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NEOTECTONIC EVIDENCE IN THE QUATERNARY CONTINENTAL CARBONATES FROM SOUTHERN VALDELSA BASIN (TUSCANY)

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ABSTRACT: E. Capezzuoli et al., *Neotectonic evidence in the quaternary continental carbonates from southern Valdelsa Basin (Tuscany)*. (IT ISSN 0394-3356, 2006).
Recognition of tectonic structures in Quaternary sediments is usually very difficult, mainly in detrital and uncemented deposits. On the contrary, Quaternary continental carbonates represent an important exception that have the quality of being potential indicators of neotectonics significance. Facies analyses of some Quaternary calcareous tufa succession in the Valdelsa Basin (Southern Tuscany) point out a neotectonics activity that have interested these deposits during the Middle Pleistocene-Holocene. Recognition of neotectonics activity is mainly based on identification of "anomalous" bedding of these recent deposits, in contrast with the original setting of their depositional environment. This evidence imply two tectonic phases in southern Valdelsa during the Middle-Late Pleistocene and the Late Pleistocene-Holocene. All this evidence will be useful for a better comprehension of the evolution of this Northern Apennine sector during the Quaternary.

RIASSUNTO: E. Capezzuoli et al., Evidenze di neotettonica nei carbonati continentali quaternari della Valdelsa (Toscana). (IT ISSN 0394-3356, 2006).
Osservazioni di campagna ed analisi di facies condotte sui depositi carbonatici continentali quaternari della Valdelsa meridionale (Provincia di Siena), hanno permesso il riconoscimento di evidenze di attività neotettonica. Questi sedimenti sono riconducibili a sei sintemi: Sintema di Campiglia dei Foci – CDF, Sintema dell'Abbadia – ABB, Sintema di Calcinaia – CAL, Sintema del Torrente Foci – FOC, Sintema di Bellavista – BEL, Sintema di Poggibonsi – POG.
Il Sintema di Campiglia dei Foci, composto da quattro litofacies (litofacies argillosa, litofacies sabbiosa, litofacies conglomeratica, litofacies calcarea), è stato interpretato come l'espressione di un episodio palustre/lacustre datato al Pleistocene inferiore-medio sulla base di una fauna a mammiferi rinvenuta nella litofacies argillosa.
I Sintemi dell'Abbadia, di Calcinaia, del Torrente Foci e di Bellavista sono riferiti ad una successione di terrazzi tutti caratterizzati da due litofacies (calcareous tufa e sedimenti detritici) in proporzioni variabili nei vari sintemi e riferiti ad episodi di sedimentazione fluvio-palustre datati al Pleistocene superiore-Olocene sulla base di una datazione radiometrica effettuata nel CAL (25690±180 B.P.).
Il Sintema di Poggibonsi corrisponde alle alluvioni attuali ed è formato da sedimenti detritici e localmente da sedimenti calcarei tuttora in formazione.
Analisi di facies effettuate sui depositi calcarei hanno permesso di individuare evidenze di attività tettonica quaternaria:
- Podere le Frigge: nelle vicinanze di Monteriggioni affiora una successione di calcareous tufa di CAL che si caratterizza per l'inclinazione degli strati, misurata in circa 15° in direzione NE. L'analisi sedimentologica ha evidenziato che l'intera successione è l'espressione di una sedimentazione in acque a scarsa energia o stagnante, confrontabile con un ambiente di tipo palustre. L'attuale giacitura dei depositi risulta contrastante con il setting deposizionale originale e riconducibile ad un basculamento degli strati legato ad una faglia diretta situata in corrispondenza dell'adiacente fosso con andamento rettilineo e direzione NW-SE.
- Podere Santa Giulia: il rilievo su cui sorge tale podere, a sud di Gracciano Val d'Elsa, è posto fra il corso del Fiume Elsa a SW ed una area pianeggiante a NE. Questo rilievo è caratterizzato dalla presenza di depositi terrazzati carbonatici dei Sintemi ABB, CAL, FOC e terrigeni (in questa località) del BEL. Tutti i sintemi carbonatici si caratterizzano per un setting giaciturale immergente verso NE, ma con differenti inclinazioni a seconda del sintema di appartenenza. Infatti il più recente dei tre (sintema FOC) mostra inclinazioni di circa 15°÷20°, quello intermedio (sintema CAL) di circa 20°÷25°, mentre quello più antico (sintema ABB) presenta inclinazioni ancora maggiori, con massimi fino a circa 40°. Nel sintema terrigeno BEL non è stato possibile apprezzare l'esistenza di una eventuale deformazione. L'analisi di facies dei calcareous tufa, rappresentati da livelli fitoermali/fitoclastici, micritici ed argillosi (talvolta con materia organica), permette di ipotizzare un ambiente deposizionale prevalentemente di tipo palustre. L'attuale inclinazione della stratificazione è da mettere in relazione all'attività di una faglia diretta con direzione NW-SE localizzata a circa 200 m nell'area pianeggiante a NE, attualmente coperta dai depositi più recenti e che ha agito in maniera sinsedimentaria alla deposizione dei diversi sintemi.
- Area del Diborrato: tale zona si colloca lungo il corso del Fiume Elsa fra Gracciano a S e Colle Val d'Elsa a N. Lungo tale settore vallivo, qui profondamente scavato, affiorano i depositi calcarei del CDF con inclinazioni dell'ordine di circa 15°, che nelle aree circostanti sono sospesi sul fondovalle di circa 40 metri e presentano giacitura suborizzontale. Nel fondovalle questi calcari sono ricoperti dai depositi più recenti del CAL. La faglia diretta responsabile del basculamento dei depositi, disposta circa NNW-SSE, non disloca i sintemi più recenti e trova il suo probabile proseguimento con una sezione rettilinea del corso del Fiume Elsa.
- Area di Montemorli-San Lucchese: nel settore ad W di Poggibonsi, i depositi del CDF sono disposti su quattro quote diverse: quelli a quota più elevata sono quasi completamente smantellati dall'erosione. Le diverse quote sono intervallate da salti morfologici rettilinei di circa 10 metri, paralleli fra loro e con direzione NW-SE. Evidenze morfolofgiche, ripetizione delle litofacies ed il parallelismo dei gradini permettono di associare questa struttura ad una gradinata di faglie dirette. Le stesse strutture non interessano i depositi dei sintemi più recenti.
Sulla base delle ricerche condotte, viene evidenziato come la Valdelsa meridionale sia stata interessata durante il Quaternario da almeno due eventi tettonici: una prima fase durante il Pleistocene medio-Pleistocene superiore (post-deposizione del Sintema CDF e precedente alla deposizione dei sintemi fluvio-palustri) e una più recente riferibile al Pleistocene superiore-Olocene (sin-deposizionale ai sintemi fluvio-palustri).

Keywords: Calcareous tufa, lacustrine limestone, neotectonics, Valdelsa, Southern Tuscany.

Parole chiave: Calcareous tufa, calcare lacustre, neotettonica, Valdelsa, Toscana meridionale.

1. INTRODUCTION

Recognition of tectonic structures in Quaternary sediments is usually very difficult. In fact these deposits, generally detrital and unlithified, are rapidly eroded and reworked by weathering, pedogenic processes and landslides. Natural evolution of morphology quickly cover or transform the fault scarp, so that the identification of faulted surface is generally confused.

Compared to the Quaternary detrital sediments, continental carbonates represent an important exception. In fact they are lithified and hence where they are preserved, they are generally young and thus potentially of neotectonic significance (Hancock *et alii*, 1999). This potential was already recognized by Barnes *et alii* (1978) in particular for the calcareous continental sediments deposited by thermal springs (travertines – Ford & Pedley, 1996; Capezzuoli & Gandin, 2004). However, it can also be applied to lacustrine limestone and continental carbonates deposited by karstic waters in fluvial-paludal environments (calcareous tufa - Ford & Pedley, 1996; Capezzuoli & Gandin, 2004). In fact alteration and weathering processes are slowed by the lithification and evidence of tectonic influence is preserved. Facies analyses of these deposits and recognition of their original depositional environment result important, particularly in comparison with the actual setting of these deposits. Identification of "anomalous" bedding of these recent deposits can be interpreted as the result of a tectonic influence.

Here are shown some evidence of neotectonic activity deduced by the Quaternary continental carbonates in the Valdelsa Basin (Southern Tuscany).

2. PRE-QUATERNARY GEOLOGICAL SETTING OF THE VALDELSA BASIN

The Valdelsa Basin is a segment of a NW-SE oriented, tectonic depression extending for over 300 km from the Serchio Valley to the N, to the upper Tiber Valley to the S (Fig.1). Its northern limit is placed in the area of Empoli where the basin is about 25 km wide, while in the southern portion, between Poggibonsi and Monteriggioni, its width quickly reduces to only 15 km. The limit between these two portions coincides with one of the most important transversal tectonic lines of the Northern Apennines (Piombino-Faenza Line; Costantini *et al*., 1980). The Valdelsa Basin is an extensional structure developed in Late Miocene and it is bordered to the W and the S by the Middle-Tuscan Ridge and by the Chianti Ridge to the E (Bossio *et al.*, 1995b). The former is mainly represented by formations of the Tuscan Domain, comprising Triassic metaquartzarenites, metaconglomerates and phyllites and the "Calcare cavernoso" tectonic carbonatic breccia derived from Late Triassic anhydrites. In the Chianti Ridge the substratum is mainly composed of flysch successions of sandstones, limestone, marly-limestones and shales of the Upper Cretaceous - Eocene, by Middle-Late Giurassic Ophiolites and by Lower Cretaceous shales with grey flinty limestones all referred to tectonic Units of the Ligurian Domain.

The Neogene sedimentation (Bossio *et al*., 2000) is characterized by a first marine cycle referred to the Late Serravallian and composed of grey-green sandstone intensely bioturbated. In the Late Tortonian the area was covered by a lacustrine environment, with the deposition of thick, clast-supported conglomerates with cross-stratification and consisting of clasts from the Ligurian Domain and heteropic with grey clays and marly clays intercalated with layers and levels of grey sandstones.

In the Late Messinian these formations were covered in disconformity by grey silty-marly clays with lenses of lignite and referred to the "Lac-Mer" depositional setting. In the marginal areas of this environment, thick coarse clastic deposits referable to alluvial fan-to-fluvial environment were present with different composition in the different areas of the basin.

In the Early Pliocene the area was covered by the sea with the deposition of thick, fossiliferous, grey-blue clays and silty clays, that locally are concordant on the Late Messinian clays (area of Borro La Strolla Valley, SE of Poggibonsi; Bossio *et al*., 1993). In this area, these Early Pliocene clays are overlain by conglomerates and clays referable to a Ruscinian continental environment. In general the clays and sands widely exposed in the Valdelsa represent a second marine sedimentary cycle referable to the Middle Pliocene. These middle-fine grained yellow sands, locally cemented, show lateral relationships with the massive grey clays. In the eastern outcrops of the basin, these sands are heteropic and overlaid by clast-supported conglomerates, formed by sub-rounded, locally embricated elements from the Ligurian Domain, and referred to marine-to-continental environment (Benvenuti & Degli'Innocenti, 2001).

In the upper Middle-Pliocene, the Valdelsa Basin, as the greatest part in southern Tuscany, is characterized by a general marine regression that led to the emersion of the area (Bossio *et al*., 1995a).

3. THE PLEISTOCENE-HOLOCENE SYNTHEMS

During the Early-Middle Pleistocene, an area of over 52 km^2 of the southern sector of the basin (among Poggibonsi to N, Monteriggioni-Gracciano d'Elsa to S, San Gimignano to W and Staggia Senese to E; Fig.2) was characterized by a continental episode (Campiglia dei Foci Synthem - CDF; Capezzuoli & Sandrelli, 2004). This synthem consists of prevalently carbonate deposits mainly located in two subhorizontal plateaux (Campiglia dei Foci and the area between Colle Val d'Elsa and Staggia) and in other smaller ones distributed between 240 and 230 m a.s.l. These deposits usually lie on Pliocene sands or directly on the pre-Neogene substratum; the types of basal contact are respectively disconformity and angular unconformity, while intensely rubefied soils overlay the deposits (Costantini & Carnicelli, 1986). In some areas, subhorizontal relict surfaces related to the base of the succession can be observed at the summit of the Pliocene highs.

This synthem presents a variable thickness (maximum about 30 m) and it is characterized by four heteropic lithofacies (clayey, sandy, conglomerate and calcareous; Fig.3) present in different proportions in the various areas. In the clayey lithofacies near San Gimignano, several lignite lenticular bodies yielded a

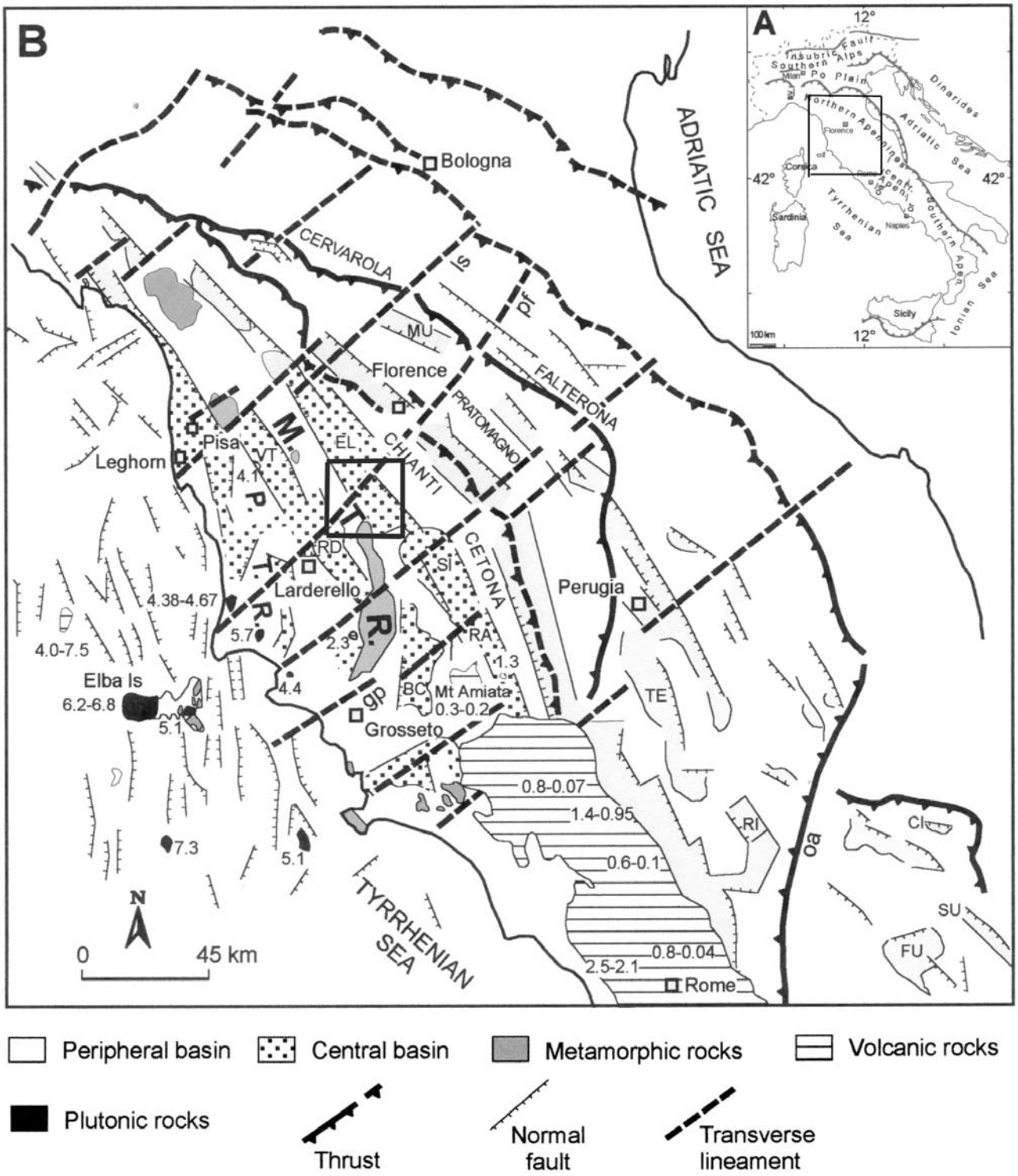

Figure 1 - Generalized structural map and localization of the studied area: A – major structures of Italy, with geologic and geomorphic subdivision of the Apennines. B - Neogene-Quaternary basins of the Northern Apennines (Basins: BC. Baccinello, E. Elsa, FU. Fucino, MU. Mugello, RA. Radicofani, RD. Radicondoli, RI. Rieti, SI. Siena, SU. Sulmona, VT. Volterra, TE. Tiberino; Transverse lineaments: oa. Olevano-Antrodoco, gp. Grosseto-Pienza, ls. Livorno-Sillaro, pf. Piombino-Faenza, sv. Sestri-Voltaggio; MTR – Middle Tuscan Ridge; PTR – Perithyrrenian Ridge;M 3.5 – radiometric age of igneous rocks in Ma)(modified from Sagri *et al.*, 2004).

Carta strutturale schematica e localizzazione dell'area: A. principali strutture italiane e suddivisioni geomorfiche dell'Appennino: B. Bacini neogenici-quaternari dell'Appennino settentrionale (Bacini: BC. Baccinello, E. Elsa, FU. Fucino, MU. Mugello, RA. Radicofani, RD. Radicondoli, RI. Rieti, SI. Siena, SU. Sulmona, VT. Volterra, TE. Tiberino; Lineamenti trasversali: oa. Olevano-Antrodoco, gp. Grosseto-Pienza, ls. Livorno-Sillaro, pf. Piombino-Faenza, sv. Sestri-Voltaggio; MTR – Dorsle Medio Toscana; PTR – Dorsale Peritirrenica;M 3.5 – età radiometrica delle rocce ignee in Ma) (modificato da Sagri et al*., 2004).*

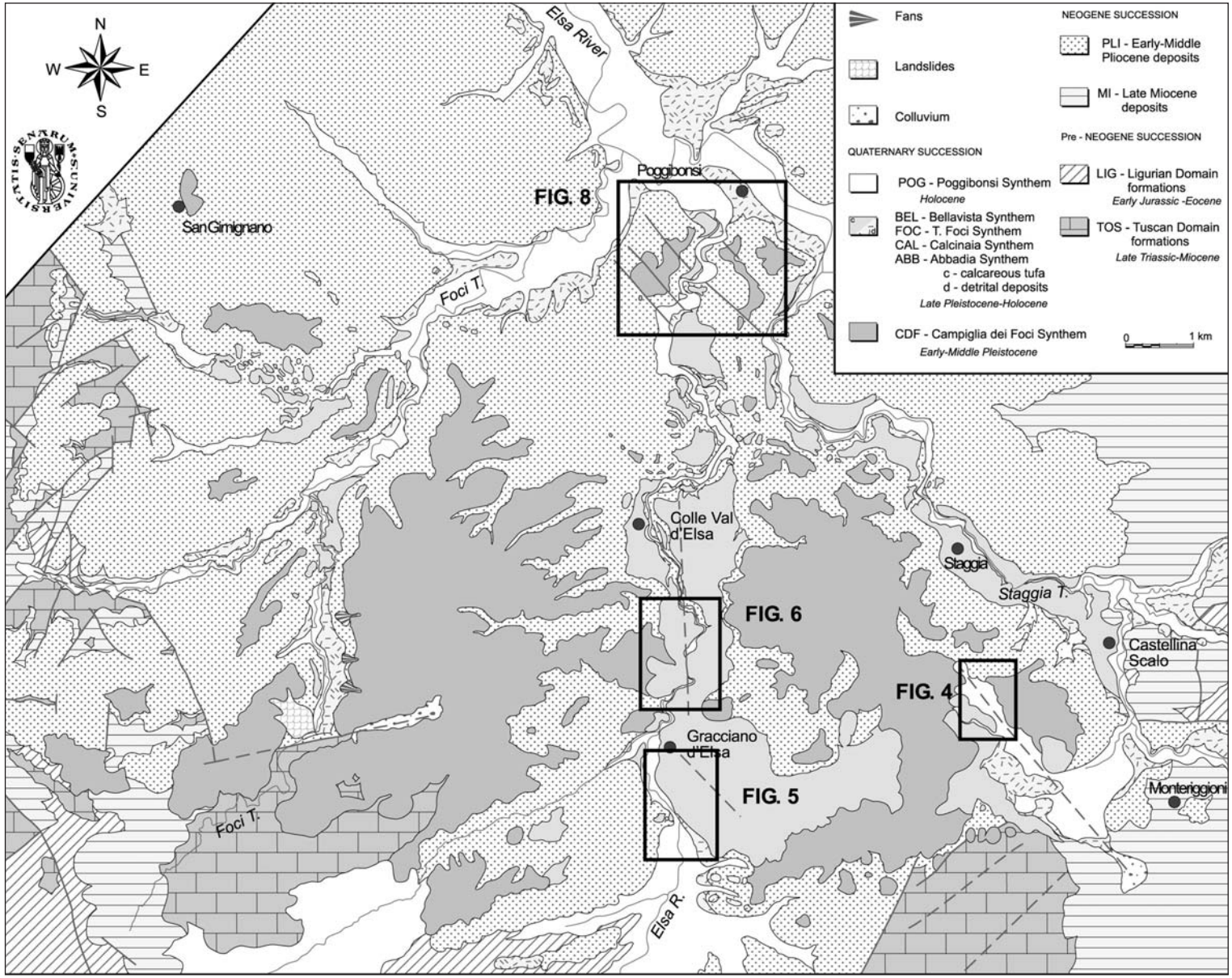

Figure 2 - Geological scheme of the southern Valdelsa Basin. The lithofacies of the CDF Synthem and the deposits of the ABB, CAL, FOC, BEL Synthems are not separately visible at this scale.

Schema geologico del settore meridionale della Valdelsa. Le litofacies del sintema CDF e i depositi dei sintemi ABB, CAL,FOC e BEL, a questa scala, non sono evidenziabili singolarmente.

mammalian and molluscan fossil fauna attributed to the Early-Middle Pleistocene (Berzi, 1972) and recently ascribed to the Ponte Galeria Faunal Unit (Petronio & Sardella, 1999; Raia *et al*., 2005). The relationships among the various lithofacies show a vertical and lateral evolution from a palustrine environment with mainly detrital sedimentation (clayey lithofacies), to a lacustrine environment characterized by the sedimentation of calcareous muds (calcareous lithofacies) in the central areas of the basin and the deposition of coarser materials in the marginal areas, especially near the mouths of small tributaries (sandy and conglomerate lithofacies). The change from clayey to calcareous sedimentation has been attributed to the input of large amounts of water with a high $CaCO_3$ concentration, probably coming from the southern sectors of the basin (Monteriggioni area, Capezzuoli & Sandrelli, 2004).

The carbonate deposition, related to saturation of the water by progressive concentration and evaporation, was probably favoured by the endorheic setting of the basin (Capezzuoli & Sandrelli, 2004) and occurred in arid climatic conditions, as documented by the presence of the gastropod *Parmacella* and *Pseudotachea* in the clayey lithofacies (Manganelli & Giusti, 1993; Manganelli *et al*., 2005). The end of the lacustrine sedimentation was followed by a new hydrographic pattern which, as a consequence of the general uplifting of the area, cut the calcareous lithofacies and locally also the underlying Pliocene sands. This caused selective erosion and produced an inverted relief in this area (Bartolini & Peccerillo, 2002).

This new fluvial network controlled the sedimentation of the four fluvial-palustrine synthems (Abbadia Synthem - ABB, Calcinaia Synthem - CAL, Torrente Foci Synthem – FOC; Bellavista Synthem - BEL), which correspond to a succession of terraces on the slopes of the main river valleys of the area (Fig.3). They consist mainly of detrital deposits (sands, silts and pebbles), associated in some valley areas with calcareous lithofacies. All synthems are characterized by erosive basal contacts (disconformity) and by an upper aggradational subhorizontal surface on which rubefied or brown soils developed. The usually poorly stratified calcareous lithofacies includes a dominant phytoclastic and phytohermal concretionary limestone due to the incrustation of plants (rushes, bryophytes and grass stems) associated with calcretes, calcareous sands and occasionally micritic limestones and/or peat shales, arranged in levels and lenticular bodies of variable thickness. These facies are characteristic of calcareous tufas, particularly those referable to the “paludal model” or “fluviatile model” *sensu* Pedley (1990) and Pedley *et al*. (2003). The extension of these carbonates is not constant in the various synthems, progressively decreasing from the oldest (ABB) to the youngest (BEL).

The detrital deposits are usually represented by irregular fining-upward sequences composed of clastic calcareous sands associated with quartz-sands, silt, and gravel lenses. The calcareous sands derive from the erosional break-up of the carbonate lithofacies, while the quartz sand derives from the surrounding Pliocene marine sands. The gravel layers, occurring mainly in the basal part of the synthems, represent the infilling of erosional pockets. They are composed of well rounded, poorly sorted (max 20 cm), locally imbricated polygenic clasts and a variable sandy matrix.

Merla & Bortolotti (1967) referred these deposits to the Holocene, but recent C^{14} radiometric dating of the organic clayey level of the CAL Synthem yielded an age of 25.690±180 years B.P. (Capezzuoli & Sandrelli, 2004), i.e. the Late Pleistocene.

The origin of the fluvial network and the control of the fluvial-palustrine sedimentation were probably due to the tectonic activity and to climatic variations. The

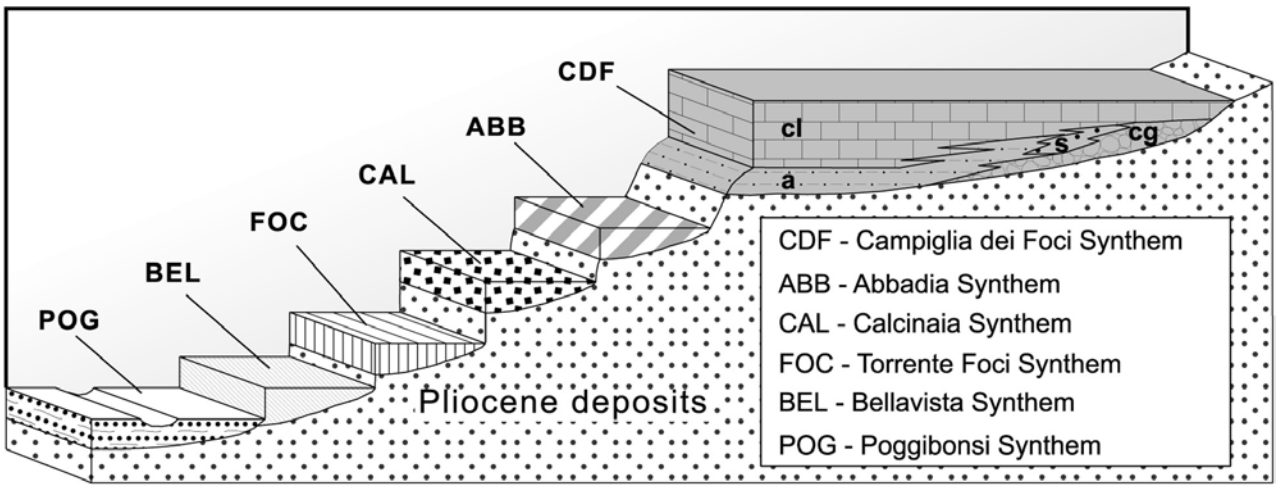

Figure 3 - Schematic reconstruction of the stratigraphic units used for the quaternary deposits of the southern Valdelsa (not in scale). cl - calcareous lithofacies; a - clayey lithofacies; s - sandy lithofacies; cg - gravelly lithofacies (from Capezzuoli & Sandrelli, 2004, slightly modified).

Ricostruzione schematica delle suddivisoni stratigrafiche adottate per lo studio dei depositi quaternari del settore meridionale della Valdelsa (non in scala). cl - litofacies calcarea; a - litofacies argillosa; s - litofacies sabbiosa; cg - litofacies conglomeratica (da Capezzuoli & Sandrelli, 2004, modificato).

tectonic activity led to the progressive cutting of river valleys and to the circulation and/or rising of carbonate waters through faults. Variations of the base level, with a consequent increase of fluvial incision in the cold and aggradation phases and precipitation of carbonates mainly in the warm and humid phases, can be related to climatic oscillations. Precipitation of the calcareous tufas occurred only in the fluvial tracts with inputs of carbonate water, at least partly derived from hydrothermal rising. The progressive decrease of the volume of carbonate sediments can be correlated to a local decrease of tectonic activity, and the following occlusion of the upward paths of carbonate water, and/or to climatic or anthropic causes, as hypothesized in other European areas (Goudie et al., 1993; Dramis *et al*., 1999).

The Poggibonsi Synthem corresponds to Holocene as well as present alluvial deposits, sometimes well developed in the valley floors of several rivers in the area. These deposits consist essentially of sands and sandy silts with associated pebbles or gravel lenses. Calcareous tufas are currently forming only in localized areas.

4. NEOTECTONICS EVIDENCE

As hypothesized by Capezzuoli & Sandrelli (2004), origin and development of these synthems was strictly related to tectonic activity in the area, even if evidence of this activity has not previously been recognized. Now facies analyses and field observations in specific outcrops demonstrate the presence of neotectonic activity that modified the original depositional setting of the local quaternary successions

4.1. - Podere le Frigge: in this locality, W of Monteriggioni, about a 4 m thick succession of calcareous tufa referred to the FOC Synthem is outcropping. This succession consists of alternating layers of Phytohermal Framestone (grass and moss cushions), Intraclast Tufa, Oncoids, porous and dense Micrite Tufa with different thickness. This type of association is typical of low-energy/stagnant water and referable to a paludal environment (Pedley, 1990). All the succession results inclined to about 15° towards NE (Fig. 4). This inclination is in contrast with the depositional setting of the sequence, probably depositing with only some degrees maximum or on local low-angle paleosurfaces. Consequently, the succession has been tilted by tectonics probably caused by a fault oriented about N 140E, located in the adjacent Fosso dei Pratini Torrent and corresponding to a NW-SE long lineament observed by aerial photos.

4.2. - Ponte Santa Giulia: the small ridge of Podere Santa Giulia, settled S of Gracciano Val d'Elsa, is located between the Elsa River to SE and a wide, NW-SE oriented plain area to NE (Pian Senese plain) (Fig. 5). Along its flanks, the ridge is covered by the terraced calcareous deposits of the ABB, FOC, CAL Synthems and detrital deposits of the BEL Synthem.

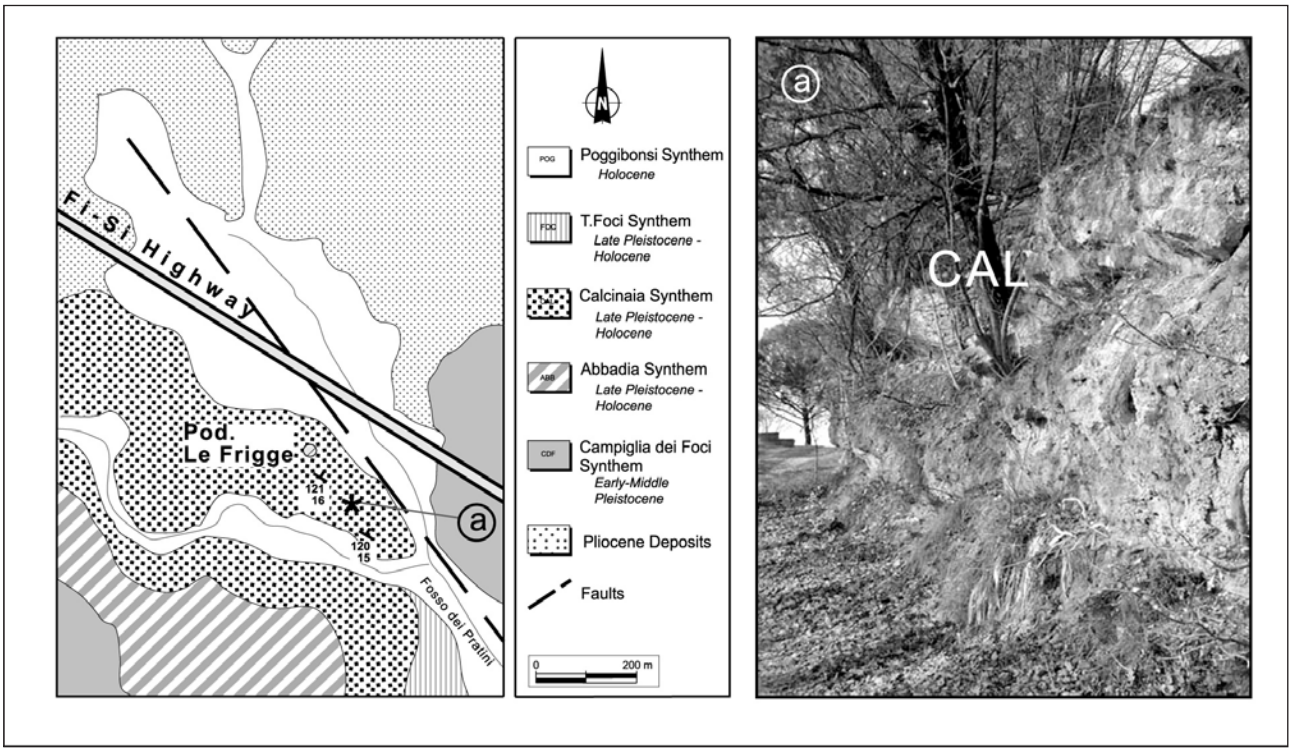

Figure 4 - Geological scheme of Podere Le Frigge area. a – view of the inclined calcareous tufa succession at Podere Le Frigge.
Schema geologico dell'area di Podere le Frigge. A – immagine della *successione inclinata di calcareous tufa presso Podere Le Frigge.*

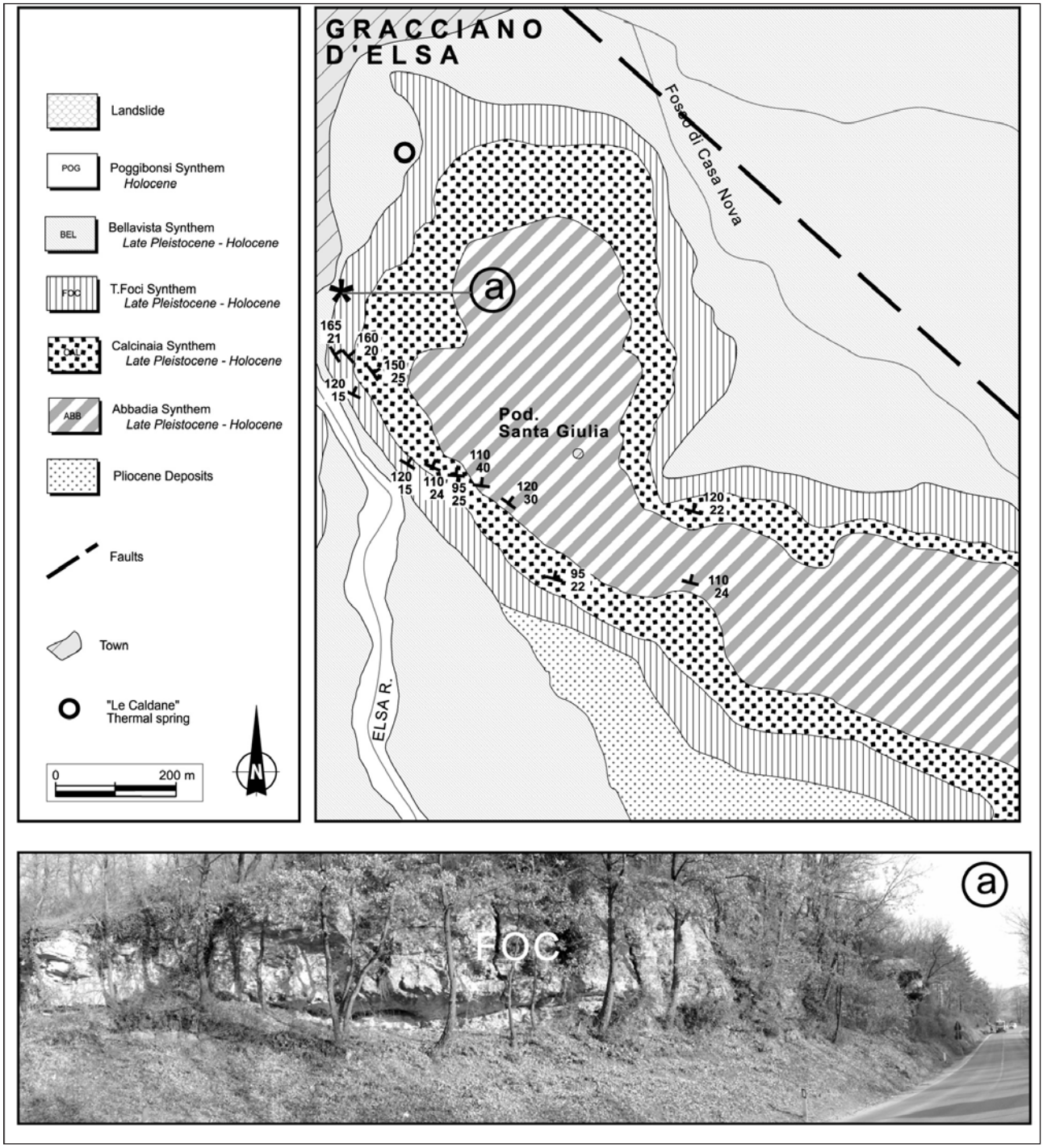

Figure 5 - Geological scheme of Ponte Santa Giulia area. a – view of the inclined calcareous tufa succession of FOC Synthem at Ponte Santa Giulia.

Schema geologico dell'area circostante il Ponte di Santa Giulia. a – immagine della successione inclinata di calcareous tufa del Sintema FOC presso Podere Le Frigge.

Facies analyses of the calcareous tufa recognized the dominating presence of layers of Phytoclast Tufa, Phytohermal Framestones, Peloidal Tufa and Micrite Tufa. Each layer exhibits evidence for both lateral and vertical accretion, and many are amalgamated laterally, producing a nodular appearance in outcrop. Secondly, thin clayey and sapropelithc level are present. All these characteristics are consistent of poorly drained depressions or valleys, colonized by hydrophytic macrophytes and bryophyte hummocks (Paludal tufas; Pedley, 1990). The calcareous terraces are characterized by an evident bedding attitude towards NE with different inclina-

tions. The lower calcareous synthem (FOC) is characterized by about 10°÷20° degrees, the rising above synthem (CAL) is about 20°÷25°, while the uppermost (ABB) presents an inclination up to about 40°. It is impossible to appreciate inclination in the younger terrace (BEL) for the detrital composition of the deposits and the absence of natural outcropping. This inclined setting of the terraces, evidently in contrast with the original environment, is related with a neotectonics activity that tilted the terraces. This activity is related with a fault probably located under the alluvial deposits in the NE flat area of Pian Senese and oriented about N 135E. This fault is probably responsible of a deep sulphate water intrusion into the aquifer complex recognized in this same area by BARAZZUOLI *et al*. (2002). Different inclinations observed for each synthem is probably connected with syn-sedimentary movements of this fault. Landslide movements are apparently neglected for absence of field and photo-aerial indicators.

4.3. - Diborrato: this is the name of a narrow gorge along the Elsa River, between Colle Val d'Elsa and Gracciano Val d'Elsa. This gorge is mainly excavated in the Late Pleistocene-Holocene calcareous tufa deposits of CAL Synthem, but in its southern part lacustrine limestones referable to the Lower-Middle Pleistocene CDF Synthem and partially covered by the CAL deposits are present (Fig. 6). All around this area, the same CDF deposits lies sub-horizontally on top of the hills, about 50 m higher of the gorge. This displacement is related with a roughly N 175W fault, actually buried by the Late Pleistocene-Holocene deposits, probably located along a straight segment of the Elsa River and partially corresponding with the Diborrato Gorge. This fault originally displaced the CDF Synthem, exposing the less cemented Pliocene sands that were easily dug by the fluvial erosion of the palaeo-Elsa river (Fig. 7). During the Late Pleistocene this valley was filled by the CAL Synthem that covered the fault scarp and partially the displaced CDF deposits. Subsequent fluvial incisions and deposition create the gorge and the recent terraces.

4.4. - Montemorli-San Lucchese area: in this locality, situated W of Poggibonsi, the calcareous CDF deposits rest unconformably on the massive Pliocene marine sands. The local Quaternary succession consist

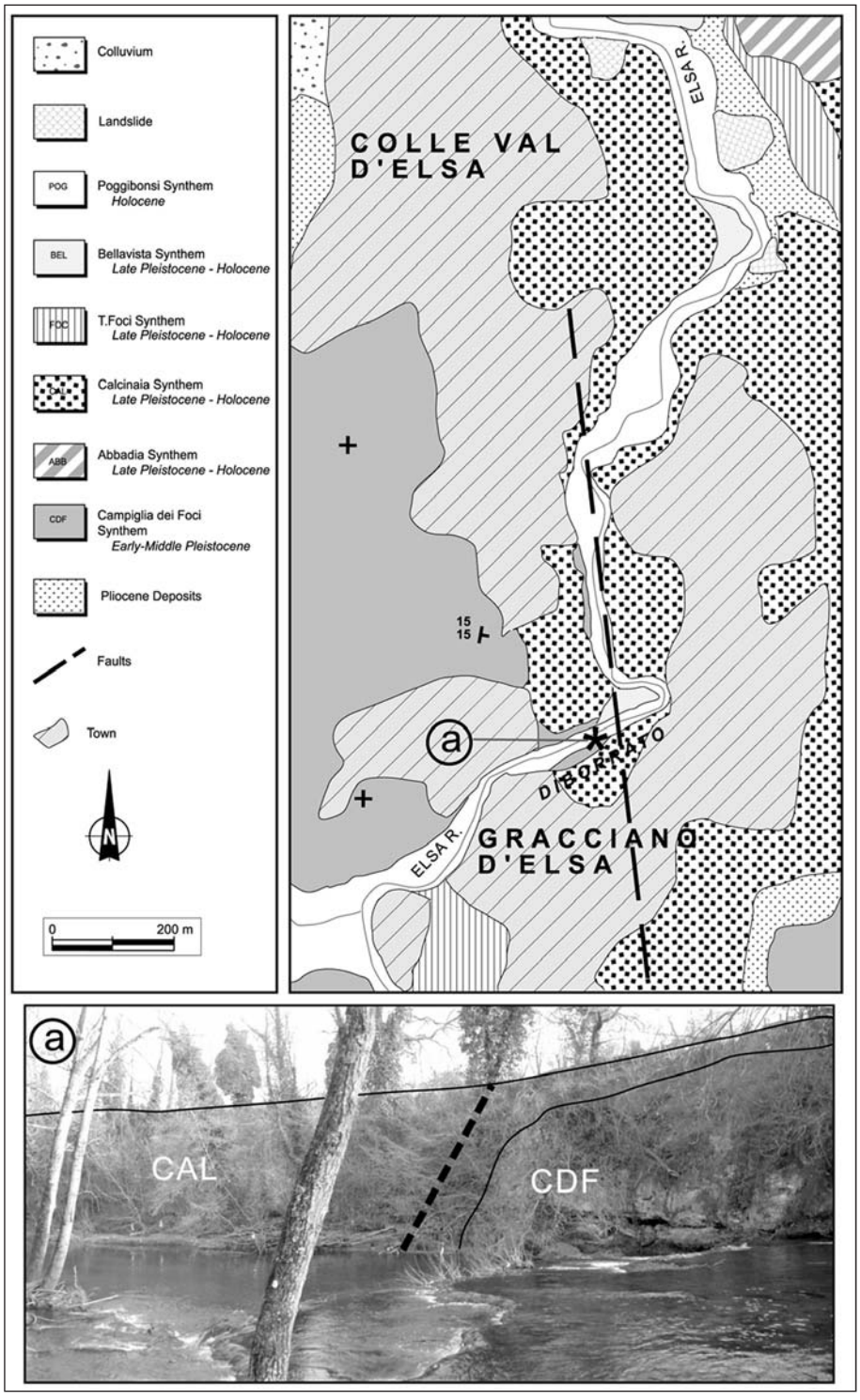

Figure 6 - Geological scheme of Diborrato area near Colle Val d'Elsa. a – line drawing of the relations between CDF and CAL Synthems in the Diborrato gorge.

Schema geologico dell'area del Diborrato vicino Colle Val d'Elsa. A – visione delle relazioni fra i Sintemi CAL e CDF nel Diborrato.

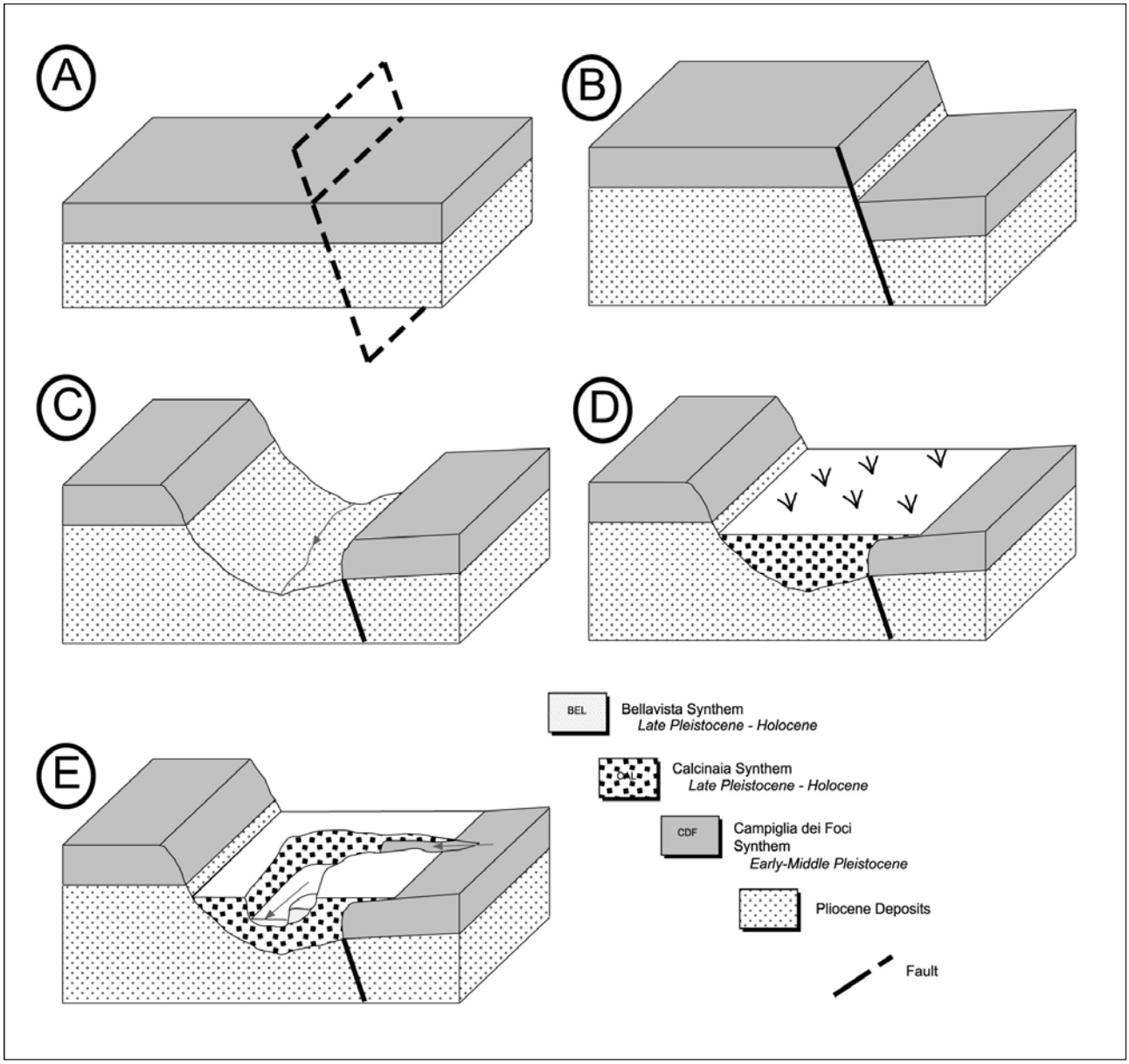

Figure 7 - Evolutional reconstruction of the Diborrato area (a – Early-Middle Pleistocene; b,c – Middle-Late Pleistocene; d – Late Pleistocene-Holocene; e – today).

Ricostruzione dell'evoluzione dell'area del Diborrato. (a – Pleistocene Inferiore-Medio; b,c –Pleistocene Medio-Superiore; d –Pleistocene Superiore-Olocene; e – oggi).

of fluvial gravel and sands up to 3 m thick, covered by carbonate sequences consisting of massive, grey-to-pink micritic limestone, microlaminated grey marl and undulose-bedded layers of Phytohermal framestones. The sequence is interpreted as a low-energy, low-gradient "ramp" margin in a lacustrine basin, similar to that described by PLATT & WRIGHT (1991).

In the Montemorli-San Lucchese area, this sequence results reiterated (Fig. 8), distributed in four different altitudes separated by parallel scarps with limited height. Some scarps, located on different sides of the Elsa River, result aligned. This feature can be inferred by the presence of a set of three minor conjugate normal faults, oriented about N 130E and with moderate displacement (i.e., in the order of 10 m or less). The faults are associated to evident steps in the topography, which are of the same order of magnitude of the fault displacement. Calcareous Tufa deposits of the Late Pleistocene-Holocene Synthem present along the fault trace in the Elsa Valley below, do not present evidence of displacement. The outcrop conditions prevent direct observation of the fault plane. Absence of similar reiterated portion of the CDF Synthem in the other part of the area, parallelism of the morphological scarps and similarity of litofacies in the different sequences prevent the possibility of different entrenched terraces.

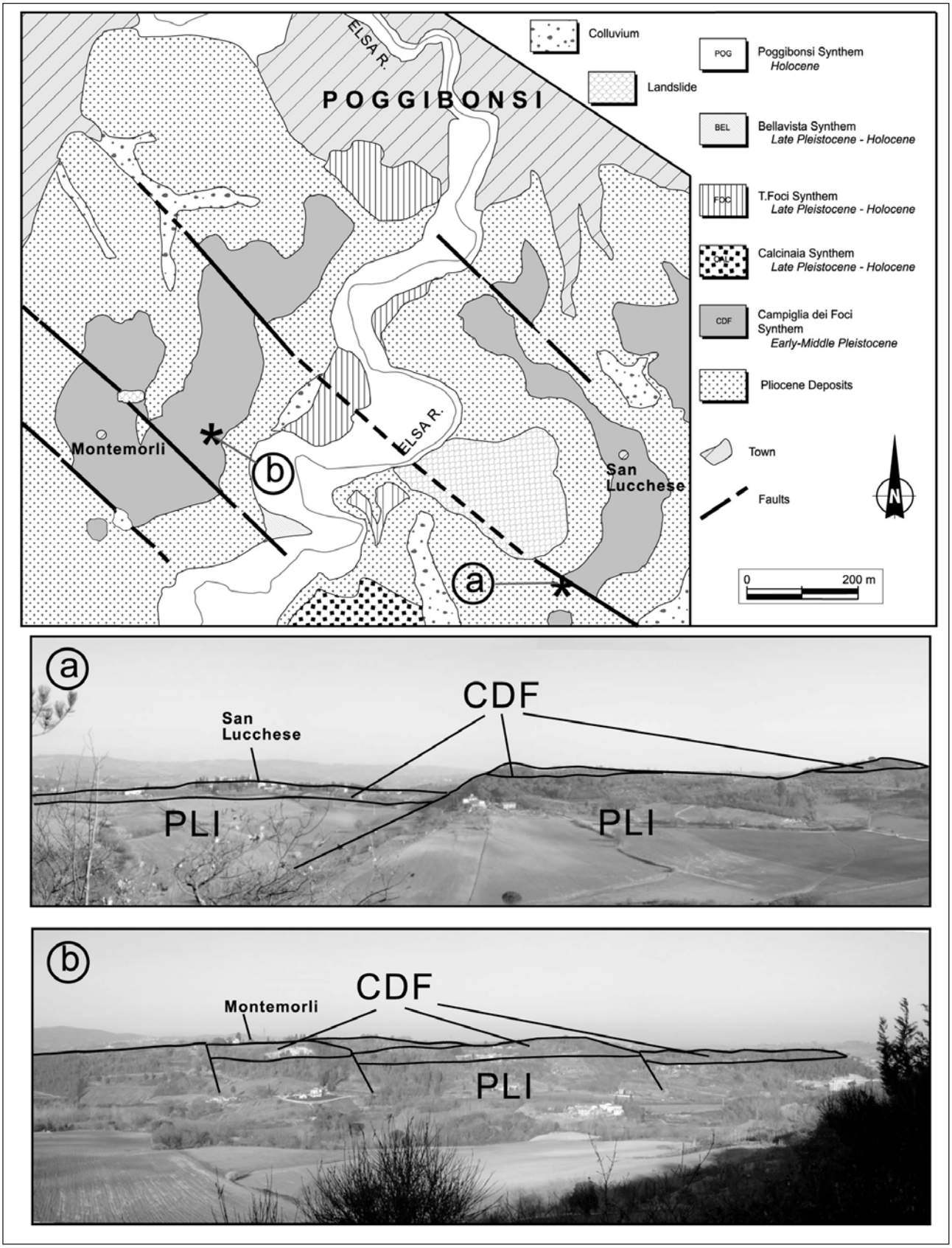

Figure 8 - Geological scheme of Montemorli-San Lucchese area. a – View of the San Lucchese area from Montemorli and line drawing of the CDF Synthem outcrops. B - View of the Montemorli area from San Lucchese and line drawing of the CDF Synthem outcrops

Schema geologico dell'area di Montemorli-San Lucchese. a – panorama dell'area di San Lucchese da Montemorli e disposizione dei depositi del Sintema CDF. B – panorama dell'area di Montemorli da San Lucchese e disposizione dei depositi del Sintema CDF.

According to SANTANGELO (2003), the presence of multiplied terraces represent one of the best geomorphic signs of recent tectonic activity in fluvial environment.

5. EVIDENCE OF NEOTECTONICS IN VALDELSA

Southern Tuscany is affected by extensional tectonics from Early-Middle Miocene (CARMIGNANI *et al*., 1994). Since the Middle Pliocene, extension was accompanied by a widespread, mainly intrusive magmatism that produced a rapid regional uplift (DALLMEYER & LIOTTA, 1998). The tectonic evolution of the Pliocene–Quaternary basins in southern Tuscany is mostly controlled by these two factors and related the coeval activity of NW-SE normal faults (BROGI *et al*., 2005 cum bibl.). An early Middle Pleistocene tectonic event was remarked by BERNINI *et al*. (1990), as revealed by the unconformities of fluvial over lacustrine deposits in various Tuscan basins, while an important uplift phase was recognized during the Middle and Late Pleistocene by BARTOLINI & PRANZINI (1981) by the rearrangement of the Arno basin drainage. This uplift is very important, because it is recognized to have transformed an area of rather low relief into becoming the Northern Apennine mountain chain (BARTOLINI, 2003). During the Late Pleistocene-Holocene extensional events are recognized in some basin (Upper Valdarno, Mugello) (BOCCALETTI *et al*., 1999).

Field evidence of all these tectonic phases are generally very difficult to recognize, mainly in detrital alluvial deposits. On the contrary, the continental carbonates, compared with the most superficial rocks, are cemented and where they are preserved, they are upstanding features.

This is the case of the Quaternary carbonate deposits present in the Valdelsa basin, that show evidence of tectonic activity.

Orientation of the recognized Valdelsa Quaternary faults are consistent with the main Apennine direction of surrounding structures.

Faults documented in the Diborrato gorge and in the Montemorli-San Lucchese area testify to a tectonic phase started after the deposition of the CDF Synthem (Early-Middle Pleistocene) and ended before the deposition of the fluvio-palustrine synthems (upper Late Pleistocene-Holocene). This phase can be related to the Middle-Late Pleistocene tectonic phase recognized in different Tuscan basins by different Authors (BARTOLINI & PRANZINI, 1981; BARTOLINI, 2003). During the Late Pleistocene-Holocene, coeval with the deposition of the fluvio-palustrine synthems, another tectonic phase is attested by faults of Podere Le Frigge and Ponte Santa Giulia. This phase is coheval with the extensional activity recognized in the Upper Valdarno and Mugello Basins by BOCCALETTI *et al*., (1999).

Precise dating of the Valdelsa fluvio-palustrine synthems will constrain the neotectonics evolution of this latter phase.

All this evidence will be useful for a better comprehension of the evolution of this Northern Apennine sector during the Quaternary.

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