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# Detrital events within pelagic deposits of the Umbria-Marche Basin (Northern Apennines, Italy): further evidence of Early Cretaceous tectonics

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ABSTRACT - Re-sedimented deposits characterize different stratigraphical intervals in the pelagic successions of the Umbria-Marche-Sabina Domain (Central and Northern Apennines, Italy). Three stratigraphic sections of the Maiolica and Marne a Fucoidi Formations, characterized by breccias and calcarenites embedded in pelagic sediments, were sampled across the Mt. Primo area (Umbria- Marche Ridge, Northern Apennines). Facies analysis indicates a gravity-driven origin for the clastic levels, interpreted as debris-flows, or turbidity flows. The massive lensoid-to-tabular levels are composed of loose shallow-water benthic material, sourced from an unknown carbonate platform, associated with: i) lithoclasts made of Lower Jurassic and Lower Cretaceous shallow-water carbonates; ii) Jurassic mudstones and wackestones referable to the pelagic succession; iii) calpionellid/radiolarian-rich soft pebbles (Maiolica-type facies). The compositional features of the studied detrital deposits imply submarine exposure and dismantling of portions of the stratigraphic succession older than the Barremian/Aptian, which had to be buried in the late Early Cretaceous. Such evidence led us to refer the investigated clastic event to an extensional tectonic phase. Our interpretation well fits with data coming from different geological settings of Italy, strongly suggesting the occurrence of a widespread extensional phase in the late Early Cretaceous.

Keywords: Apennines; Maiolica Fm.; Early Cretaceous; Tectonics; Re-sedimented deposits.

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## 1. INTRODUCTION

In this paper we present preliminary results from three stratigraphic sections of the Maiolica and Marne a Fucoidi Formations sampled across the Mt. Primo area, in the surroundings of Pioraco, Sefro and Agolla villages (Marche Region - Italy) (Figs. 1, 2).

The study area is part of the Umbria-Marche-Sabina (UMS) Domain, in Central/Northern Apennines, where a well-known Jurassic-to-Neogene stratigraphic succession crops out (Colacicchi et al., 1970; Centamore et al., 1971; Farinacci et al., 1981; Galluzzo and Santantonio, 2002; Fabbi and Santantonio, 2012; Pierantoni et al., 2013; Donatelli and Tramontana, 2014; Fabbi, 2015).

An anomaly in the stratigraphy of the UMS Domain is the occurrence, at different stratigraphic levels, of detrital bodies intercalated to the pelagic succession. Gravity deposits related to the Early Jurassic Tethyan rifting are well known in literature (e.g. Cantelli et al., 1978; Galluzzo and Santantonio, 2002; Di Francesco et al., 2010 and references therein); differently, the occurrence of calcirudites and calcarenites interbedded with the Middle-Upper Jurassic (Giannini et al., 1970; Bartoccini and Rettori, 1991; Galluzzo and Santantonio, 2002; Di Francesco et al., 2010; Tomassetti, 2010) and the Lower Cretaceous pelagites (Giannini, 1960; Giannini et al., 1970; Centamore et al., 1971; Mattei, 1987; Pierantoni et al., 2013; Fabbi, 2015; Fabbi et al., 2015) is poorly investigated. Whereas the existence of a wide productive carbonate platform in Central Italy (Latium-Abruzzi Platform) can easily explain the presence of such material in the neighboring basins (Galluzzo and Santantonio, 2002; Rusciadelli et al., 2009; Pierantoni et al., 2013; Rusciadelli and Ricci, 2013; Cardello and Doglioni, 2015), the occurrence of detrital bodies in paleogeographic areas far from this platform is less obvious, being those areas separated from the Latium-Abruzzi Platform by belts where the coeval sediments are free of any re-sedimented shallow-water material.

Sedimentological and paleontological analyses, along with a general preliminary discussion based on the study of three stratigraphic sections, characterized by several clastic events (encompassing the Barremian/Aptian time interval), are here reported.

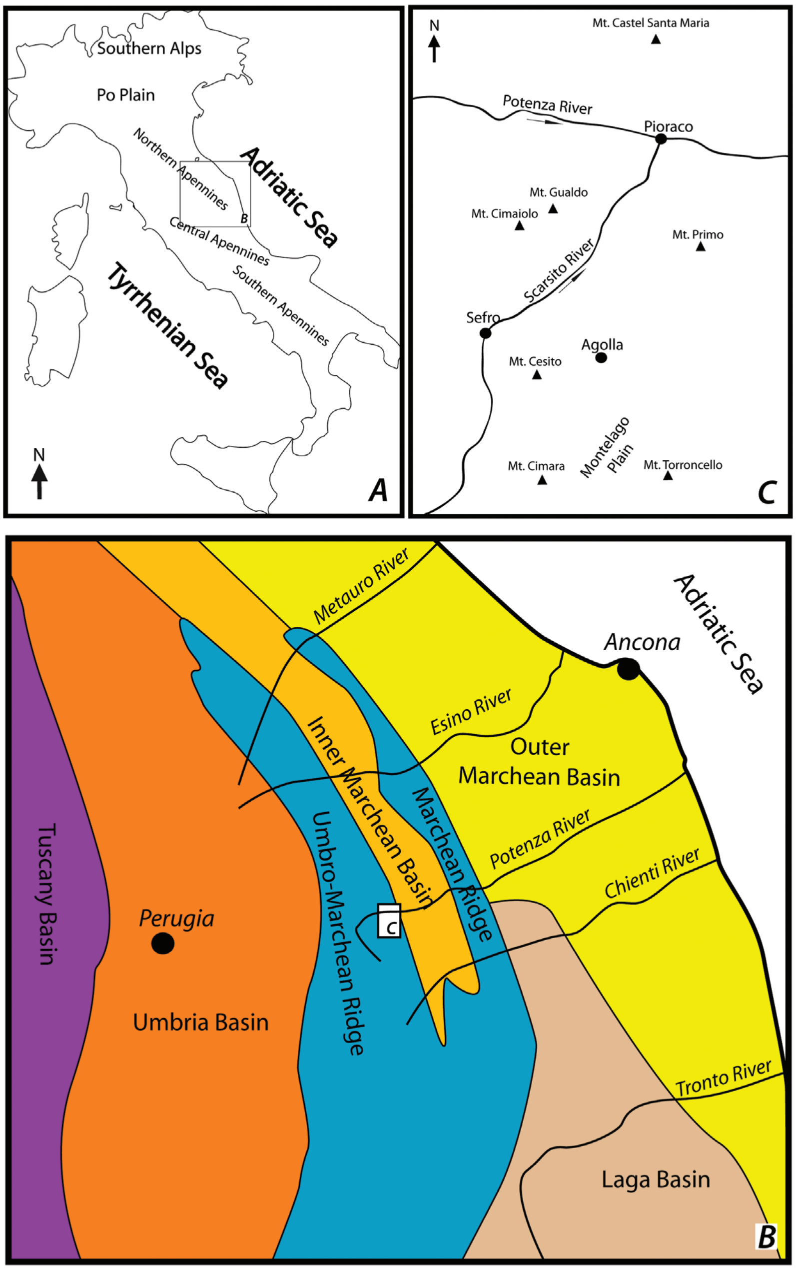


Fig. 1 - Location of the study area in the UMS Basin (after Fabbi, 2015).

### 1.1. Geological setting

The studied sections were sampled in the Mt. Primo Range, a roughly N-S trending anticline in the southern part of the so-called "Umbria-Marche Ridge". Meso-Cenozoic rocks, mainly limestones, marls and cherts, outcrop in the area (Fabbi, 2015) and are referable to the regionally known Umbria-Marche sedimentary succession (e.g. Centamore et al., 1971) (Fig. 2).

The outcropping succession of the UMS Domain starts from the lower Jurassic. The Jurassic stratigraphy of the region was controlled by a Rhaetian-Hettangian extensional phase (Colacicchi et al., 1970; Centamore et al., 1971; Farinacci et al., 1981; Santantonio and Carminati, 2011; Fabbi and Santantonio, 2012; Cardello and Doglioni, 2015), which dismembered the "Calcare Massiccio" carbonate platform. This tectonic phase caused the drowning of the benthic factory producing a complex submarine paleotopography, characterized by structural highs and lows, hosting different sedimentary successions (Santantonio, 1993, 1994; Galluzzo and Santantonio, 2002 and references therein). In the structural lows the carbonate platform drowned around the Hettangian/Sinemurian boundary (Bucklandi Zone - Passeri and Venturi, 2005) and a thick (some hundred meters in average) pelagic succession, including the "Corniola", "Rosso Ammonitico", "Calcari a Posidonia", "Calcari Diasprigni" and "Calcari a Saccocoma e Aptici" formations ("complete series" *sensu* Centamore et al.,

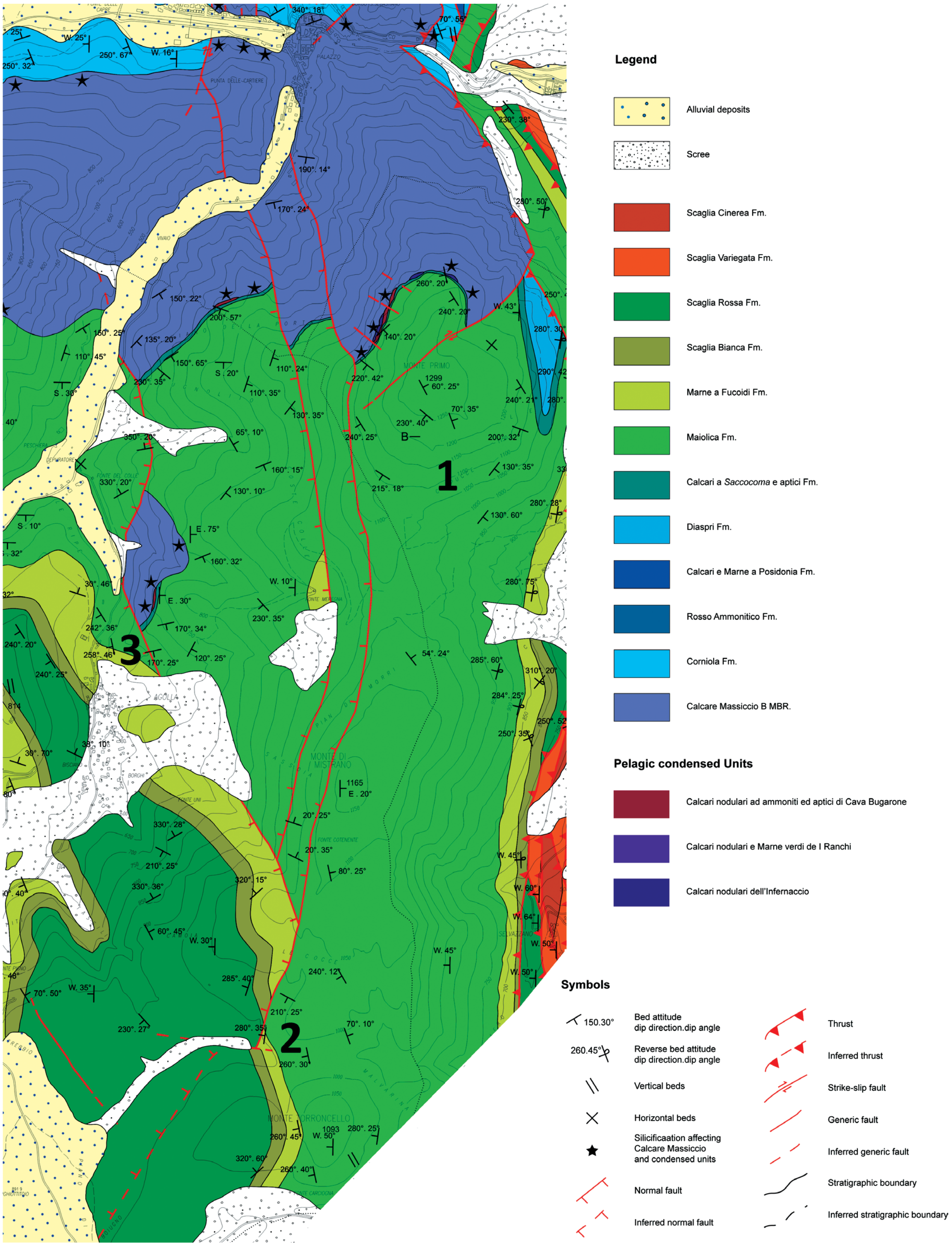


Fig. 2 - Geological map of the study area with the location of the studied stratigraphic sections marked by numbers: 1 - Mt. Primo section; 2 - Mt. Mistrano section; 3 - Agolla section (modified after Fabbi, 2015).

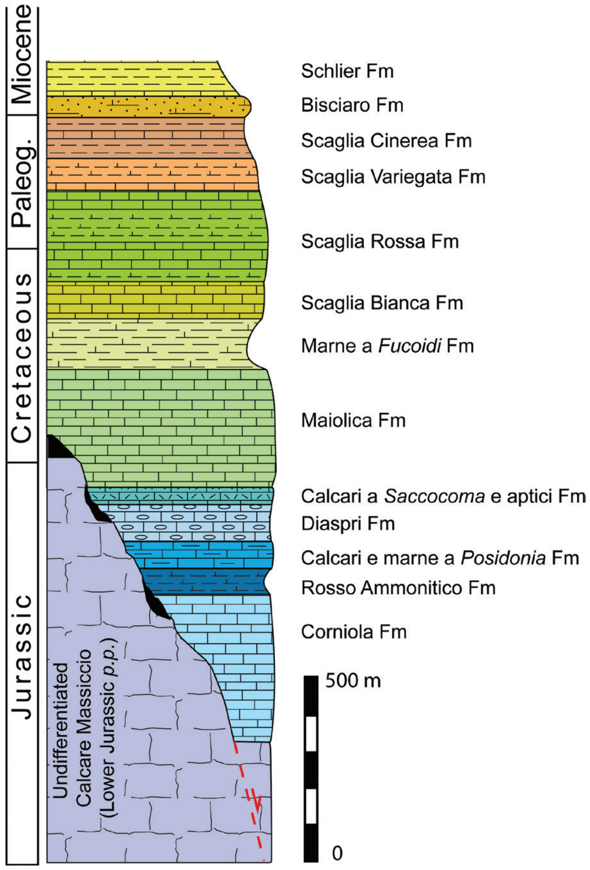


Fig. 3 - Stratigraphy of the study area (after Fabbi, 2015).

1971; "facies association B" *sensu* Santantonio, 1993) was sedimented. On the structural highs, the platform drowned in the early Pliensbachian (Ibex Zone - Morettini et al., 2002; Marino and Santantonio, 2010) and was followed by a thin (some meters), very condensed, often lacunose, cephalopod-rich pelagic succession ("condensed series" *sensu* Centamore et al., 1971; "facies association A" *sensu* Santantonio, 1993) (Fig. 3). Patches of very condensed facies unconformably rest, also, above the Calcare Massiccio Jurassic paleoescarpments that bordered the structural highs, in the form of epiescarpment deposits (Galluzzo and Santantonio, 2002; "facies association C" - Santantonio, 1993). Excluding the sparse occurrence of those thin veneers of condensed pelagites, the Jurassic submarine paleoescarpments were essentially erosive/non-depositional margins, progressively unconformably covered by the basin-fill onlapping deposits. As widely described in literature (Centamore et al., 1971; Farinacci et al., 1981; Cecca et al., 1990; Santantonio, 1993, 1994; Galluzzo and Santantonio, 2002; Donatelli and Tramontana, 2014; Cardello and Doglioni, 2015; Fabbi, 2015), the Jurassic submarine relief was finally blanketed in the Early Cretaceous by the Maiolica Fm. (late Tithonian p.p. - early Aptian p.p.). The Maiolica Fm. is characterized by a widespread pelagic facies in the whole Tethyan realm (Wieczorek, 1988), and is typically a white, well-bedded cherty mudstone, whose deposition resulted from the calcareous nannoplankton bloom occurring in the latest Jurassic (Erba, 2006 and references therein). The microfauna is also composed by calpionellids (up to the Valanginian - Andreini et al., 2007) and radiolarians.

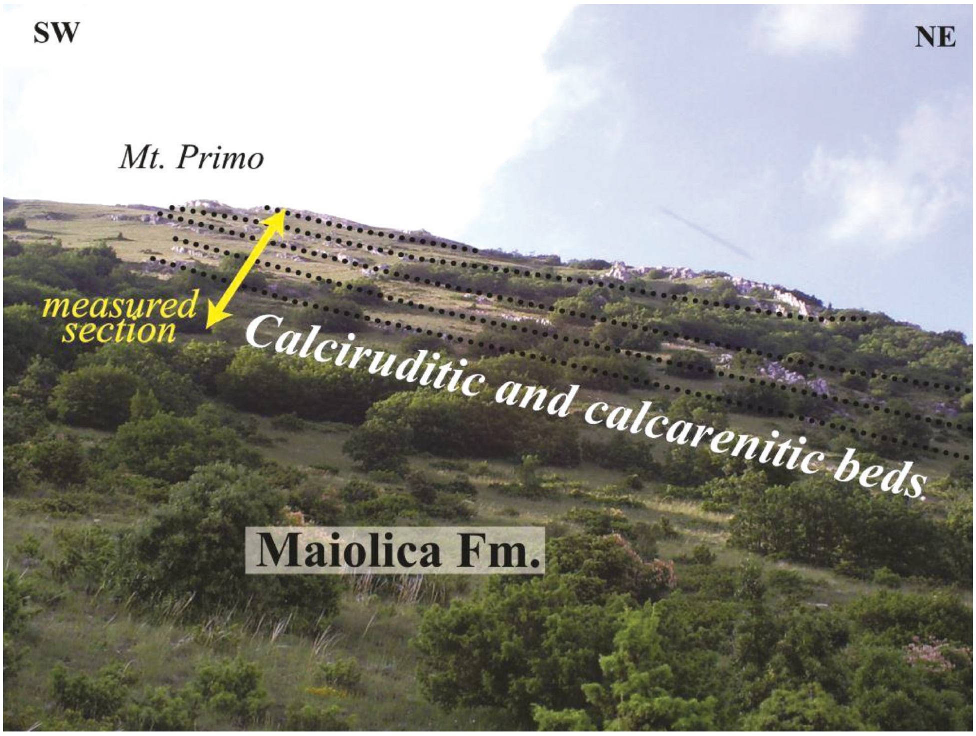


Fig. 4 - Panoramic view of the Mt. Primo section.

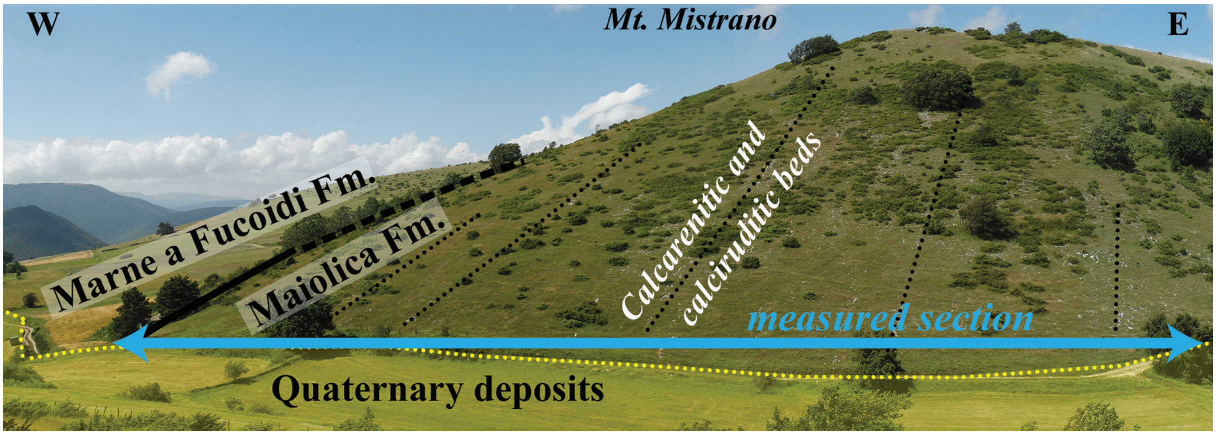

Fig. 5 - Panoramic view of the Mt. Mistrano section.

Differently from this common picture, in the study area the upper part of the Maiolica Fm. (which exceeds 300 m in thickness) bears clastic, polygenic, coarse-grained lensoid beds resulting from submarine sliding, along with graded and laminated beds interpreted as turbidites. The Marne a Fucoidi Fm. (early Aptian *p.p.* - Albian *p.p.*) stratigraphically follows the Maiolica Fm. and is an up to 100 m thick succession of green/grey/purple marls and marly limestones with very rare chert nodules.

In continuity with the upper part of the Maiolica Fm., also the lowermost portion of the Marne a Fucoidi Fm. in the study area contains re-sedimented material, in the form of laminated calcarenites. The paleontological content is represented by abundant planktonic forams (*Planomalina* spp., *Ticinella* spp., *Hedbergella* spp.) and by ichnofossils (*Chondrites* sp. - 'Fucoidi' *Auctt.*). The described units are followed by a thick pelagic and hemipelagic Upper Cretaceous - Neogene succession ("Scaglia Bianca", "Scaglia Rossa", "Scaglia Variegata", "Scaglia Cinerea", "Bisciaro" and "Schlier" formations) and finally by the thick siliciclastic succession of the middle/late Miocene "Marnoso-Arenacea" Fm., representing the turbiditic sedimentation in the foredeep facing the advancing Apennine chain. The final uplift and emersion of this portion of the chain occurred during the Pliocene (Pierantoni et al., 2013).

## 2. MATERIAL AND METHODS

Three stratigraphic sections were measured and sampled. The first section encompasses the upper portion of the Maiolica Fm. (Mt. Primo section - ca. 63 m, Fig. 4); the second section includes the upper portion of the Maiolica Fm. and the base of the Marne a Fucoidi Fm. (Mt. Mistrano section - ca. 74 m, Fig. 5); finally, the third section was measured in the lower part of the Marne a Fucoidi Fm. (Agolla section - ca. 9 m).

The total measured thickness of the three sections is 146 m. A classical litho-biostratigraphic approach was used during the field and laboratory work. Sedimentological observations and facies analyses were firstly made in the field, distinguishing the clastic deposits on the base of the sedimentological structures and recognized granulometric classes (calcilutite, calcarenite and calcirudite). Each of the detrital levels was sampled and analyzed under the optical microscope. About 110 thin sections were produced for microfacies analysis and determination of paleontological content. Four polished slabs were realized to analyze coarser clasts and sedimentological observations. For the microfacies analysis the expanded classification of Embry and Klovan (1971) was used.

Biostratigraphy is based on benthic and planktonic foraminifers. The occurrence of benthic fauna in the coeval (intrabasinal) loose grains, re-sedimented in pelagites, allowed to correlate carbonate platform and basinal settings, following the biostratigraphic schemes proposed for the carbonate platform by Chiocchini et al. (2008, 2012).

## 3. THE LOWER CRETACEOUS "CLASTIC INTERVAL"

The three measured stratigraphic sections (see Fig. 2) are located respectively: i) along the eastern slope of Mt. Primo (Lat.: N 43°9'25,34"; Long.: E 12°59'46"); ii) along the northern slope of the cleft between Mt. Mistrano and Mt. Torroncello (Lat.: N 43°7'44,97"; Long.: E 12°59'13,27"); iii) upside the Agolla village, along the pathway to Mt. Primo (Lat.: N 43°8'53,22"; Long.: E 12°58'36,91").

The base of the first section is not biostratigraphically fixed, but the benthic and planktonic content allowed to constrain the overlying deposits. The detrital events outcropping in the analyzed area have been already mentioned in literature (Centamore et al., 1971; Fabbi, 2015), and are sedimentologically represented by coarse-grained, often chaotic, sometimes graded calcirudites, referred to gravity-driven debris-flows, and coarse-to-fine grained, graded calcarenites, referred to turbidity-flows. From a geometrical point of view, the clastic beds occur as massive- (up to 1 m thick, Fig. 6 a,b) to thin-bedded (less than 0,1 m), embedded in cm-thick pelagic mudstones with chert nodules. Sharp and erosive contacts

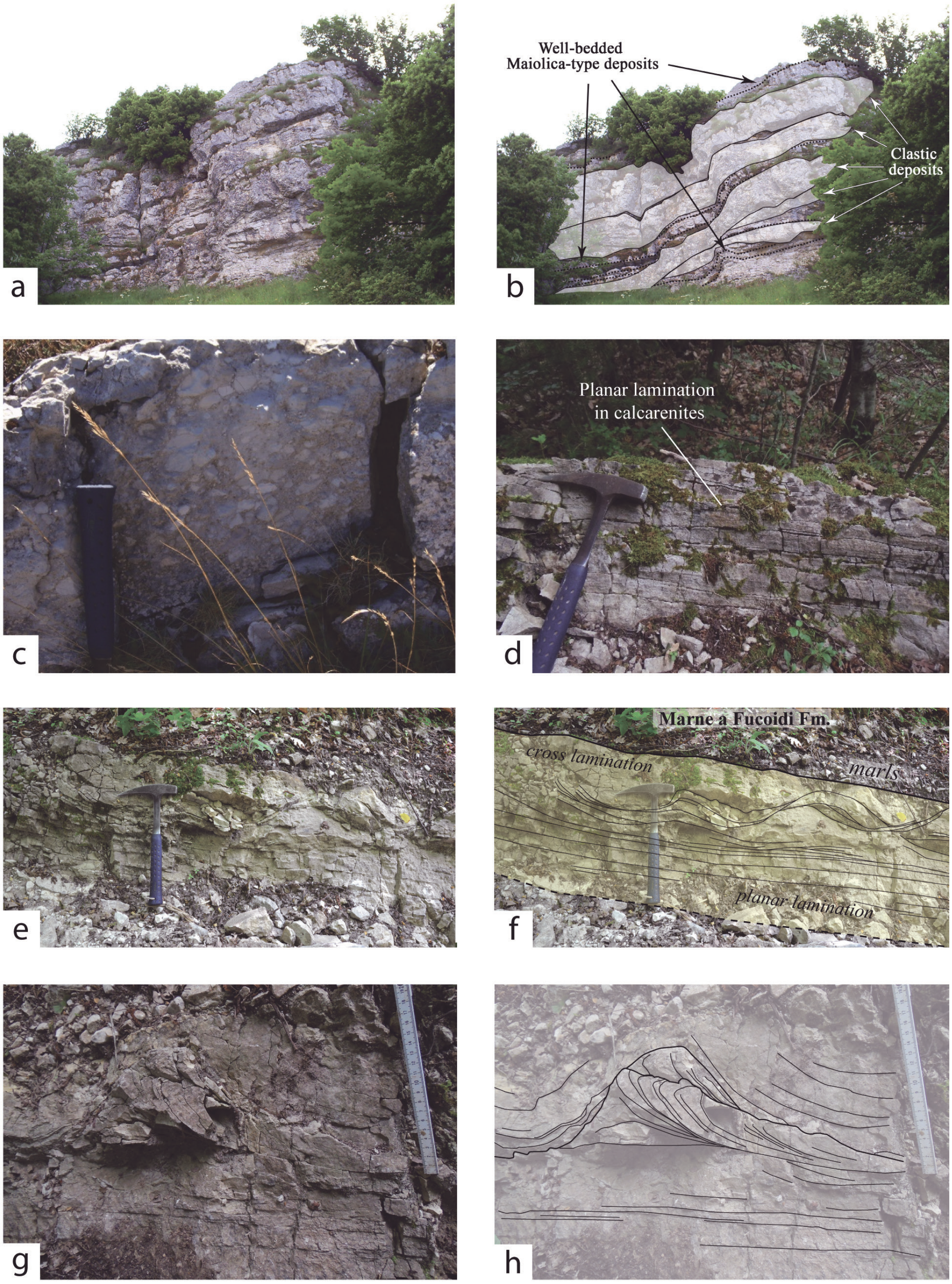


Fig. 6 - a,b) Outcrop views and interpretation of the coarse clastic beds embedded in the Maiolica Fm. (Mt. Primo section); c) floatstone with Maiolica soft pebbles, representing the uppermost sampled level of the Mt. Primo section; d,e,f) planar and cross-laminated calcarenites intercalated to the Marne a Fucoidi Fm. (Agolla section); g,h) particular of cross lamination in calcarenites intercalated in to the Marne a Fucoidi Fm., (note the asymptotic termination of the laminae).

mark the base of the detrital levels, forming both lensoid and tabular beds (Fig. 7). The microfacies of the coarse-grained calcirudites are characterized by bioclastic and lithoclastic rudstones and floatstones.

The grains are poorly sorted, centimeter to millimeter in size, and usually dispersed in mud-supported deposits; less frequently they form grain-supported facies. The calciruditic beds are mainly characterized by heterometric (max some cm in size), angular or sub-rounded, polygenic clasts ascribable both to the local Mesozoic succession and to stratigraphic units not outcropping in the study area. Lower Cretaceous shallow


Fig. 7 - Outcrop view of a lensoid breccia embedded in the Maiolica Fm. (Mt. Primo section).

water carbonates are associated with loose coeval grains and have been sourced from a productive, photozoan-type, carbonate platform (Fig. 8). Lower Jurassic peritidal limestones (Calcare Massiccio Fm.) and Jurassic-Lower Cretaceous pelagites of the UMS succession also occur. In particular, the pelagic carbonates came from both the hangingwall-block ('facies association B' - Santantonio, 1993) and horst-block top successions ('facies association A' - Santantonio, 1993). Cobble/pebble intraclasts of Maiolica-type facies (with and without calpionellids) are associated to extraclasts.

The texture of the graded and laminated calcarenites (Fig. 6d) is a bioclastic grainstone-to-wackestone. Calcarenitic levels are essentially formed by sand-size grains, with the rare occurrence of coarse pebbles/cobbles. The grains are dominated by shallow-water bioclasts and small-size lithoclasts, sometimes associated with planktonic forams.

Although rarely preserved, awesome sedimentary structures, with massive, laminated and cross-bedded intervals, typical of the Bouma sequence (Bouma, 1962), can be observed (Fig. 6 d-h). The scarcity of preserved tractive structures, coupled with the lack of any observable sole marks, prevented a detailed paleocurrent study, and a more precise provenance analysis of the sand-to pebble-size material, based on physical sedimentology.

The background sedimentation facies are the pelagic deposits characterizing the Maiolica and the Marne a Fucoidi Fms., consisting respectively of radiolarian mudstones with rare planktonic forams and planktonic foraminifer/radiolarian-rich marly-lime mudstones.

### 3.1. The Mt. Primo section

The first section (Fig. 9) is essentially a thick (63 m) alternation of clastic levels and "clean" pelagites with chert nodules.

The geometry of the detrital beds varies from tabular (calcarenites) to lensoid (coarser levels). The lowermost clastic level is a graded and laminated calcarenite, mainly composed of loose benthic carbonate grains; coarser sediments, also bearing lithoclasts, occur in the upper levels. The uppermost clastic interval is a floatstone, whose coarser clasts are essentially soft pebbles of Maiolica (Fig. 6c), also with calpionellids, in a matrix composed of pelagic lime-mud bearing sparse benthic loose grains.

Gravity-driven soft deformations and slumps also occur about 57 m above the base of the measured section. The uppermost sampled level of the section represents the physical end of the outcrop. The paleontological content is essentially made of benthic carbonate grains, including dasycladacean algae (*Suppiluliumaella polyreme*), calcareous sponges, benthic forams (*Montseciella arabica*, *Troglotella incrustans, Coscinophragma* aff. *cribrosum*), crinoids, fragments of serpulid tubes, *Lithocodium-Bacinella* crusts, chaetetids, bryozoans (Fig. 8). Common millimeter-to-centimeter size lithoclasts are essentially made of Lower Jurassic and Lower Cretaceous shallow-water carbonates and calpionellid-rich soft pebbles (lower portion of the Maiolica Fm.).

### 3.2. The Mt. Mistrano section

The Mt. Mistrano section (Fig. 10) is a 75 m-thick succession, encompassing the upper part of the Maiolica and the lowermost part of the Marne a Fucoidi Fm. Part of the measured section is covered by vegetation, but most of the clastic levels are very well exposed and clearly recognizable in the field due to differential erosion. Clastic intervals range from graded and laminated calcarenites to massive rudstones and floatstones. The calcarenites are essentially composed of loose benthic carbonate grains, along with mm-size lithoclasts and muddy intraclasts. The faunal assemblages are made of benthic forams, crinoids, calcareous sponges, fragments of bivalves, *Lithocodium-Bacinella* crusts and fragments of dasycladal algae. The rudstones and floatstones present a lensoid bed shape, and are made of both centimetric lithoclasts and bioclasts. Among the largest clasts, Lower

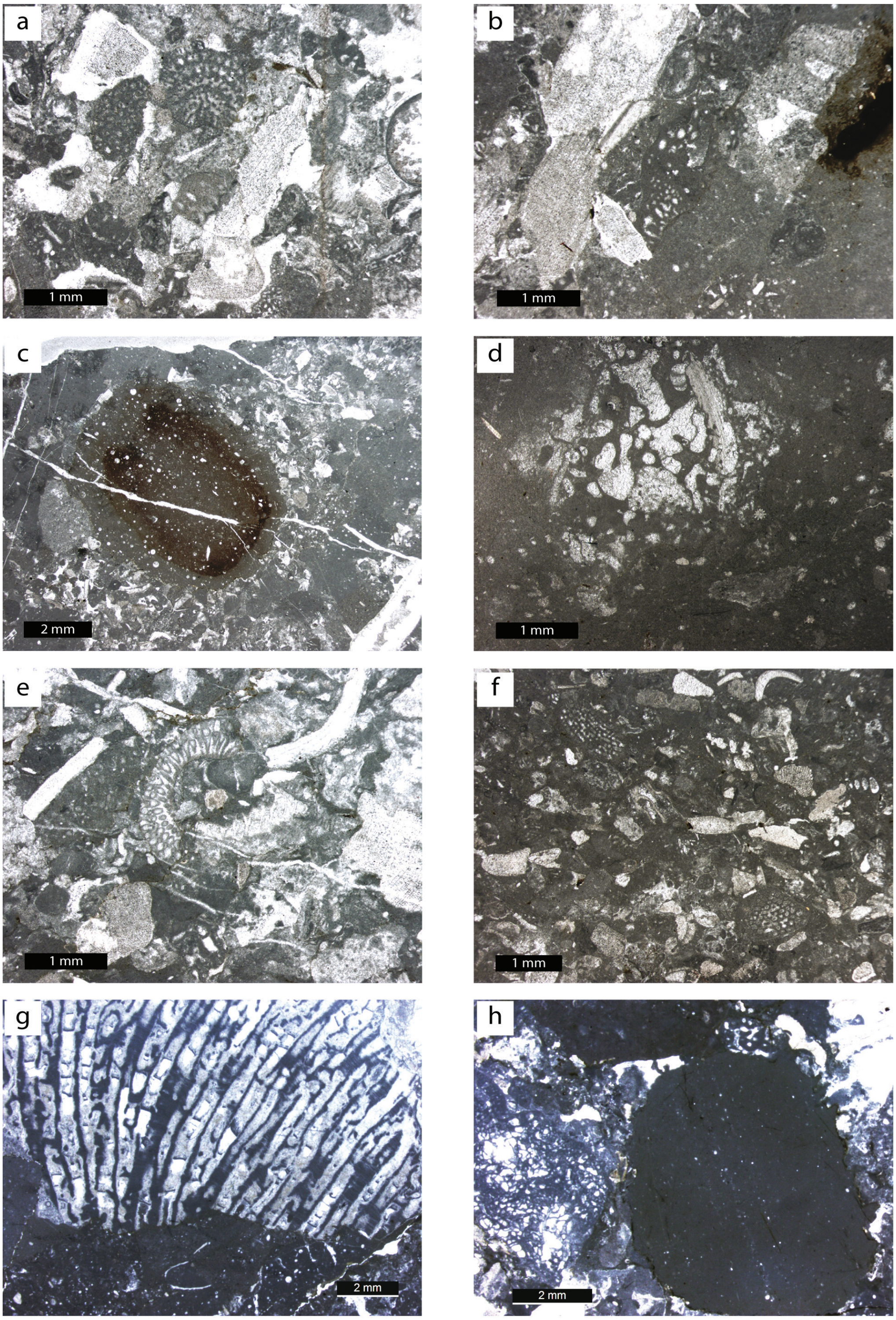


Fig. 8 - Microfacies of the studied deposits: a) bioclastic grainstone rich in echinoderm fragments, angular lithoclasts of microbial carbonates, *Bacinella-Lithocodium* and orbitolinids; b) bioclastic floatstone with millimetre-size fragments of echinoderms and microbial grains dispersed in a radiolarian mudstone; c) rudstone/floatstone with a large intraclast of radiolarian-rich wackestone (Maiolica Fm.), sometimes bounded by stylolithic surfaces, associated with shallow-water elements (fragments of echinoderms and molluscs, peloids, microbial structures, undefinable benthic forams; d) *Lithocodium* sp. and echinoderm fragments floating in a radiolarian mudstone; e) bioclastic grainstone rich in echinoderm and mollusc fragments and dasycladacean algae, associated with lithoclasts of clotted peloidal and microbial structures and intraclasts of radiolarian-rich mudstones; f) biolastic packstone with mollusc fragments, parts of echinoderms, small gastropods, microoncoids, ?briozoans, benthic forams (*Montseciella arabica*); g) floatstone with a chaetetid fragment and undeterminable bioclasts in a typical Maiolica –type mudstone matrix; h) Maiolica soft-pebbles associated with a *Lithocodium/Bacinella* assemblage.

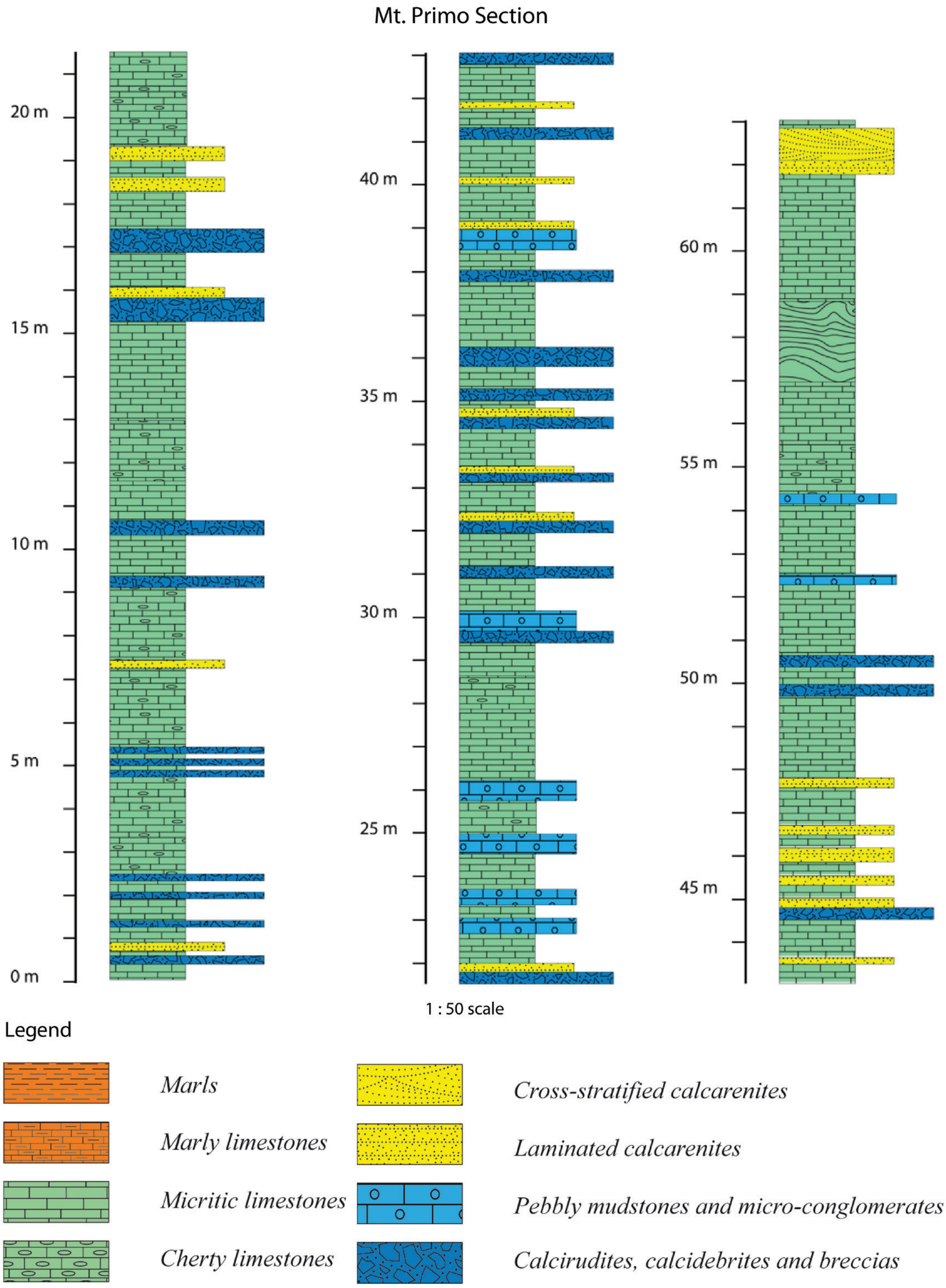


Fig. 9 - The Mt. Primo section stratigraphic log.

Jurassic platform carbonates, Jurassic condensed pelagites and chaetetids (?*Chaetetopsis* sp.) associated with Lower Cretaceous shallow-water limestones (Fig. 11) occur.

**3.3. The Agolla section**

The Agolla section (Fig. 12) is a 9 m-thick stratigraphic section of the lower part (not basal) of the Marne a Fucoidi Fm. It is characterized by the occurrence of several levels of bioclastic calcarenites. The sand-size sediments present typical sharp and erosive contacts, and are sedimentologically organized in planar and cross laminae, sometimes with asymptotic geometries (Fig. 6 g,h). Chert nodules occur in the coarser portion of the calcarenites. The thin lamination is marked by variation in mud/fine sand ratio. Unfortunately, the fine bioclastic debris characterizing the calcarenites is undeterminable.

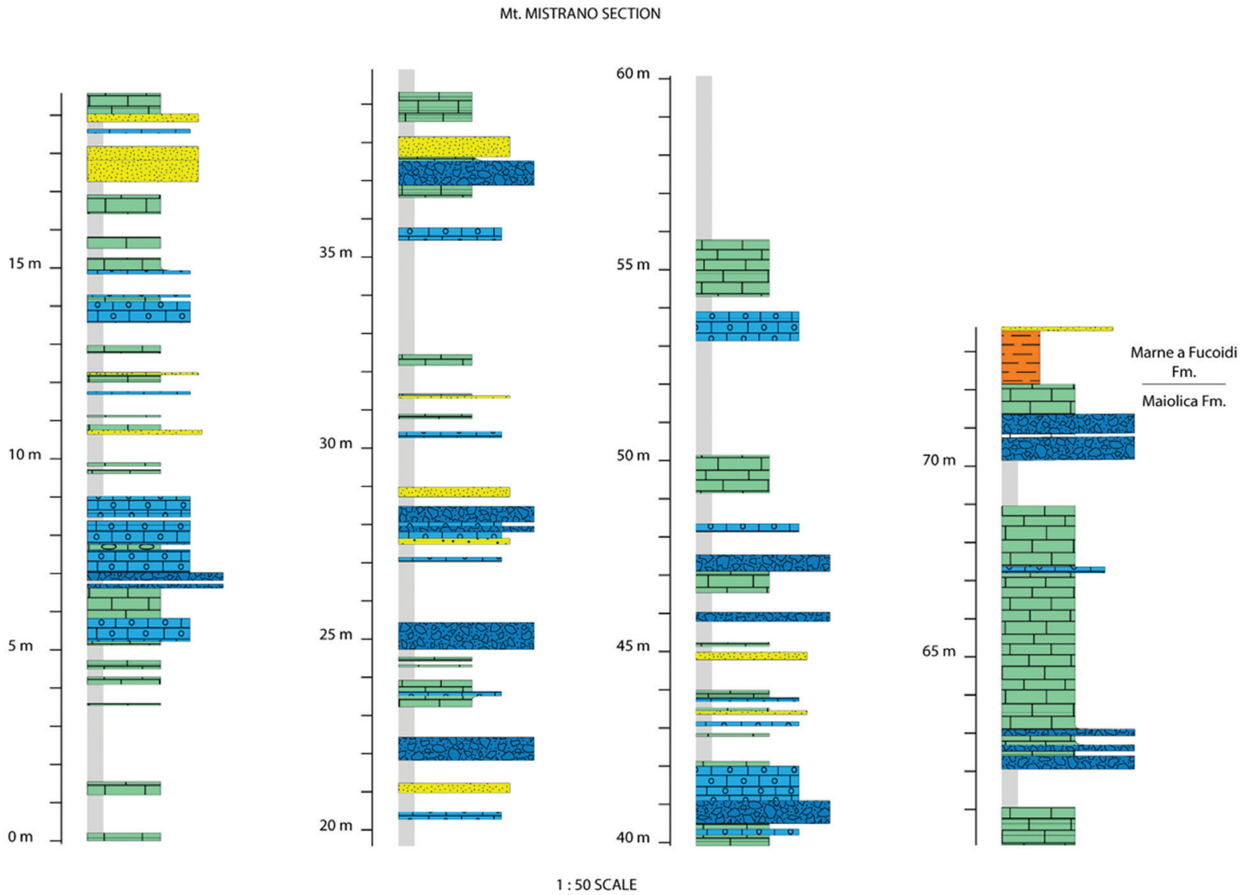


Fig. 10 - The Mt. Mistrano section stratigraphic log. See Fig. 9 for legend.

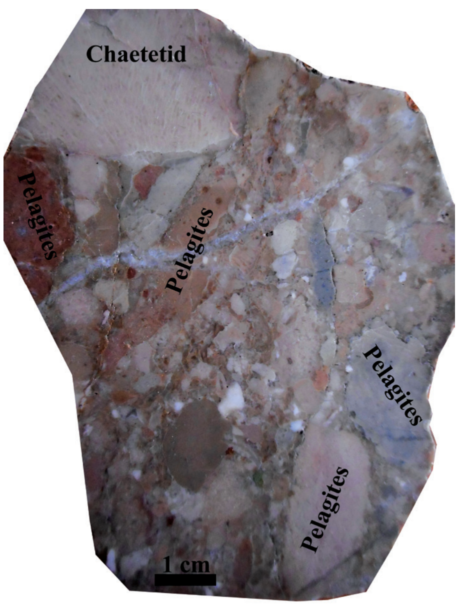


Fig. 11 - Polished slab of a calcirudite whith clasts of condensed pelagites and chaetetids (Mt. Mistrano section).

## 4. DISCUSSION

The studied clastic interval is at a whole >70 m thick, and encompasses part of the Maiolica Fm. and the lower part of the Marne a Fucoidi Fm. The occurrence in the lowermost sampled pelagic levels of *Hedbergella similis*, coupled with the occurrence of *Montseciella arabica* and *Suppiluliumaella polyreme* in the calcarenites, suggest a Barremian-earliest Aptian age for the studied stratigraphic interval. Facies analysis, performed both on field and in thin section, indicates a gravity-driven origin for the clastic levels, interpreted as debris-flows and turbidity-flows (for the bad-sorted calcirudites and the graded calcarenites, respectively). The occurrence of such abundant re-sedimented material in pelagic basins is generally related to tectonic perturbations of the depositional setting or eustatic oscillations, or both (e.g. Reijmer et al., 2015).

The lowest massive lensoid and tabular beds are interbedded with the typical pelagic mudstones of the Maiolica Fm., with a sudden switch from the typical fine-grained pelagic sedimentation to a coarse-grained clastic one. In thin-section, rudstone-to-floatstone microfacies are dominated by bioclasts of benthic foraminifers, dasycladacean algae, microbial crusts, *microproblematica*

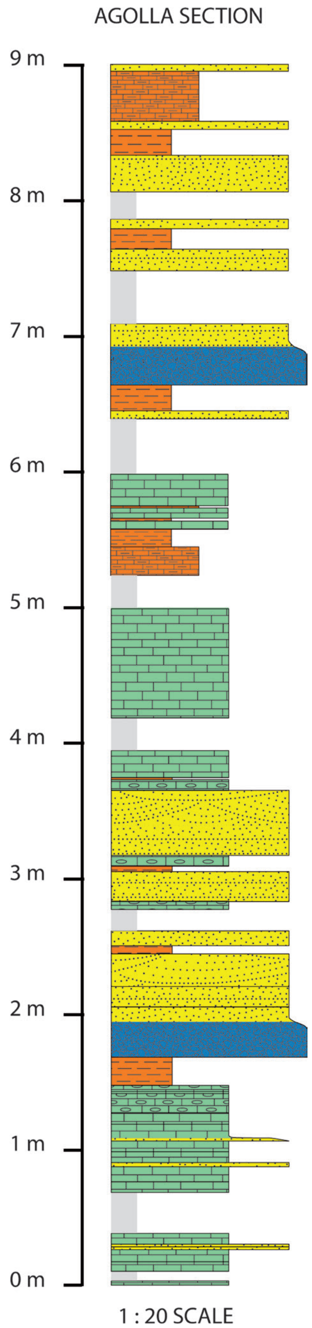


Fig. 12 - The Agolla section stratigraphic log. See figure 9 for legend.

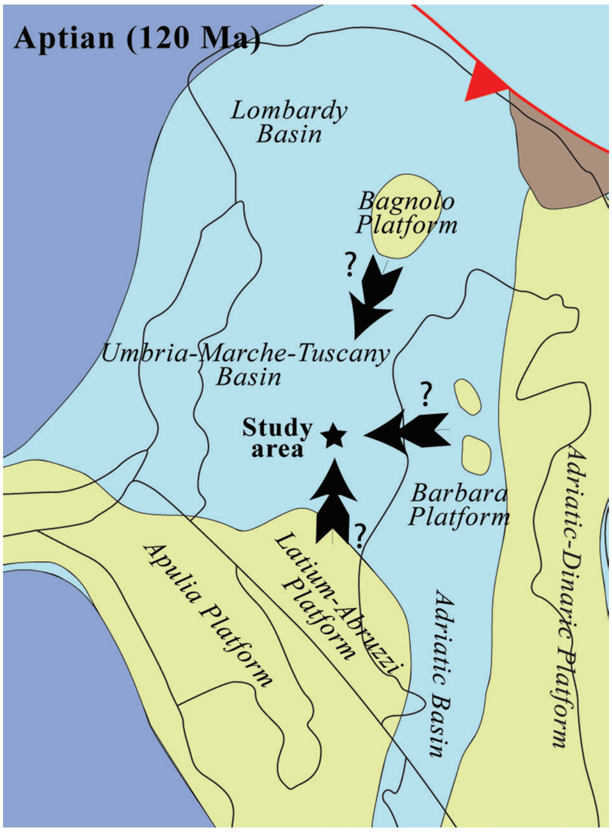


Fig. 13 - Aptian paleogeography and possible source-area(s) of the studied shallow-water benthic material (modified from Turco et al., 2007).

and bivalves indicating a productive photozoan-type carbonate platform(s) as source area(s). Although it is not possible, basing on our data, to determine the certain origin of this material, during the studied time interval the productive carbonate platform likely able to shed the benthic grains in the UMS basin were the Latium-Abruzzi, Barbara, Scorpena and Bagnolo platforms (Fig. 13).

Associated to these loose grains, millimeter-to-centimeter size lithoclasts are made of: i) Lower Jurassic and Lower Cretaceous shallow-water carbonates; ii) Jurassic mudstones and wackestones referable to the pelagic Umbria-Marche succession; iii) calpionellid-rich soft pebbles referable to the

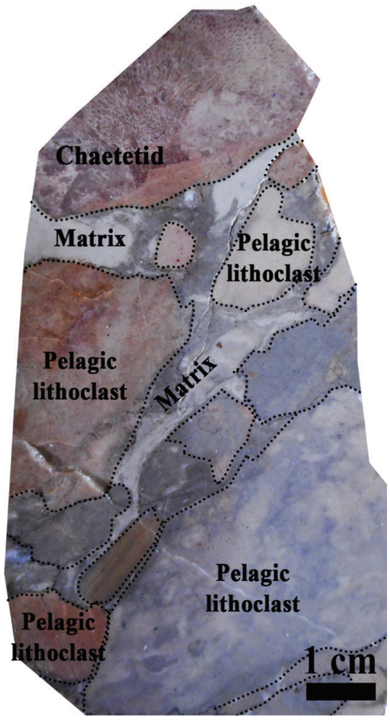


Fig. 14 - Centimetric, rounded to sub-angular clasts of condensed pelagites and of Maiolica-type facies embedded in a radiolarian-rich whitish pelagites (Maiolica Fm.). Polished slab of the clastic deposits sampled in the Mt. Mistrano section.

lower portion of the Maiolica Fm.

While the occurrence of the loose benthic material could be referred to eustatic perturbations, a number of clues suggest a tectonic rather than an eustatic origin for the studied clastic interval. First of all, the mentioned sudden shift from pelagic to clastic sedimentation is consistent with an "episodic" (*sensu* Dott, 1983) event, punctuated in time, and not with eustatic oscillations, which should lead to multiple clastic events repeated in time. Regarding this issue, it is worth saying that a continuous record of turbidites, triggered by sea-level oscillations, is actually described in the Upper Cretaceous/Paleogene pelagic successions of the UMS (Bice et al., 2007). These events, however, show some remarkable differences with those described in the present paper: i) the turbidites in the basin totally lack of any carbonate platform-derived grains; ii) turbidites containing shallow-water material are confined to areas very close to the productive carbonate platforms; remarkably, our study area is characterized by "clean" Upper Cretaceous/Paleogene successions (Bice et al., 2007). Back to the compositional features of the clastic beds object of the present paper, the occurrence of lithoclasts of Cretaceous shallow-water carbonates strongly suggests exhumation and dismantling of a carbonate platform margin, likely triggered by a tectonic backstepping process. Furthermore, also lower Jurassic carbonate platform lithoclasts and condensed pelagites lithoclasts occur within the rudites (Fig. 14), most likely sourced by Jurassic pelagic carbonate platforms (PCPs) located nearby the study area.

Being all the PCPs of the region buried in the earliest Cretaceous (Santantonio, 1993; Fabbi, 2015), there is no possibility to find such material in our studied interval if not after an exhumation produced by extensional tectonics (Cipriani, 2016).

An extensional event causing submarine exposure of the lower portion of the Maiolica Fm. could, furthermore, easily explain the occurrence of calpionellid-rich pebbles (max. lower Valanginian in age - Andreini et al., 2007) re-sedimented in the upper Barremian/lower Aptian portion of the Maiolica Fm.

Our preliminary interpretation is that the Barremian/Aptian clastic interval of Mt. Primo is the result of an extensional phase affecting both a (or more) carbonate platform(s), which sourced the Cretaceous benthic material and lithoclasts, and the UMS domain, which sourced the pelagic Cretaceous intraclasts and the Jurassic lithoclasts. This interpretation well fits with already known and new data coming from different geological settings of Italy (e.g. Farinacci, 1967; Castellarin, 1972; Graziano, 2001; Rusciadelli, 2005; Bertok et al., 2012; Santantonio et al., 2013; Hairabian et al., 2014; Cipriani, 2016; Menichetti, 2016), strongly suggesting the occurrence of a widespread extensional phase in the late Early Cretaceous.

## 5. CONCLUSIONS

The stratigraphic sections analyzed in the Mt. Primo Range (UMS domain), pertaining to part of the Maiolica Fm. and to the lower portion of Marne a Fucoidi Fm., are particularly interesting for their sedimentological characters, strongly different from those otherwise considered canonic. The most interesting character of the stratigraphic sections is the sudden occurrence of coarse-grained detrital bodies embedded in pelagic mudstones and the association of lithoclasts, sourced from both shallow-water carbonate platform(s) and Jurassic intrabasinal structural high(s). All these evidences, whose age is constrained to the Barremian-early Aptian on the basis of the micropaleontological content, are reliable clues further reinforcing the interpretation of a regional late Early Cretaceous extensional tectonic event.

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