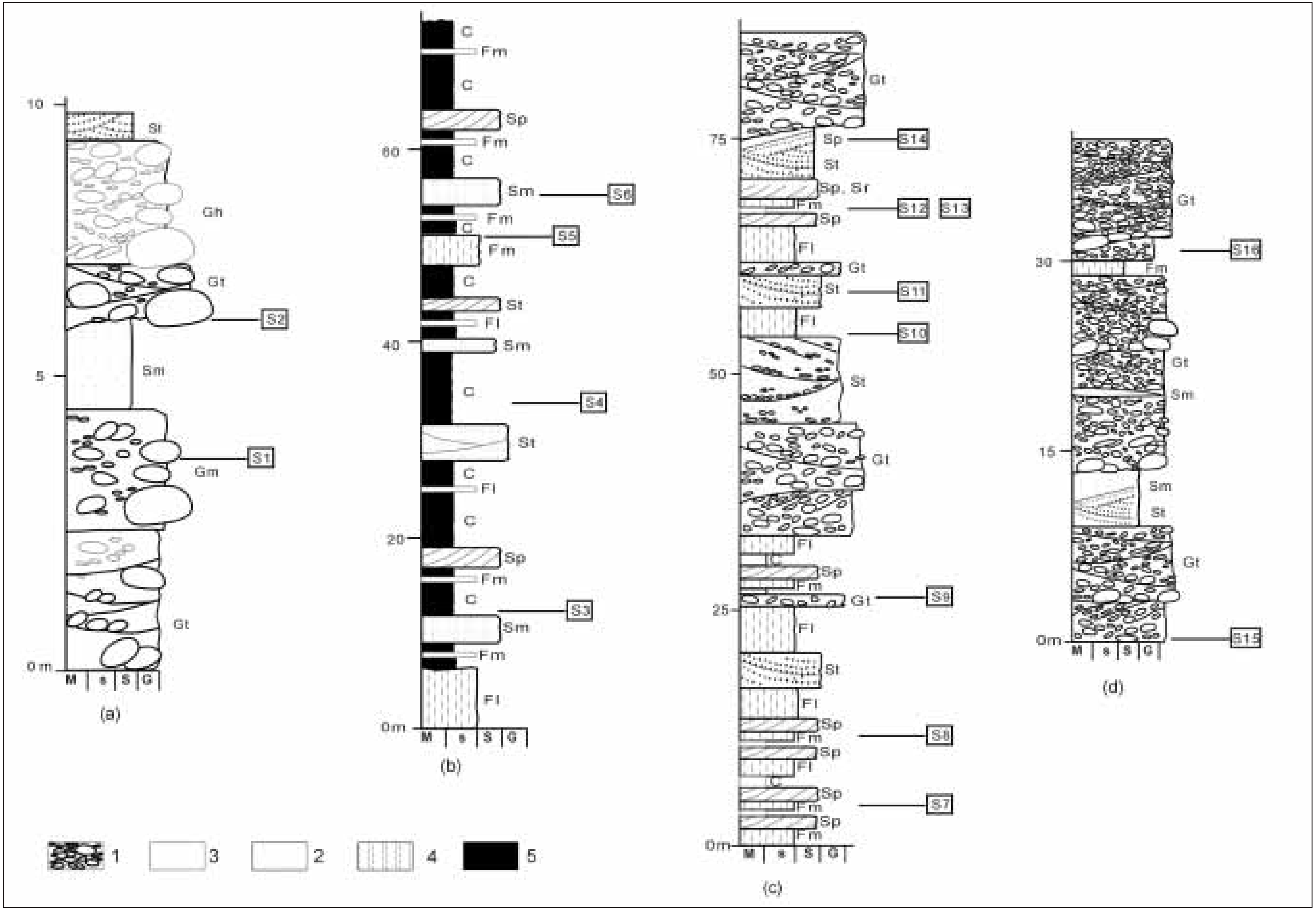

Fig. 8 - Stratigraphic sections related to the recognised synthems inside the S. Barbara Basin: a. Spedalino subsynthem, b. Meleto subsynthem, c. Montevarchi synthem, d. Bucine synthem. The facies are of Miall (1996). S1-S16 mark the relative position of the portions of the stratigraphic sections related to Fig. 7.

Sezioni stratigrafiche sintetiche relative ai sintemi riconosciuti all'interno del bacino della S. Barbara: a. subsintema di Spedalino, b. subsintema di Meleto, c. sintema di Montevarchi, d. sintema di Bucine. Le facies sono relative allo schema di classificazione utilizzato da Miall (1996). S1-S16 indicano la posizione relativa delle porzioni delle sezioni stratigrafiche analizzate e relative alla Fig.7.

These Authors suggest that the erosion of a cover up to 5.000 metres thick affected the Ligurian Units. An important erosion of the Ligurian terrains is documented in the area because these terrains are completely missing along the Chianti Ridge as well as in many surrounding areas. However, in the investigated area, there is no evidences that the Ligurian terrains could ever have reached such a thickness. Because the base of the sequence is older than 3.5 Ma the best place where this erosional event could be recorded is the major unconformity at the base of the filling. Rather than explaining the cooling event with uplift followed by denudational process of 5 km of rocks, we suggest that the unusual very rapid erosion was partly associated with the delamination created by the detachment of the Ligurian Units. A later important planation processes at the beginning of the Pliocene is to be added to this event. The origin of this planation is difficult to establish. Coltorti & Pieruccini (1997A; 1997B; 2002) suggested that in later times, a plain of marine erosion, preserved as a planation surface, was modelled across the Apennines as a result of a major transgression during the late Early Pliocene. We suggest that a similar process could be responsible for most of the erosion associated with the older unconformity . It could correspond to the effects of the Zanclean transgression, again a major and long lasting event, that created a major unconformity in continental and marine sequences all around the Mediterranean. Usually, the sequence stratigraphy suggests that a major unconformity is not modelled during a transgression but during a regression. In our opinion when the sea level drops in correspondence with a cold climate the rivers are overcharged of sediments and do not have the energy to carve an erosional surface. This is also confirmed by the Holocene events recorded in many seismic profiles of the Italian continental shelf where a major unconformity affects the top of the Late Pleistocene sequence (Chiocci & Normark, 1992; Lecca *et al*., 1986; Lecca et al., 1998). When sea level rises the rivers have almost no solid load and therefore all the energy is consumed in the erosion of bedrock. The result of such a transgression is a very thin layer of shells and coarse sediments associated with the ravinement surface that could be easily removed or weathered if it is not rapidly buried. This would be one of the reasons for the absence of marine deposits. In fact, the Spedalino subsynthem, testifies to a phase of continental erosion after the planation and fills shallow valleys slightly incised into the bedrock. It also testifies to a relief located slightly to the west of the present-day basin.

There is no other evidence of coarse clastic sediments coming from the west during the deposition of the Meleto subsynthem, when a wide fine grained meander alluvial plain was established locally covered by a *Taxodium* forest and affected by peat deposition. Similar to what has been suggested in the nearby Tiber Basin and in other continental basins in the Central-Northern Italy (Coltorti & Pieruccini, 1997A; 1997B) the peat-rich levels of the Valdarno Basin could be related to the Early Pliocene. The negative signal (Albianelli *et al*, 1997) in the lower part of the sequence could correspond to the Gilbert magnetic Chron and therefore could be older than 4 Ma (Cande & Kent, 1995). These layers are found lying unconformably on the bedrock along the margin of the Chianti Ridge.

In the study area, a major unconformity developed after the deposition of the Meleto subsynthem that was tilted up to 40° in proximity of the actual slope (Fig. 9B, C and D). Because the faults recognised along the western margin of the basin (Figs. 2, 3) also dip 50-60° to the NNE, and were sealed by the Early Pliocene sedimentation they underwent the same tilting. If we restore the geometry of the faults to before tilting they become sub-horizontal (X point in Fig. 9).

We do not know (this is the significance of the question marks in Fig. 9C) if during this erosional phase the westward continuation of the oldest units, that is the connection with the Siena Basin, was interrupted or if this occurred in slightly later times. However, we can suppose that this plain was close to sea level since there are coheval marine sediments in the adjacent Siena (to the west) and Val di Chiana Basins (to the south). Middle Pliocene marine deposits are also found up to 800 m on the Cetona Mt. (Passerini, 1964; Liotta & Salvatorini, 1994) that constitutes the southern continuation of the Chianti Ridge. In the southern part of the Siena Basin, between S. Quirico d'Orcia and Montalcino a general unconformity was recognised but in the northern part, to the west of the study area, this evidence is lacking, most probably for the very few detailed sedimentological investigations (Bossio *et al*., 1995; Riforgiato *et al*., 2005). Also in the Siena Basin, peat layers with trunks are found in the lower part of the sequence interlayered with marine coastal sediments (Celle sul Rigo Fm.; Liotta, 1996) recording the LCO of G. *puncticulata*, around 3.6 Ma that we suppose could also be a good chronological setting for the final deposition of the Meleto clays. The following second cycle, that includes the uppermost coastal and deltaic sediments belongs to the Zanclean/Piacenzian Interval, around 3.1. Ma (Riforgiato *et al*., 2005). The unconformity, that has also been recognised in many other Tuscan basins would last about 500 ky.

Although the relationship between the different synthems testifies to a doming of the Chianti Mts., there is no evidence that it attained the present-day elevation. It could still represent a "drowned sill" between the Siena and Valdarno Basins. Similar evidence is widespread in the present-day Adriatic basin testified to by seismic profiles to the west of the more external thrust fronts (Ori *et al*., 1986; Argnani & Gamberi, 1995). In the Adriatic sea, antiforms emerged for a short period from the sea level but were later planated and sealed by Plio-Pleistocene sediments generating progressive unconformities similar to what we observe in the Chianti Ridge. In the Valdarno Basin there is no evidence of sediments coming from the erosion of the present-day Apennine Ridge as also observed in the coheval sedimentation of the East Tiber basin, located slightly to the south (Coltorti & Pieruccini, 1997A; 1997B). The Apennine chain, at that time could represent simply another antiform in the peri-Adriatic basin that only in later times was transformed into a mountain ridge. In this model, the Valdarno Basin represented the alluvial plain bordering the palaeo-Po plain before the uplift of the Apennines. The mountain chain was located further to the west. Similar conclusions have recently been reached during the investigation of the Barga Basin (Coltorti *et al*., sub-

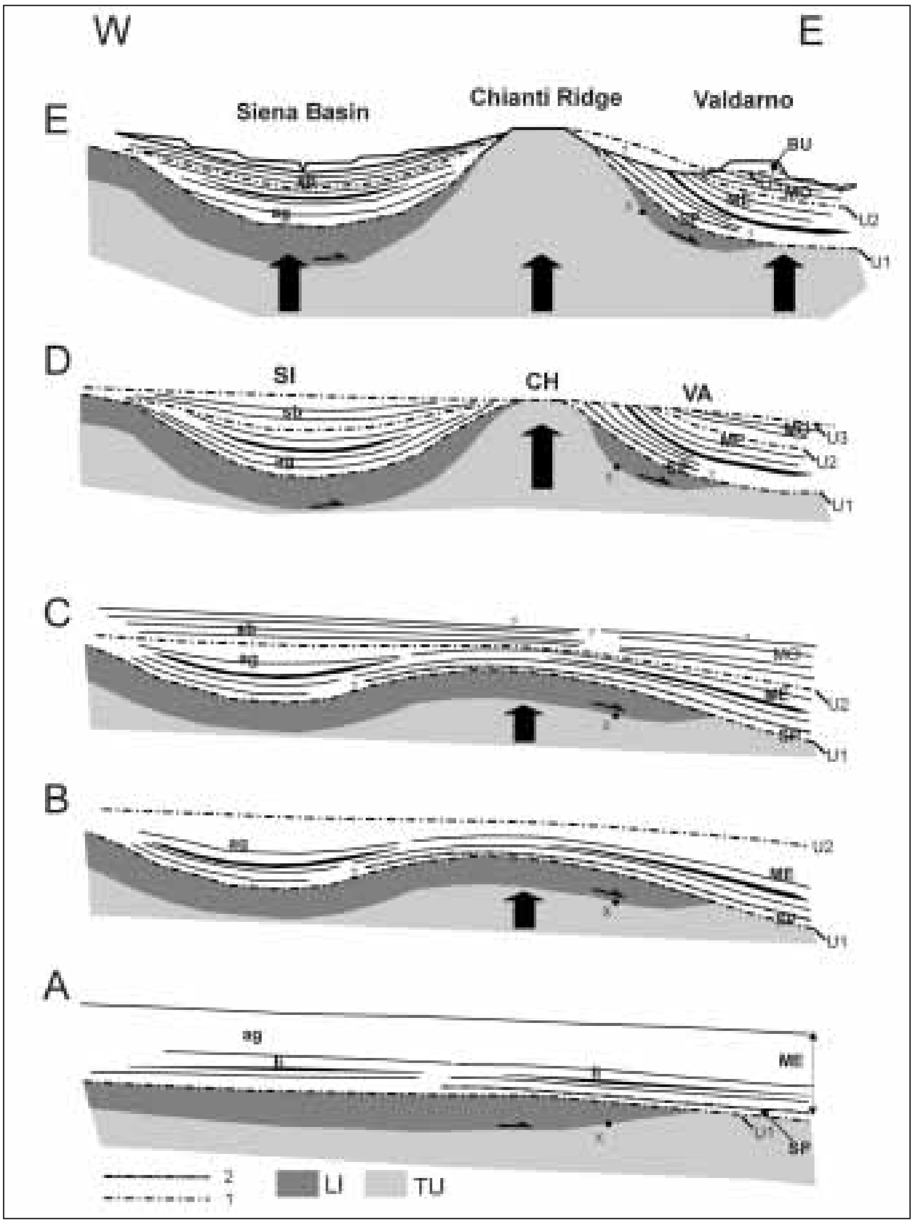

Fig. 9 - Hypothesis of the dynamic evolution of the S. Barbara Basin. A: the beginning of the evolutive history, the Spedalino and Meleto subsynthems overlain by a major unconformity (U1) the deformed bedrock made by Ligurian Terrains, Tuscan Nappe and Cervarola-Falterona Units; between the two subsynthems is inferred by a minor unconformity (Early Pliocene-Late Early Pliocene, older than 3.5 Ma); B: modelling of planation surface/unconformity (Early-Middle Pliocene, 3.5÷3.1 Ma); C: the Montevarchi synthem lies unconformably (U2) on the previous sediments (3.1÷1.8? Ma); D: the uplift of the Chianti Ridge has the effect of the formation of a new unconformity (U3) that cut the previous deposits (younger than 1.8 Ma); E: the Bucine synthem lies by unconformity (U3) on the previous sediments and it represents the last unit deposited during the Late Pleistocene. SI: Siena Basin; CH: Chianti Ridge; VA: Valdarno Basin; BU: Bucine synthem; MO: Montevarchi synthem; ME: Meleto subsynthem; SP: Spedalino subsynthem; sb: sands; ag: clays; li: lignite banks; LI: Ligurian Units; TU: Tuscan Nappe. 1: main unconformity; 2: minor unconformity.

Ipotesi dell'evoluzione dinamica del bacino della S. Barbara. A: inizio della storia evolutiva, i subsintemi di Spedalino e di Meleto giacciono in discordanza (U1) sul substrato deformato fatto di Unità Liguri, Falda Toscana e Unità Cervarola-Falterona; tra questi due subsintemi è ipotizzata una minore discordanza (Pliocene inferiore-Pliocene inferiore finale, più vecchio di 3.5 M; B: modellamento della superficie di spianamento/discordanza (Pliocene Inferiore – Pliocene Medio, 3.5÷3.1 Ma); C: il sintema di Montevarchi si depone in discordanza (U2) sui precedenti depositi (3.1÷1.8? Ma); D: il sollevamento della Dorsale del Chianti causa la formazione di una nuova discordanza (U3) che taglia i depositi precedenti (più giovani di 1.8 Ma); E: il sintema di Bucine giace in discordanza sui precedenti sedimenti e rappresenta l'ultima unità depostasi durante il Pleistocene Superiore. SI: bacino di Siena; CH: dorsale del Chianti; VA: bacino del Valdarno; BU: sintema di Bucine; MO: sintema di Montevarchi; ME: subsintema di Meleto; SP: subsintema di Spedalino; sb: sabbie; ag: argille; li: banchi di lignite; LI: Unità Liguri; TU: Falda Toscana. 1: discordanza principale; 2: discordanza minore.

mitted) and a large part of the Apennine drainage system (COLTORTI, submitted).

The Montevarchi synthem, made by coarser sediments, testifies to the presence of a wide braided alluvial plain. The absence of lateral facies variations suggests that the connection with the Siena Basin, where there are a series of interlayered coastal and fluvial systems, could still be possible (Fig. 9C). In fact, the source area for the Montevarchi synthem was located to the west as also evidenced from paleocurrent measurements by GHINASSI & MAGI (2004).

Afterwards also the Montevarchi synthem was tilted up to 20° eastwards indicating that the Chianti Ridge was still a growing antiform becoming a real "sill" separating the Siena from the Valdarno Basins. There is a long sedimentary hiatus between the deposition of the Montevarchi and Bucine synthems and there are no elements to establish when the deformation ended. However, it is widely accepted that in the Apennine area a generalised uplift activated at the end of the Early Pleistocene (AMBROSETTI *et al.*, 1982; COLTORTI & PIERUCCINI, 1997A; 1997B; CALAMITA *et al.*, 1999). The uplift is commonly responsible for the rapid incision of the river network (Fig. 9E) interrupted by the deposition of the Bucine synthem, during the Late Pleistocene in a landscape similar to the present-day one.

5. DISCUSSION AND CONCLUSIONS

Geological and geomorphological evidences together with facies analysis of the Plio-Pleistocene sediments allow us to reconstruct the evolution of the Chianti Ridge and the westernmost part of the Valdarno Basin. The reconstruction also partially involves the nearby Siena Basin to the west and the Apennine Ridge to the east. We demonstrated that:

A. The area was affected by an important planation surface

(Early Pliocene) (U1; Fig. 9A). The deposition of the Spedalino gravels (SP) is the result of the first subaereal erosion probably following deformational events. With the Meleto subsynthem (ME) the area became a wide flood plain whose limits are not well recognisable. All these events are older than 3.5 Ma.

B. A major antiform developed in correspondence with the Chianti Ridge after the deposition of the Meleto subsynthem and before the deposition of the Montevarchi synthem (Fig. 9B). At the edge with the Valdarno Basin, which represented a large synform, a progressive unconformity (U2) separates the two sequences. A sedimentological signature of this tectonic event is missing except for the later occurrence of a generally coarser depositional environment. Most probably the antiform was rapidly erased similar to what has been observed with seismic profiles in numerous sectors of the Adriatic sea (ORI *et al*.,1986; ARGNANI & GAMBERI, 1995). These events occurred between 3.5. and 3.1.Ma.

C. Deposition of the Montevarchi synthem (MO; Fig. 9C) the base of which possibly corresponds with the second cycle of the Siena Basin (Sb) although the relationship between these two areas is unknown. The Montevarchi synthem was deposited after 3.1 Ma and slightly before the Rena Bianca Sands, Late Pliocene in age. The relationship between the different sequences shows a progressive unconformity that reveals a differential movement between the ridge and the basin.

D. A major unconformity (U3), in younger times, was modelled across the area finally separating the Siena and Valdarno Basins. The re-exumation of the older rocks on top of the Chianti ridge probably occurred during these events (Fig. 9D). We suppose that it corresponds to the planation surface recognised by Sestini (1981) at the summit of the Chianti ridge, partly re-exuming the older one.

E. The long erosive hiatus between the Bucine and Montevarchi synthems prevents us from establishing, if the ridge continued to rise during the Early and Middle Pleistocene. However, most probably, differential movements ended during the Early Pleistocene and have been followed by a generalised uplift affecting both basins and ridges similar to what has been observed in the nearby areas (DRAMIS, 1992; CALAMITA *et al*., 1999). More recently, differential movements could also be connected with the activity of the normal faults delimiting the easternmost part of the Valdarno Basin (FINETTI *et al*., 2001). The Valdarno, being filled with softer sediments and bordered by harder terrains, constituted a favourite site for a rapid erosion generating one of the most important fluvial systems of the Apennines. The thickness of fluvial sediments of the Montevarchi synthem that were removed is hard to evaluate. This long erosional phase cancelled the eventual connection with the surrounding Lower Valdarno and Val di Chiana Basins.

As evidenced above, the history of the Chianti Ridge is very complex with the main modelling Pliocene phases occurring close to sea level. Only since the Early-Middle Pleistocene did the area gradually reach the present-day situation, mostly as a result of a combination of generalised uplift and differential erosion mostly activated by the deepening of the hydrographic network.

The results of our investigations coupled with the recent thermochronological data led to an evolutionary scheme for the ridges and the basins of the Northern Apennines that is very different from that proposed in the past (ELTER *et al*.,1975; MAZZANTI & TREVISAN, 1978; ALVAREZ, 1999). In that model the ridges rise progressively from W to E as the consequence of the eastward migration of the compressive front. However, our results shows that: 1. the Chianti Ridge, as the other ridges of the eastern sectors (CALAMITA *et al*., 1999), are not anticlines but antiforms; 2, they were modelled after the emplacement of the Ligurian Units that moved along a major detachment; 3, there are no synsedimentary Pliocene faults between the ridge and the basin but progressive unconformities as a result of deformations of the sedimentary cover; 4, there are no lacustrine deposits in these basins but they are mostly filled by meander and braided flood plain deposits, similar to what was recognised in the nearby East Tiber Valley (COLTORTI & PIERUCCINI, 1997A; 1997B) and, in the Barga Basin to the north (LANDI *et al*., 2003; COLTORTI *et al*., submitted). There is also no evidence that suggests the existence of the main Apennine divide with a ridge in a position similar to the present-day one up to the Late Pliocene and it is our conclusion that the Upper Valdarno could have represented the western part of the peri-Adriatic basin. If this is confirmed, the eastward migration of the compressional movements and the creation of the present day Apennine watershed was not gradual but very rapid in the geological time scale and occurred mostly during the Pleistocene.

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