

VILLAFRANCHIAN DEPOSITS OF THE BARGA AND CASTELNUOVO GARFAGNANA BASINS (TUSCANY, ITALY): LITHOSTRATIGRAPHY AND SEDIMENTARY FEATURES

Nicola Perilli, Alberto Puccinelli, Giovanni Sarti & Giacomo D'Amato Avanzi

Dipartimento di Scienze della Terra, Università di Pisa.

Via S. Maria 53 – 56126 Pisa – Italy

sarti@dst.unipi.it

perilli@dst.unipi.it

ABSTRACT: N. Perilli *et al.*, *Villafranchian deposits of the Barga and Castelnuovo Garfagnana basins (Tuscany, Italy): lithostratigraphy and sedimentary features.* (IT ISSN 0394-3356, 2004).

Based on a refined mapping of the sedimentary wedges accumulated in the so-called Barga and Castelnuovo Garfagnana basins and on a review of previous studies, the distinguished formations are here described. The "Argille, sabbie e conglomerati di Fornaci di Barga" mainly consists of fine grained lithofacies with organic-rich horizons and coarse grained conglomerate. The "Conglomerati di Barga", dominated by coarse grained lithofacies, is also characterized by silty to sandy interbeds, whilst organic-rich levels and paleosol horizons are rare. Within this formation, the Mt. Alfonso member is also distinguished, albeit hardly mappable. Sedimented in two separated tectonic depressions, connected by the "Mt. Perpoli high", this succession has been interpreted in previous studies as ranging from cohesive sediment anabranching ("Argille, sabbie e conglomerati di Fornaci di Barga") to gravel bed-load braided river deposits ("Conglomerati di Barga"), roughly flowing from north to south. In the Castelnuovo Garfagnana area, the Mt. Alfonso member also records the development of a tributary river flowing from west to east and interpreted as a braided fluvial fan. In this frame, the "Mt. Perpoli high" acted as a sedimentary by-pass, since the beginning of the sedimentation.

RIASSUNTO: N. Perilli *et al.*, I depositi villafranchiani dei bacini di Barga e Castelnuovo Garfagnana (Toscana, Italia): litostratigrafia e caratteristiche sedimentarie. (IT ISSN 0394-3356, 2004).

Sulla base di rilevamenti geologici di dettaglio effettuati nei depositi villafranchiani dei bacini di Barga e Castelnuovo Garfagnana e di una revisione della letteratura, vengono definite le caratteristiche litostratigrafiche delle due formazioni riconosciute. La formazione delle "Argille, sabbie e conglomerati di Fornaci di Barga" giace in discordanza sul substrato costituito da unità toscane metamorfiche (Nucleo Metamorfico Apuano) e non metamorfiche (Falda Toscana) e, subordinatamente, da unità liguri e subliguri (Unità Ottone e Unità Canetolo); essa è caratterizzata prevalentemente da litofacies fini, con livelli di accumulo organico e di orizzonti pedogenetici e intercalazioni di conglomerati. La formazione dei "Conglomerati di Barga" è invece costituita da litofacies conglomeratiche, con sporadiche intercalazioni siltoso-sabbiose, a cui talvolta si associano paleosuoli e rari livelli di accumulo organico. All'interno di questa formazione, è stato distinto nell'area di Castelnuovo Garfagnana il membro di M. Alfonso, costituito da conglomerati grossolani eterometrici. La formazione dei "Conglomerati di Barga" giace in possibile discordanza sulle "Argille, sabbie e conglomerati di Fornaci di Barga", anche se le cattive condizioni di affioramento non permettono di escludere a priori un possibile passaggio stratigrafico. Le due formazioni vengono attribuite a due sistemi fluviali riferibili rispettivamente a un cohesivo sediment anabranching river ("Argille, sabbie e conglomerati di Fornaci di Barga") e a un gravel bed-load braided river ("Conglomerati di Barga"), ambedue ad andamento circa nord-sud. Il membro di M. Alfonso registrerebbe invece la deposizione, nel bacino di Castelnuovo Garfagnana, di un sistema tributario attribuibile ad un braided fluvial fan a decorso circa ovest-est e alimentato dalle Alpi Apuane. In questo quadro, la soglia di Monte Perpoli avrebbe agito come by-pass sedimentario fin dall'inizio della deposizione villafranchiana.

Keywords: Lithostratigraphy, Continental deposits, Villafranchian, Tuscany, Italy.

Parole chiave: Litostratigrafia, Depositi continentali, Villafranchiano, Toscana, Italia.

1. INTRODUCTION

Since the 19th century, the Villafranchian succession cropping out in the Barga and Castelnuovo Garfagnana tectonic depressions (Tuscany) was investigated due to its fossil record, mainly represented by vegetable and mammal remains. The paleontological data increased as a consequence of the lignite and clay mining, that ended during the first and last decades of the 20th century, respectively. On the basis of few paleontological studies and limited number of vertebrate remains (De Stefani, 1887 and 1889; Ugolini, 1902; Zaccagna, 1932 and Masini, 1936), the Villafranchian age of this succession is accepted.

The main lithological features of these deposits have been described, among the others, by Nardi (1961) and Calistri (1974), and mapped at 1:10,000

scale by Nardi *et al.* (1986 and 1987). Unfortunately, these papers were not supported by detailed lithostratigraphic and sedimentological studies. Nevertheless, based on the significant lignite contents of the fine grained basal sediments and the dominant coarse grained overlying deposits, the whole succession was interpreted as a fluvial-lacustrine cycle. Recently, lithostratigraphy and facies analysis of these deposits were investigated by Puccinelli *et al.* (in press, a) and Landi *et al.* (2002-2003), respectively. On the basis of these studies, the main lithostratigraphic and sedimentary features of the Villafranchian formations, discontinuously exposed in the Barga and Castelnuovo Garfagnana areas, will be described in this paper.

A similar succession, dividable in two formations, crops out north-westward in the Aulla-Olivola and Pontremoli tectonic depressions (Bertoldi, 1997 and

Bernini *et al.*, 1990). Mainly consisting of fine grained lithofacies with medium to thick coarse grained interbeddings, the "Argille, sabbie e conglomerati di Aulla" (Puccinelli *et al.*, in press, b) is characterized by a variable amount of centimetric to decimetric lignite fragments and organic-rich horizons. It is overlain by the coarse grained "Conglomerati di Olivola" (Puccinelli *et al.*, in press, b), characterized by subordinate fine grained interbeddings.

2. GEOLOGICAL SETTING

The investigated area (Fig. 1) is one of the continental intermontane tectonic depressions, that opened as a consequence of the counter-clockwise migration of the chain-foredeep-foreland system and of the extension of the Northern Apenninic Tyrrhenian margin (Meletti *et al.*, 1995 and references therein) during the Late Ruscinian/Early Villafranchian time interval (Bernini *et al.*, 1990; Bertoldi, 1995 and 1997).

Roughly comprised between the Apuan Alps and the Apenninic watershed, the studied area includes two tectonic depressions, 5 Km wide and 10 (Barga) to 15 Km (Castelnuovo Garfagnana) long, separated by the so-called "Mt. Perpoli high" (Soglia di Monte Perpoli) (Puccinelli, 1987). These depressions are related to the movement of tectonic blocks collapsed and rotated

along antithetical faults and interpreted as half-graben, with the master faults plunging towards the Tyrrhenian border (Martini & Sagri, 1973; Eva *et al.*, 1978).

The Villafranchian succession laid down in the Barga and Castelnuovo Garfagnana depressions unconformably overlies sedimentary successions of the Apennine thrust-and-fold belt, here represented by the Falda Toscana (mainly with the Macigno Formation), Canetolo and Ottone Units. Along the western sides of both depressions, the Falda Toscana in turn tectonically overlies the Metamorphic Core Complex of the Apuan Alps.

3. PREVIOUS STUDIES AND INFERRED AGE

The sedimentary succession, cropping out in the Barga and Castelnuovo Garfagnana areas, was investigated entirely by few authors. Among them, De Stefani (1887 and 1889), Zaccagna (1917 and 1932), Ugolini (1902), Masini (1932 and 1936), Tongiorgi & Trevisan (1953), Azzaroli (1955), Nardi (1961) and Calistri (1974) focused on stratigraphy, even if only this latter studied the entire Villafranchian sedimentary succession. The papers of Bartolini & Bortolotti (1971), Nardi (1961 and 1965), Nardi *et al.* (1986 and 1987), D'Amato Avanzi & Puccinelli (1988), Puccinelli (1987), Dallan *et al.* (1991) and Moretti (1990) mainly deal with neotectonics and/or landslide hazard.

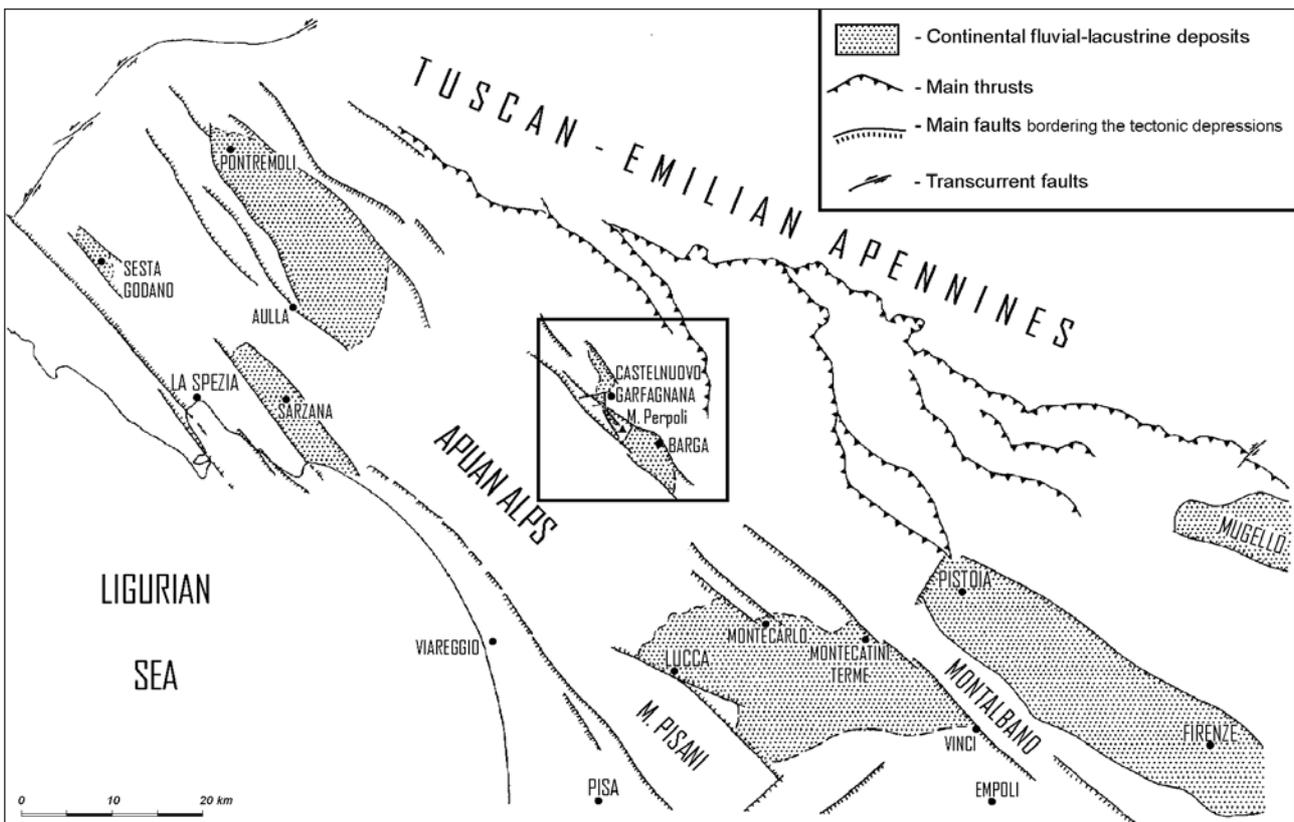


Fig. 1 - Tectonic sketch of the Northern Apennines and location of the main intermontane tectonic depressions nearby the study area (within the square).

Schema strutturale dell'Appennino settentrionale con la localizzazione delle principali depressioni tettoniche limitrofe all'area di studio (nel riquadro).

Unfortunately, the paleontological data as well as the age-significant fossil remains are scarce (Tab. 1).

However, the mammal fragments and the presence (Landi *et al.* 2002-2003) of some molluscs (*Laminifera villafranchiana*, *Prososthenia paulae*, *Theodoxus cf. groyanus*) and characean species (*Nitellopsis cf. Megarensis* - Carnevale *et al.*, 2003) point to (according to Azzaroli, 1977 and De Giuli & Masini, 1983) a Lower-Middle Villafranchian age for the “Argille, sabbie e conglomerati di Fornaci di Barga” and allow to assign the overlying “Conglomerati di Barga” to Late Villafranchian.

Tab. 1 - List of vertebrate fossils remains from the “Argille, sabbie e conglomerati di Fornaci di Barga” and “Conglomerati di Barga” formations.

Elenco dei resti dei vertebrati fossili provenienti dalle formazioni delle “Argille, sabbie e conglomerati di Fornaci di Barga” e dei “Conglomerati di Barga”.

Authors	Localities	Fossil remains	Formations
De Stefani (1889)	Barga	<i>Equus stenonis</i>	Conglomerati di Barga
Meneghini (1880)	Ghivizzano	<i>Tapirus</i> <i>Hystrix</i>	Argille, sabbie e conglomerati di Fornaci di Barga
De Stefani (1889)	Fornaci di Barga	<i>Rhinoceros etruscus</i>	
De Stefani (1889)	T. Loppora	<i>Rhinoceros etruscus</i> <i>Sus arvernensis</i> <i>Cervus sp.</i> <i>Felis cfr. isdiorensis</i> <i>Meganthereon nestii</i> <i>Hystrix sp.</i> <i>Tapirus sp.</i> <i>Mastodon arvernensis</i>	
Ugolini (1902)	Fornaci di Barga	<i>Tapirus arvernensis</i> <i>Cervus pardinensis</i>	
Masini (1936)	Fornaci di Barga	<i>Mastodon arvernensis</i>	
De Stefani (1887)	La Fossa	<i>Emys sp.</i> <i>Tapirus sp.</i> <i>Sus sp.</i> <i>Felis cfr. isdiorensis</i> <i>Cervus sp.</i> <i>Mastodon arvernensis</i>	
De Stefani (1887)	Custia	<i>Mastodon arvernensis</i>	
De Stefani (1887)	Fornaci del Ponte Castiglione	<i>Cervus sp.</i> <i>Mastodon arvernensis</i> <i>Tapirus sp.</i> <i>Machiarodus eultridens</i>	
De Stefani (1887)	Fornaci del Bianchi	<i>Tapirus sp.</i> <i>Sus arvernensis</i>	
Ugolini (1902)	T. Loppora	<i>Tapirus arvernensis</i> <i>Cervus pardinensis</i>	
Masini (1932)		<i>Mastodon arvernensis</i>	

4. LITHOSTRATIGRAPHY AND SEDIMENTARY FEATURES OF THE MAPPED FORMATIONS

As it is well known, the continental successions cropping out in the intermontane, post-collisional basins are usually badly exposed, due to both the large diffusion of the anthropic activities (e.g. agriculture, urbanization) and vegetation cover. Consequently, the vertical and/or lateral outcrop extension is often limited, and the geometric and stratigraphic relationships between formations overshadowed. However, based on some well exposed sections, the entire succession has been rather well reconstructed.

In the study areas, most significant sections are located in the Barga area, where the mapped formations and the boundary between them are also well exposed. According to previous papers (Nardi *et al.*, 1986 and 1987; Dallan *et al.*, 1991), in the investigated area two formations have been recognized, and named by Puccinelli *et al.* (in press, a): “Argille, sabbie and conglomerati di Fornaci di Barga” (AFB) and “Conglomerati di Barga” (PLB). In the Castelnuovo Garfagnana area, within PLB, the Mt. Alfonso member is distinguishable. The extension of both formations (AFB+PLB) is represented in Fig. 2.

4.1. Argille, sabbie e conglomerati di Fornaci di Barga (Puccinelli *et al.*, in press, a)

Synonymies

Argille azzurre lignifere e sabbie ocracee (Nardi, 1961)
Argille di Fornaci di Barga *pro parte* (Calistri, 1974)
Sabbie e argille lignifere (Nardi *et al.*, 1986)
Argille e sabbie lignifere (Nardi *et al.*, 1987)
Formazione di Fornaci di Barga (Catanzariti *et al.*, 2002)
Lithostratigraphic Unit 1 (Landi *et al.*, 2002-2003)

Significant outcrops (see Tab. 2)

Barga: Rio Secco, Fornaci di Barga, T. Loppora, Rio Zanesi, Rio Cavo, T. Giuvicchia, Rio Val di Lago, Le Palmente and Corsonna.
Castelnuovo Garfagnana: Rio la Fossa, Rio Dezza, Bamborino, Rio Valardino, La Bottegaccia, Villa Collemantina, Gamberone, Antisciana and Belvedere.

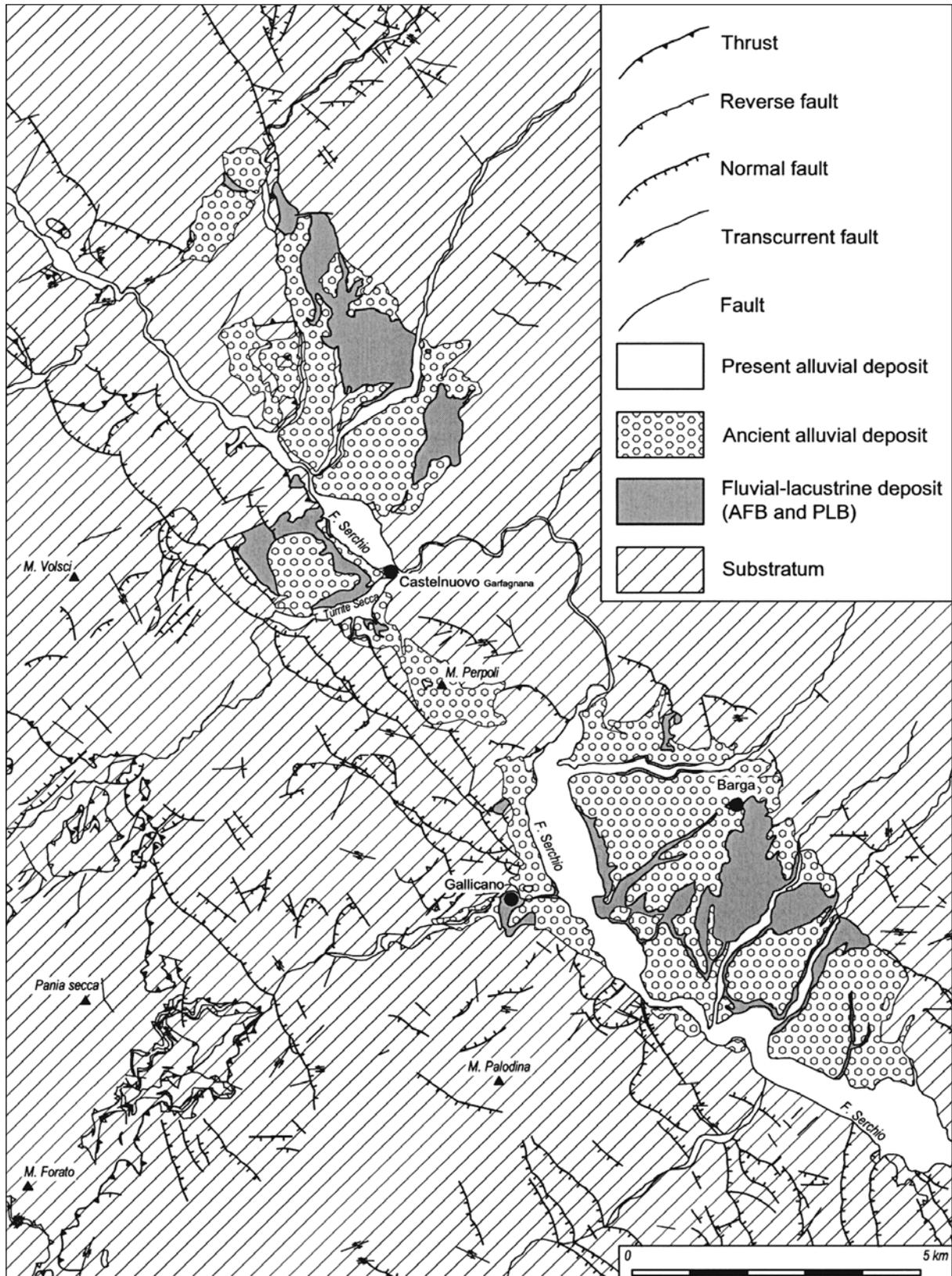


Fig. 2 - Schematic geological map of the Barga and Castelnuovo Garfagnana depressions and nearby areas, based on the Geological Map at 1:50,000 - Sheet 250 Castelnuovo Garfagnana (Puccinelli et al., in press, a) and on some geological maps at 1:10,000 scale (Nardi et al., 1986 and 1987; Dallan et al., 1991).

Carta geologica schematica dei bacini di Castelnuovo Garfagnana e Barga e delle aree limitrofe, basata sulla Carta Geologica a scala 1:50.000 - Foglio 250 Castelnuovo Garfagnana (Puccinelli et al., in press, a) e su alcune carte geologiche a scala 1:10.000 (Nardi et al., 1986 and 1987; Dallan et al., 1991).

AFB mainly consists of fine (clayey to sandy) grained lithofacies interbedded by medium to coarse conglomerate (from channel to wedge or sheetlike shaped), that sometimes can be dominant. The formation is also

characterized by a variable amount of centimetric to decimetric lignite fragments, that in places are abundant and concentrated in organic-rich horizons (Fig. 3a).

The fine grained deposits, ranging from 0.5 to 3-7

Tab. 2 - Most significant outcrops in the Barga and Castelnuovo Garfagnana depressions of the "Argille, sabbie e conglomerati di Fornaci di Barga" and "Conglomerati di Barga" formations. Exposed lithofacies are also synthetically described.

Affioramenti maggiormente significativi nelle aree di Barga e Castelnuovo Garfagnana delle formazioni delle "Argille, sabbie e conglomerati di Fornaci di Barga" e dei "Conglomerati di Barga". Sono anche descritte in modo sintetico le litofacies caratteristiche affioranti.

Localities	Member (Mb.) Lithofacies (Lt.)	Formations	
Barga area			
T. Loppora	Lenticular-shaped conglomerate (Lt.) channel-shaped conglomerate (Lt.)	Conglomerati di Barga	
Rio Latrani	Sheet-like conglomerate (Lt.)		
Rio Zanesi	Sheet-like conglomerate (Lt.)		
Corsonna	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Le Palmente	Lenticular-shaped conglomerate (Lt.) & sandy (Lt.)		
Casa Volpaia	Fine grained (Lt.) and organic-rich horizons & channel-shaped conglomerate (Lt.)		
Pieve di Loppia-Barga road	Lenticular-shaped conglomerate (Lt.) & sandy (Lt.)		
Barga	Lenticular-shaped conglomerate (Lt.) & sandy (Lt.)		
Castelnuovo G. area			
Rio Dezza	Mt. Alfonso (Mb.). Poorly sorted conglomerate		
Il Colle	Mt. Alfonso (Mb.). Poorly sorted conglomerate		
Mt. Alfonso	Mt. Alfonso (Mb.). Poorly sorted conglomerate		
S. Lucia	Lenticular-shaped conglomerate (Lt.) & sandy (Lt.)		
Castegni	Lenticular-shaped conglomerate (Lt.) & sandy (Lt.)		
Soffiana	Sand and silty (Lt.) & rare organic-rich horizons		
Bamborino	Lenticular-shaped conglomerate (Lt.) & sandy (Lt.)		
Liana	Sandy (Lt.) & lenticular shaped conglomerate (Lt.)		
Barga area			
Rio Secco	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)	Argille, sabbie e conglomerati di Fornaci di Barga	
Cava Fornaci	Fine grained (Lt.)		
T. Loppora	Channel-shaped conglomerate (Lt.) & fine grained (Lt.)		
Le Palmente	Fine grained (Lt.)		
Rio Cavo	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Rio Zanesi	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Rio Val di Lago	Fine grained (Lt.) and organic-rich horizons & channel-shaped conglomerate (Lt.)		
Corsonna	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Rio della Giuvicchia	Fine grained (Lt.) and organic-rich horizons & channel-shaped conglomerate (Lt.)		
Casa Volpaia	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Castelnuovo G. area			
Rio Dezza	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Rio la Fossa	Fine grained (Lt.) and organic-rich horizons & channel-shaped conglomerate (Lt.)		
Collemandina	Fine grained (Lt.) & sandy (Lt.)		
Bamborino	Fine grained (Lt.)		
La Bottegaccia	Fine grained (Lt.) & organic-rich horizons		
Gamberone	Fine grained (Lt.), organic-rich horizons & sandy (Lt.)		
Antisciana	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Belvedere	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		
Rio Valardino	Fine grained (Lt.) & channel-shaped conglomerate (Lt.)		

m in thickness, are usually organized in centimetric to decimetric rhythmical alternance of grey-dark, grey to bluish or violet clay to silty-clay and yellowish silty or sandy beds, with horizontal to cross or through lamination, in places well evidenced by small lignite fragments. They can be associated with 0.5 to 3.5 m thick massive to horizontal laminated organic-rich clay or silty to sandy interbeddings, that somewhere show soft deformation structures. The organic-rich levels, more abundant in the lower portion of the formation, contain scattered lignite fragments, that can concentrate in 20 to 40 cm thick horizons, with limited (10-15 m) lateral extent. The sandy intervals, usually 10-20 cm thick and up to 1.5-2 m wide, can be up to 1.5 m thick and 10 m wide. In the thickest sandy levels, thin to medium thick lens-shaped conglomerate can be present.

At different levels, and mainly within the clay and silty-clay intervals centimetric to decimetric (20-30 cm), dark grey paleosols containing land fossils (Landi *et al.*, 2002-2003) are present. Unfortunately, the lateral extent of these horizons is limited and their correlation unreliable. The scarce fossil remains of the fine grained lithofacies include ostracods and gastropods, along with extremely rare teeth of fish and charophytes oogonia (genus and species names in Landi *et al.*, 2002-2003). Fragments of leaves and chunks of trees are also present and in few places the latter are still observable in life position (Rio Dezza).

The isolated channel-shaped, clast-supported poly-mictic conglomerate, from grey/dark grey to brownish, consist of sub-rounded to well rounded clasts, in places imbricated. This medium to coarse grained massive and well sorted conglomerate shows a low percentage of silt to fine matrix, not always present. This deposit, with weak to strong erosive basal surface and limited (3-5 to 15-20 m) lateral extent, ranges from 1 to 3 m in thickness.

The coarse grained lithofacies can also be represented by an alternance of clast-supported, wedge- to sheet-like conglomerate or sandy conglomerate, and medium to coarse sand. This conglomerate, from 1 to 3 m thick and up to 20-40 m wide, lacks any evidence of basal erosive surface. The pebbles and cobbles range from sub-angular to sub-rounded/rounded. The medium to coarse sandy matrix is present in variable amount, that can vary in percentage at metric scale. The sandy interbeds range from massive to cross laminated.

In both types of conglomerate, the clasts are mainly represented by unmetamorphosed lithotypes, with the arenaceous clasts (referable to the Macigno Fm.) slightly more abundant than the carbonatic ones. In places, the arenaceous clasts can be dominant. The metamorphic (Landi *et al.* 2002-2003) ones are more abundant in the Barga (up to 15-20%) than in the Castelnuovo Garfagnana area, where they are extremely rare (below 1%).

Scattered along the Apenninic border, **AFB** is interbedded, at different levels, with medium/coarse to very coarse grained, monomictic, massive conglomerate, mainly made of clasts referable to the Macigno Fm. (i.e. Units 3 and 4 of Landi *et al.*, 2002-2003). This unsorted to poorly sorted, matrix- to clast-supported conglomerate is nicely exposed at Colle Buvicchia and Mologno. It chiefly consists of sub-angular to rounded cobbles and boulders, in places well imbricated. The medium to coarse sandy matrix is furnished by the Macigno Fm.

weathering. Ranging in thickness from few metres up to 100 m, such coarse clastic wedges (in places) can represent the entire Villafranchian sedimentary record.

According to Landi *et al.* (2002-2003), the association of fine and coarse grained lithofacies with *in situ* accumulated organic matter (mainly represented by lignite) was sedimented in a braided fluvial system, referable to an anabranching organo-clastic substage (*sensu* Nanson & Knighton, 1996), flowing from Castelnuovo Garfagnana to Barga. It interfingers with the alluvial fan deposits (dominated by debris-flow processes), cropping out along the Apenninic border (i.e. Units 3 and 4 of Landi *et al.*, 2002-2003), and develops transversally to the tectonic depression axis.

The thickest exposures range from 10-40 to 80 m in the Barga area and from 10 to 30-40 m in the Castelnuovo Garfagnana area. The maximum thickness of this formation measured near Castelnuovo Garfagnana, including a drilled portion, can reach 200 m (De Marco & Caielli, 1995; Cancelli *et al.*, 2002). Usually, the outcrops are not thicker than 10-30 m in Barga as well as in Castelnuovo Garfagnana areas.

The unconformable contact with the underlying formations is exposed in few localities, with bad exposure conditions and very limited lateral extent. Along the eastern border of the Barga depression, the Macigno Fm. is topped by the basal coarse grained and poorly sorted conglomeratic lithofacies of **AFB**. In the boreholes drilled near Villa Collemadina, the substratum (represented by Ligurian successions) has been reached below 90-100 m of **AFB**.

The **AFB/PLB** contact is frequently well exposed and characterized by an abrupt facies change, suggesting a possible disconformity surface. Nevertheless, in some places (Gallicano and Barga areas) the heteropy between the two formations is not excluded. In fact, conglomeratic interbeddings are locally present in the uppermost part of **AFB**; they are similar to those interbedded in the lowermost part of **PLB**. In other areas, **AFB** is topped by the erosive post Villafranchian coarse grained terraced deposits. According to the quoted fossil remains, the lowermost portion of this formation could be assigned to the Lower Villafranchian, whilst its upper portion could reach the Middle Villafranchian.

4.2. Conglomerati di Barga (Puccinelli *et al.*, in press, a)

Synonymies

- Ghiaie con prevalenza di rocce mesozoiche e metamorfiche (Nardi, 1961)
- Ciottoli e sabbie di Loppia (Calistri, 1974)
- Conglomerati a ciottoli prevalentemente calcarei (Nardi *et al.*, 1986)
- Ghiaie e conglomerati calcarei (Nardi *et al.* 1987)
- Conglomerati di Barga (Catanzariti *et al.*, 2002)
- Lithostratigraphic Unit 2 (Landi *et al.*, 2002-2003)

Significant outcrops (see Tab. 2)

- Barga: T. Loppora, Rio Latrani, Rio Zanesi, Le Palmente, Pieve di Loppia-Barga road, Barga and Casa Volpaia.
- Castelnuovo Garfagnana: Bamborino, Rio Dezza, Il Colle, S. Lucia, Castagni, Soffiana, Mt. Alfonso and Liana.

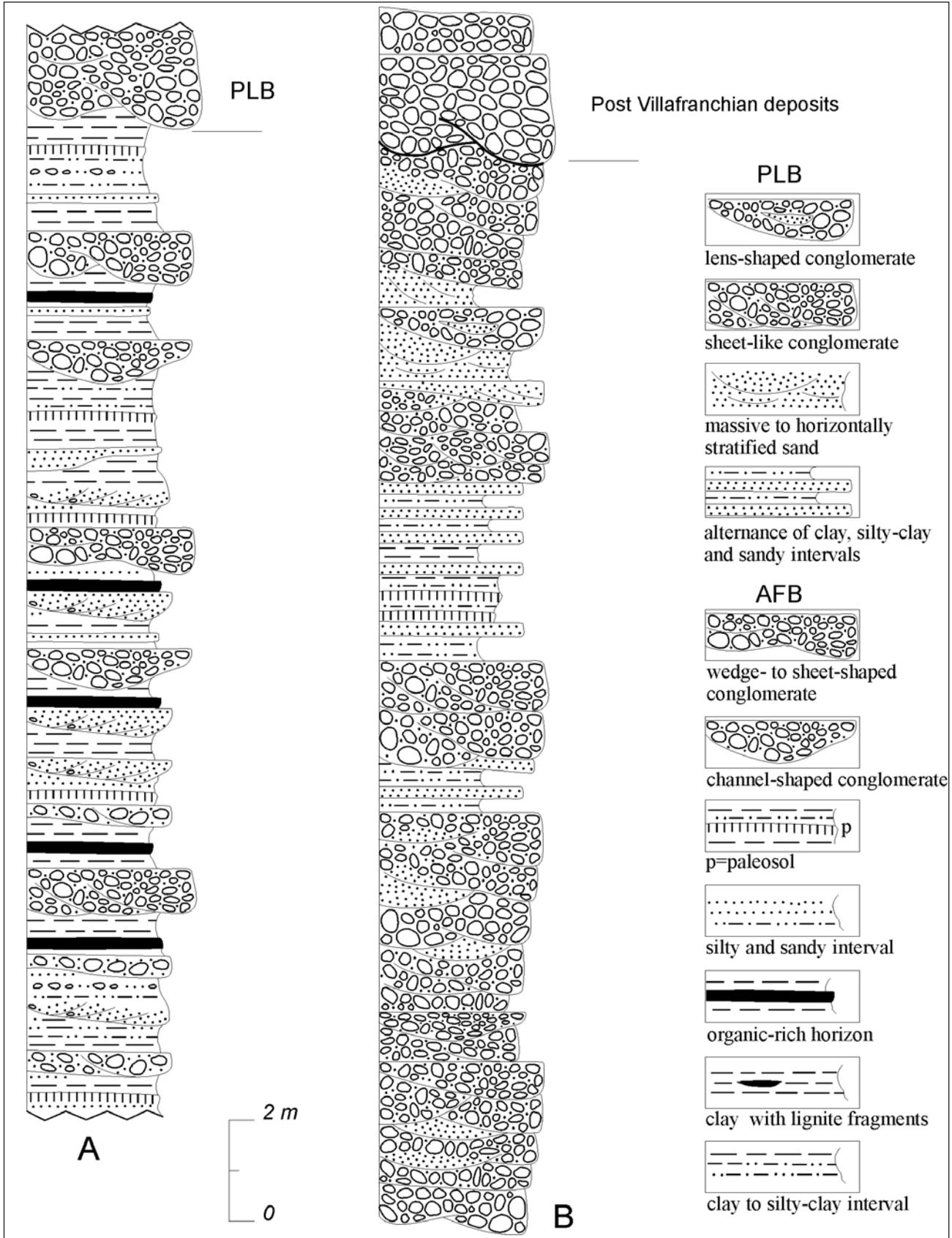


Fig. 3 - Main lithological features of the "Argille, sabbie e conglomerati di Fornaci di Barga" Fm. (A) and of the "Conglomerati di Barga" Fm. (B).

Colonne stratigrafiche mostrandoti le principali caratteristiche litologiche delle "Argille, sabbie e conglomerati di Fornaci di Barga" (A) e dei "Conglomerati di Barga" (B).

PLB is characterized by the dominance of medium to coarse (from pebbles to cobbles) grained lithofacies, whilst sandy to silty-clayey levels, with very rare paleosols, are subordinate. Though texture, sedimentary structures and shapes of the conglomerate can change even at metric scale, two end-members can be described: one shows sheet-like geometry and significant presence of sand interbeddings, the other is lens-shaped and characterized by erosive basal surface and small amount of matrix (Fig. 3b).

The sheet-like, clast-supported conglomerate, with massive to crude bedding is interbedded with thin (2-3 to 5-10 cm), massive to horizontally stratified, lenticular yellowish sand. These coarse grained intervals, with very rare sedimentary structures, mainly consist of poorly to moderately sorted conglomerate, with well rounded pebbles and cobbles, rarely imbricated and with a variable amount of sandy-silty to silty matrix; the matrix percentage may change even within the same interval. This disorganized to poorly organized conglomerate, frequently ranging in thickness from 0.5 to 1 m, can be up to 3 m thick and 20-30 m wide.

The lens-shaped, medium to coarse conglomerate, is chiefly composed of well sorted clasts and small percentage of silty to sandy matrix. The sub-rounded to rounded clasts are frequently imbricated and the matrix can be, in places, either absent or significantly present. This conglomerate, sometimes channellized, shows weakly erosive basal surface and planar to through cross stratification. Ranging in thickness from 0.5 to 3 m, it can be up to 20-30 m wide. Within this conglomerate, thin to thick (10-50 cm) interbeddings of massive, brownish to brown-reddish sand, with small lateral extension, are present.

In both types of conglomerate, the clasts are chiefly represented by non-metamorphic or metamorphic carbonatic lithotypes; whilst sandstone (referable to the Macigno Fm.) is subordinate. Within the coarse grained lithofacies, interbeddings of silt and fine to medium grained yellowish to reddish sand, up to 1 m thick, are present. More abundant in the sheet-like conglomerate and sometimes bioturbated, silt and sand frequently show through and planar cross-bedding. In places, grey to dark-grey, millimetric to centimetric lenses of clay evidence the sedimentary structures of these fine grained interbeddings.

PLB is also characterized by the occurrence of centimetric to decimetric rhythmical interbeddings of grey clay or silty-clay to sandy beds, with horizontal to cross or through lamination, similar to those described for the underlying formation. These fine grained lithofacies, usually ranging from few decimetres to 1-2 m (Rio Latrani, Rio Sartoiani, T. Giuvicchia and T. Corsonna), are up to 20 m thick at Casa Volpaia. In the silty-sandy or sandy beds micro and macro vegetable remains may concentrate and at different levels, centimetric to decimetric dark grey or blackish paleosols are also present. In all quoted localities, the heteropic transitions with the coarse grained deposits are visible.

As reported by Landi *et al.* (2002-2003), the described lithofacies association is dominated by conglomerate together with sandy lenses and centimetric to decimetric alternance of fine grained deposits (characterized by organic-rich horizons and paleosols). This association is referable to a gravel bed-load braided river system, flowing from NE to SW (i.e. from

Castelnuovo Garfagnana to Barga).

As described for **AFB**, along the Apenninic border, also **PLB**, interfingers with coarse grained lithofacies (Unit 3 of Landi *et al.*, 2002-2003), characterized by sub-angular to rounded (the boulders) clasts, chiefly consisting of sandstone (referable to the Macigno Fm.), and interpreted as coalescent alluvial fan deposits (dominated by debris-flow processes) developed transversally to the tectonic depression axis.

PLB is superbly exposed along the oriental side of the Serchio Valley, and ranges in thickness from 70 (Galliciano) to 170 m (Barga). The better exposures are located between Loppia and Barga and in the Villa Collemandina area. Usually, the outcrops can be 20-40 m thick and from 100 to 200 m wide. The clearly erosive contact between the Conglomerati di Fornaci di Barga and the post Villafranchian coarse grained terraced deposits is frequently well exposed. According to the few listed paleontological remains, this formation could be assigned to the Middle to Late Villafranchian.

West of the Castelnuovo Garfagnana area, **PLB** is represented by medium to coarse clast-supported conglomerati of Mt. Alfonso member (Unit 5 of Landi *et al.*, 2002-2003). Showing a tabular geometry with thickness ranging from 0.5 to 3 m, these deposits can vary even in a short distance from disorganized to organized sedimentary body. The poorly sorted clasts, with a diameter up to 50 cm, in places imbricated, are mainly composed of carbonate, whilst the presence of sandstone is subordinate, though sometimes it can be significantly present. The 100 (westward) to 40 m (eastward) thick Mt. Alfonso member is interpreted as a braided fluvial fan, supplied by the Apuan Alps and developed transversally to the basin axis (Landi *et al.* 2002-2003).

5. CONCLUSIVE REMARKS

On the basis of the main lithostratigraphic and sedimentological features of the described Villafranchian succession, the following points should be emphasized.

- In the Barga and Castelnuovo Garfagnana areas, **AFB** and **PLB** are characterized by distinctive lithofacies associations, and the boundary between the two formations is quite easily recognizable.
- Within **AFB**, clay and conglomerate are subordinate and the formalized name points out the wide lithological spectrum, that characterizes this formation. Nevertheless, lateral and vertical variations between fine grained and coarse grained lithofacies are distinguishable at outcrop scale, but hardly mappable, due to their limited thickness and lateral extent.
- The clayey intervals of **AFB** are more widespread and thicker in the Castelnuovo Garfagnana than in the Barga depression, whilst sandy intervals are thicker and wider in the Barga than in the Castelnuovo Garfagnana area. Thin to very thin and well stratified, clayey-silty to sandy laminated (varve-like) intervals are peculiar of the Castelnuovo Garfagnana area.
- The organic-rich horizons within **AFB** are relatively more abundant in the lower portion of the formation. They are usually represented by centimetric to decimetric horizons within the fine grained portions. The largest fragments of lignite and the chunks of trees

are scattered throughout the formation, and some of these latter are sometimes still in life position. The lignite banks, including the mined ones, are thicker and more continuous than those cropping out or mined in the Barga area.

- In **AFB** the coarse grained intervals are mainly represented by channelized conglomerate interbedded by clayey-silty or sandy dominant lithofacies. Likewise, the sheetlike conglomerate (almost absent in the Castelnuovo Garfagnana area), present in the lower portion of the formation, is associated with clayey-silty or sandy lithofacies.
- In spite of the lateral and vertical lithological variation of the different lithofacies, the dominance of the coarse grained conglomerate allows the easy mapping of the **PLB**, also characterized by sandy interbeddings. Silty-clayey to sandy fine grained lithofacies (with thin organic-rich horizons similar to those present in **AFB**), with reduced thickness as well as lateral extent, are clearly in heteropy to the conglomerate. Also in the Castelnuovo Garfagnana area these lithofacies (including organic-rich horizons) are very limited in thickness and lateral extension.
- Lignite fragments or other biogenic remains, as well as paleosols, are extremely rare and scattered within **PLB**. Indeed, large lignite fragments can be present within the coarse grained lithofacies, whilst millimetric to centimetric lignite flakes are relatively more frequent within the finest grained lithofacies.
- In the Castelnuovo Garfagnana depression, within the **PLB**, the Mt. Alfonso member is distinguishable. Mainly consisting of polymictic, poorly sorted medium to coarse conglomerate and subordinate coarse grained sand, it can be correlated with the conglomerate cropping out in the Gallicano area (D'Amato Avanzi & Puccinelli, 1988) and mapped within the **PLB**.
- In spite of similar lithologies present in both formations, the lithofacies assemblages point out the superposition of gravel bed-load braided river deposits (**PLB**) on cohesive sediment anabranching river deposits (**AFB**). Both successions interfinger with the alluvial fan conglomerate, that in places can represent the entire Villafranchian succession.
- The abrupt facies change between these two clastic successions can be interpreted as a disconformity surface (Landi *et al.*, 2002-2003). Unfortunately, it is neither supported by paleontological data nor confirmed by other field evidence. However, the conglomeratic lithofacies interbedded within the **AFB** shows neither a polarity towards the top of the formation nor significant similarities with the coarse grained lithofacies of the **PLB**.
- On the other hand, the erosive contact between **AFB** and **PLB** can be also interpreted as stratigraphic, because erosive surfaces are frequent within this type of deposits (from anabranching to gravel bed-load braided). Moreover, the presence of channelized conglomeratic lenses within the uppermost part of the **AFB**, similar to those present in the overlying lowermost part of **PLB**, can support (at least in some places) a quite sharp but transitional boundary between **AFB** and **PLB** (Puccinelli *et al.*, in press, a).
- In summary, though the Villafranchian clastic wedges sedimented in two distinct tectonic depressions, connected by the sedimentary by-pass (Landi *et al.*,

2002-2003) of the "Mt. Perpoli high", active since the beginning of the Villafranchian deposition, the lithofacies associations characterizing **AFB** as well as **PLB** are quite similar in both areas. Furthermore, the boundary between **AFB** and **PLB** shows the same features in both depressions, even if the field evidence is not helpful to choose between the existence of a disconformity or a stratigraphic transition between **AFB** and **PLB**.

- Although the correlation between continental clastic successions, not supported by sedimentological analysis and paleontological data is difficult, in our opinion the **AFB** and **PLB** can be correlated with the "Argille, sabbie e conglomerati di Aulla" and the "Conglomerati di Olivola", respectively (Puccinelli *et al.*, in press, b). Both crop out north-westward in the Magra Valley (Aulla-Olivola and Pontremoli tectonic depressions) and show strong affinities with **AFB** and **PLB**. The "Argille, sabbie e conglomerati di Aulla" consists of fine grained lithofacies characterized by a variable amount of centimetric to decimetric lignite fragments and organic-rich horizons, with medium to thick coarse grained sandy conglomeratic interbeddings. The overlying "Conglomerati di Olivola" is represented by coarse grained conglomerate and subordinate fine grained interbeddings.

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