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Marine fossils in the Late Carboniferous metasediments of the Pisani Mountains (Tuscany, Italy)

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ABSTRACT

Marine fossils (?brachiopods, bivalves, bryozoans, crinoids) were first found in the lower part of the Late Carboniferous-Early Permian San Lorenzo Schists Formation that crops out in the Valle del Guappero type-area (Pisani Mountains, Tuscany). These sediments have so far provided only continental fossils (mainly paleofloras). The new findings modify the current reconstructions of the Late Carboniferous paleogeography and paleoenvironment in the Northern Apennines area.

Key words: *Northern Apennines, Tuscan Metamorphic Units, Late Carboniferous, stratigraphy, marine fossils.*

RIASSUNTO

Fossili marini nei metasidementi del Carbonifero Superiore dei Monti Pisani (Toscana, Italia).

Alcuni fossili marini (brachiopodi?, briozoi, crinoidi) sono stati rinvenuti nella parte inferiore della Formazione degli Scisti di San Lorenzo, di età Carbonifero Superiore-Permiano Inferiore, i cui affioramenti principali si trovano nell'area della Valle del Guappero (Monti Pisani, Toscana). Questi sedimenti hanno fino ad ora restituito associazioni fossilifere continentali (essenzialmente paleoflore). Tali ritrovamenti fossili porterebbero a modificare le ricostruzioni paleogeografiche e paleoambientali del tardo Carbonifero dell'Appennino Settentrionale.

Termini chiave: *Appennino settentrionale, Unità Toscane Metamorfiche, Carbonifero Superiore, stratigrafia, fossili marini.*

INTRODUCTION

The San Lorenzo Schists Formation of the Pisani Mountains (Northern Apennines, figs. 1, 2) are a Late Carboniferous-Early Permian unit, which yielded abundant plant remains and rare limnic bivalves, insects and crustaceans (Rau & Tongiorgi, 1974; Pandeli *et alii*, 1994; Landi Degl'Innocenti *et alii*, this volume and references therein). The unit has been related to a fluvial-lacustrine environment which developed in a humid intertropical or equatorial climate (Rau & Tongiorgi, 1974, 1976).

During recent geological surveys in the Valle del Guappero type-area, we identified a new fossiliferous site near Montuolo (SW of San Lorenzo a Vaccoli, location in fig. 3) with marine paleofaunas in the lower part of the San Lorenzo Schists. The results of the preliminary study of these fossils are discussed herein, together with their implications for both the paleoegeographical and paleoenvironmental reconstructions of the Tuscan area during Late Carboniferous times.

GEOGRAPHICAL AND GEOLOGICAL SETTING OF THE PISANI MOUNTAINS

The studied area is located in the Pisani Mountains which belong to the so-called Middle-Tuscan Ridge, a regional morpho-structural high, extending NNW-SSE, from the Apuane Alps to the Leoni Mountain (fig. 1). The Pisani Mountains represent a relatively wide tectonic window of the deepest Tuscan Metamorphic Units buried below the non-metamorphic Tuscan Nappe and the sub-Ligurian and Ligurian Units (fig. 2). This inlier is bounded by mainly NW to SE- and NE to SW-trending high angle normal faults systems linked to the Neogene-Quaternary extensional tectonics (see for more details: Rau & Tongiorgi, 1974; Pandeli *et alii*, 2004 and references therein). The core of the Pisani Mountains inlier comprises two epimetamorphic units: the Monte Serra Unit and the overlying Santa Maria del Giudice Unit (fig. 2) (Rau & Tongiorgi, 1974). Both units include siliciclastic Paleozoic formations which are unconformably overlain by the Tuscan, passive margin-type sedimentary sequence that ranges from the syn-rift, siliciclastic successions of the Middle/Upper Triassic Verrucano Group to Mesozoic pelagic carbonates and cherts in the Monte Serra Unit (Rau & Tongiorgi, 1974; Tongiorgi *et alii*, 1977). The younger stratigraphic units of this sequence are preserved only in the upper part of the Santa Maria del Giudice Unit and consist of Late Cretaceous to Tertiary pelagic shales, carbonates, and Late Oligocene foredeep siliciclastics (Pseudomacigno). All these successions were affected by polyphased tectono-metamorphism, essentially in the greenschist facies, with peak conditions of T = 400 °C and P = 0.8-0.9 GPa (Franceschelli *et alii*, 1986, 2004; Conti *et alii*, 1991; Carosi *et alii*, 1993, 1995), during the Apenninic tectogenesis which occurred in the 27 to 10 Ma time interval (radiometric ages from the Apuane Alps core: Kligfield *et alii*, 1986).

The reconstructed stratigraphic column of the Paleozoic to Norian units of the Pisani Mountains (Rau & Tongiorgi, 1974) is shown in fig. 4. Three formations, sepa-

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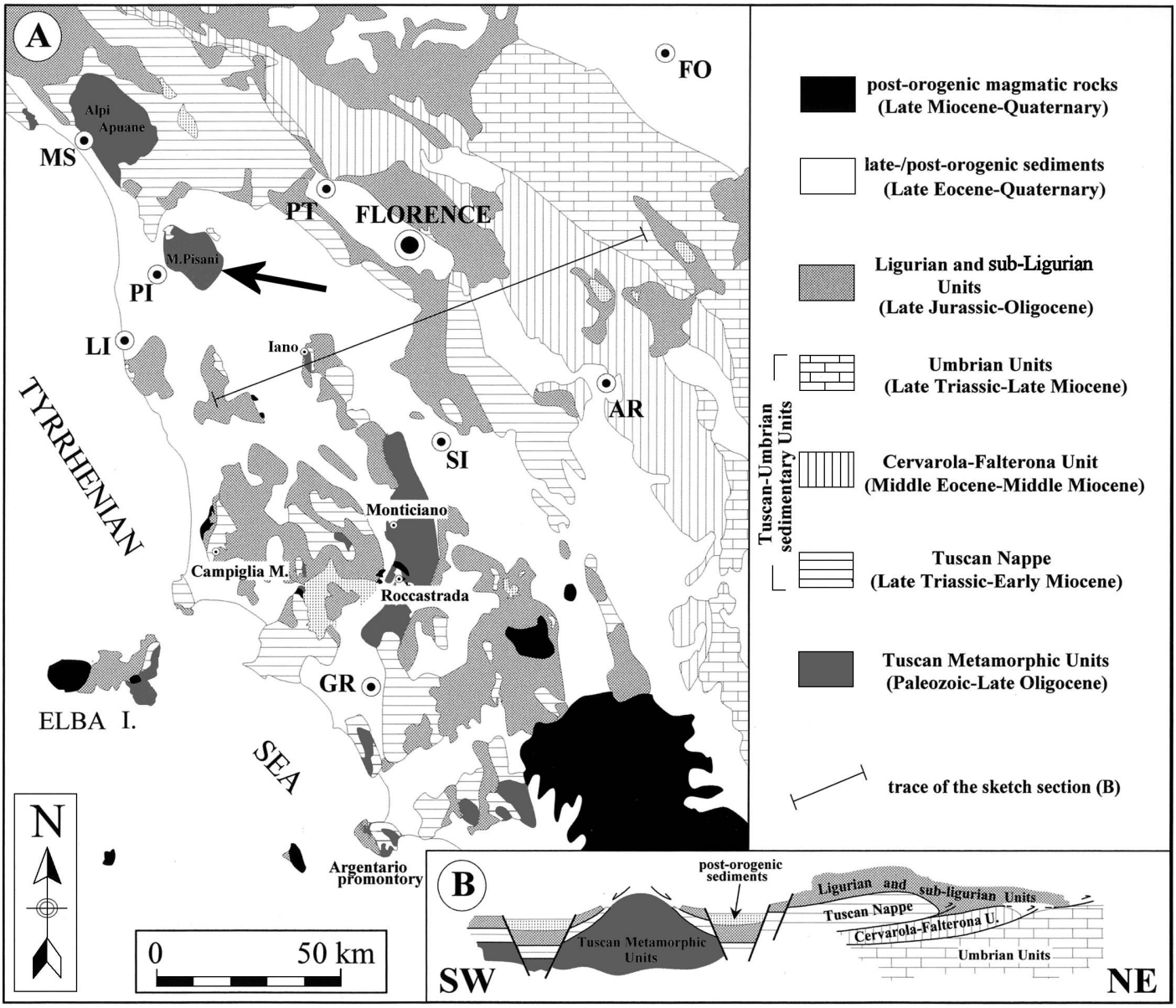

Fig. 1 - Geological sketch map (A) and cross-section (B) of the Northern Apennines. Arrow indicates the location of the Pisani Mountains. – *Carta (A) e sezione (B) geologica schematica dell'Appennino Settentrionale. La freccia indica l'ubicazione dei Monti Pisani.*

rated by unconformity surfaces, can be distinguished in the Paleozoic section (for details see RAU & TONGIORGI, 1974; PANDELI *et alii*, 1994, 2004):

1) The Buti Banded Quartzites and Phyllites (?Late Ordovician), 2) The San Lorenzo Schists (?Westphalian D/Stephanian-Autunian), 3) The Asciano Breccias and Conglomerates (?middle/?Late Permian).

All the above mentioned units are unconformably overlain by the Triassic syn-rift Verrucano sediments (i.e. the fluvial Verruca Fm. and the overlying neritic-deltaic Serra Mt. Quartzites: RAU & TONGIORGI, 1974; TONGIORGI *et alii*, 1977).

THE SAN LORENZO SCHISTS

These Late Paleozoic, often graphite-rich metasediments, typically outcrop in the Valle del Guappero area (figs. 2, 3), where the first fossiliferous findings and stratigraphical studies date back to the 19th century (see De Stefani collection in LANDI DEGL'INNOCENTI *et alii*, this volume). The main fossiliferous sites of the San Lorenzo Schists in the Valle del Guappero area are Valentona, Monte Togi, Traina, Monte Vignale and Sasso Campanaro, on the eastern side of the Valle del Guappero, Villa Massagli and Montuolo (the latter is a new fossiliferous site) on its western side (fig. 3). In these localities abundant plants (mainly ferns: DE STEFANI, 1901), limnic bivalves (*Anthracosia*: CANAVARI, 1891; RAU & TONGIORGI, 1974), insects (Blattinariae: CANAVARI, 1892) and crustaceans (Estherie: RAU & TONGIORGI, 1974) were found.

Following RAU & TONGIORGI (1974), we distinguish two main lithofacies within the San Lorenzo Schists (base to top):

a) A mainly pelitic and pelitic-arenaceous lithofacies, which crops out in the Villa Massagli-Montuolo and Monte

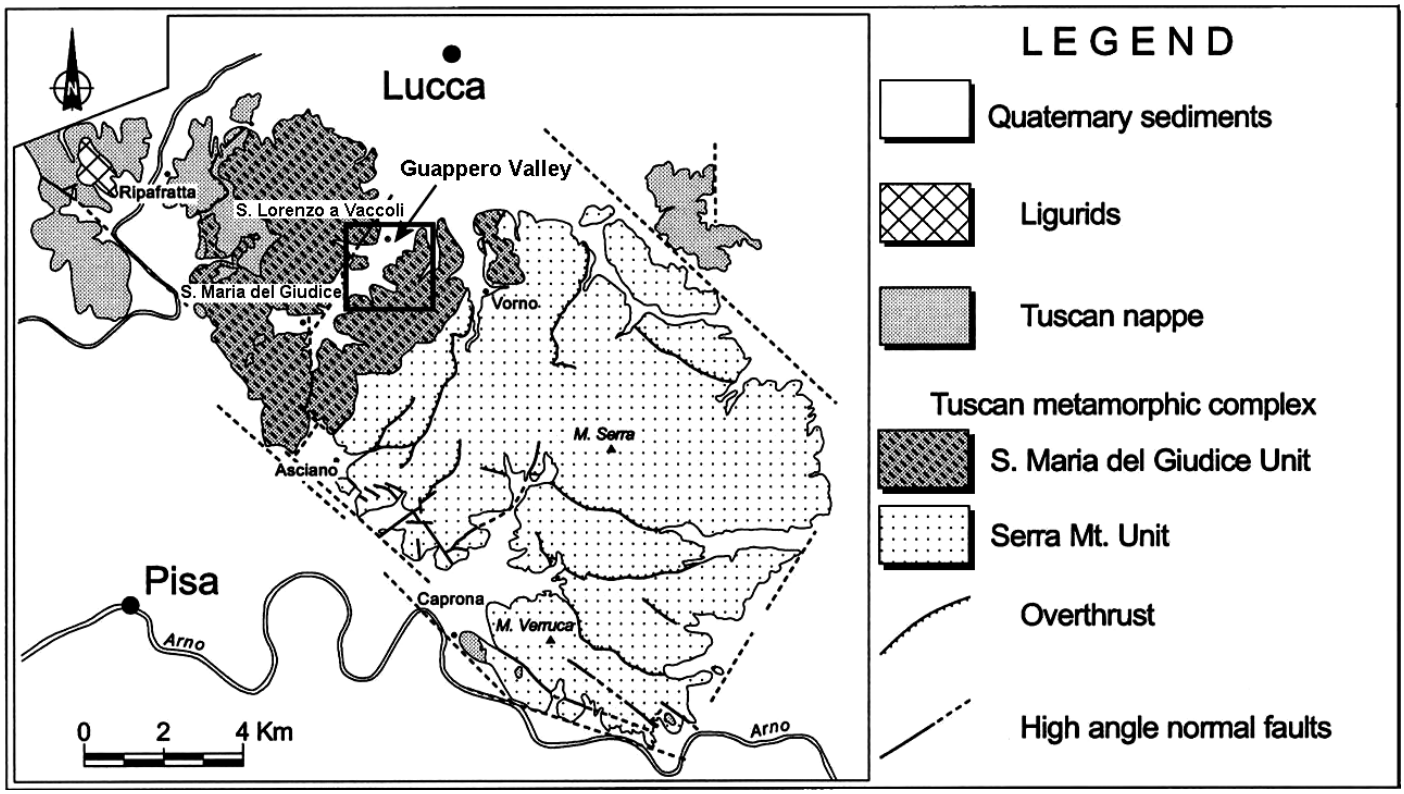

Fig. 2 - Structural sketch of the Pisani Mountains (redrawn from RAU & TONGIORGI, 1974; TONGIORGI *et alii*, 1977) and location of the studied area (squared area), in the Valle del Guappero.
– *Schema strutturale dei Monti Pisani (modificato da RAU & TONGIORGI, 1974; TONGIORGI* et alii, *1977) e ubicazione dell'area studiata, la Valle del Guappero (area riquadrata).*

Togi-Traina-Valentona areas and consists of dominant grey to black, graphite rich phyllites and metasiltstones with local intercalations of grey metasandstones. Coarse-grained metasandstone beds are rare. Its thickness is more than 100 m.

b) A mainly arenaceous-pelitic lithofacies, cropping out in the Sasso Campanaro-Via Pari area and consisting of decimetres- to meters-thick bedded, coarse- to fine-grained metasandstones, locally characterized by cross-bedding and graphite-rich metapelitic intercalations, with some coal concentrations. Withish-grey, quartz pebble metaconglomerate beds, often with erosional bases, also occur. These lithotypes are generally organized in metric fining- and thinning-upward cycles which can be referred to the filling of small fluvial channels. Its minimum thickness is about 150 m.

During the field investigations of the Paleozoic succession of the Valle del Guappero area, new fossiliferous sites were found in the Montuolo area which is located south-west of San Lorenzo a Vaccoli and at the foot of Monte Moriglion di Penna (fig. 3), yielding previously undescribed fossiliferous associations of marine faunas. On the basis of reconstructed stratigraphic and structural setting of the Valle del Guappero area, the Montuolo outcrop can be likely positioned in the lower part of the San Lorenzo Schists.

MARINE FAUNAS OF THE SAN LORENZO SCHISTS

Two fossiliferous sites, respectively named locality A and locality B, were discovered in the Montuolo outcrop (fig. 3). The collected fossils are hosted at the Natural History Museum of Florence (Geology and Paleontology Section); the specimens are below indicated by IGF numbers (= acronym of Istituto Geologico Fiorentino). Grey phyllites with ochre alterations of the locality A yielded three different taxa (see next paragraph) (numbers: IGF14131E and IGF14134E), while dark-grey metasiltstones of the locality B provided other fossils (numbers: IGF14129E, IGF14130E, IGF14132E and IGF14133E).

DESCRIPTION

The outer surface of a shell is visible in a metasiltstone sample from locality B («problematica 1»: pl. 1, fig. 1, IGF14132E). The outer outline of the fragment is not visible, nor there is evidence of an hinge. The surface is finely costellate with secondary custation which are visible in its marginal side; costae are slightly curved. This character is shared with: *a*) articulated brachiopods of Orthotetoidea, a superfamily that experienced an evolutionary radiation during the upper Paleozoic and that went extinct at the end of the Permian; *b*) posterior areas of rostroconchs of superfamily Conocardiacea, similarly present in Carboniferous and Permian marine environments. An isolated crinoid columnal (pl. 1, fig. 3, IGF14133E) was found in the same sample. The crenularium is characterized by more than 40 radii and by an areola diameter that is about one third of the whole facet.

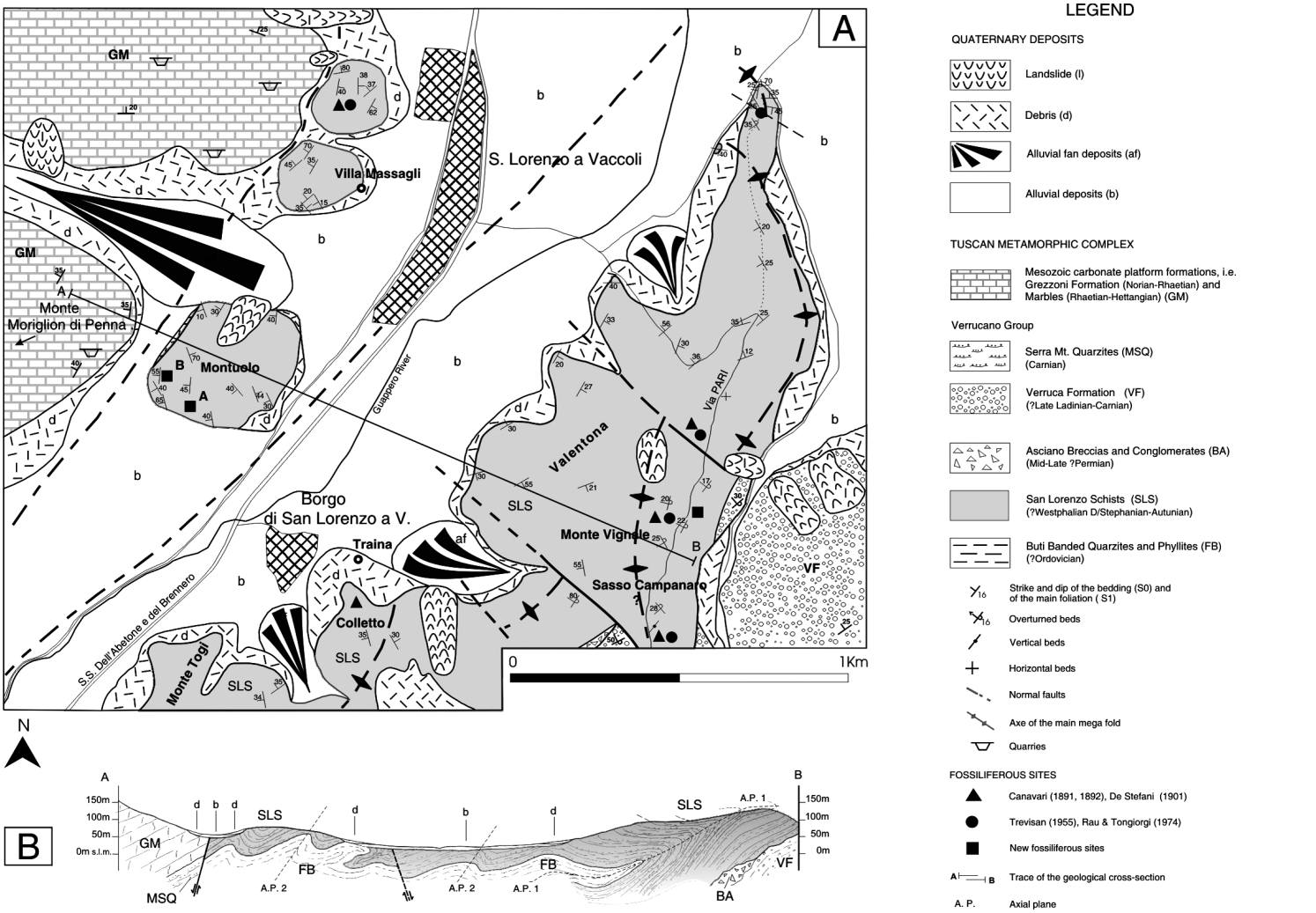

Fig. 3 - Geological map (A) of the San Lorenzo a Vaccoli area, in the Valle del Guappero and geological cross section (B).
– Carta (A) e sezione (B) geologica dell'area di S. Lorenzo a Vaccoli nella Valle del Guappero.

About 30 disarticulated crinoid internodal columnals and fragments are present on another metasiltstone sample from locality B (pl. 1, fig. 6, IGF14129E). Articular facets have a crenularium with 30-34 radii and the diameter of the areola is slightly larger than half of the facet whole diameter, furthermore they show disarticulation and random orientation.

Moreover bivalves were recovered in the metasiltstones of the locality B (pl. 1, fig. 4, IGF14130E). The fossil can be interpreted as the inner cast of a right valve, and has a suboval outline suggestive of the order Veneroidea, but the cardinal area is not visible and the problem cannot be definitely solved.

A second problematic fossil, coming from the phyllites of the locality A, shows curved sub-parallel structures also reminiscing costae, but lacking evidence of bifurcating patterns, is here assigned to a second species («problematica 2», pl. 1, fig. 2, IGF14131E). This same phyllitic sample, containinig «problematica 2», also gave a specimen of an almost intact colony of a fan-shaped fenestellid bryzoa, belonging to the Class Stenolaemata (pl. 1, fig. 5, IGF14134E). However, the internal structure of the branches (a morphological character that is distinctive for a reliable identification at the family- and genus-level) is not visible. Crinoid columnals are also present in the IGF14134E sample.

DISCUSSION AND CONCLUSIONS

The Montuolo fossil association lacks distinct freshwater or brackish water forms. Moreover, if we consider the distribution of extant relatives of the studied Upper Paleozoic species (if any), a marine environment with normal salinities can be inferred. In fact, crinoids as a whole are diagnostic of marine waters (BREIMER & LANE, 1978). All modern articulated brachiopods are of open-marine environment, with a preference for hard substrata from very shallow waters to bathyal depths (RICHARDSON, 2000; LOGAN *et alii*, 2004), like all the upper Paleozoic forms. If the «problematica» belong to the rostroconchs, the conclusion does not differ. Finally, fenestrate bryozoans of the Class Stanolaemata are forms particularly well-diversified in shallow marine environments of the Late Paleozoic (e.g. SNYDER, 2006). The only possible form that may have been tolerant of changing salinities is the bivalve. However, the uncertainty on its taxonomy prevents from any inference based on this fossil.

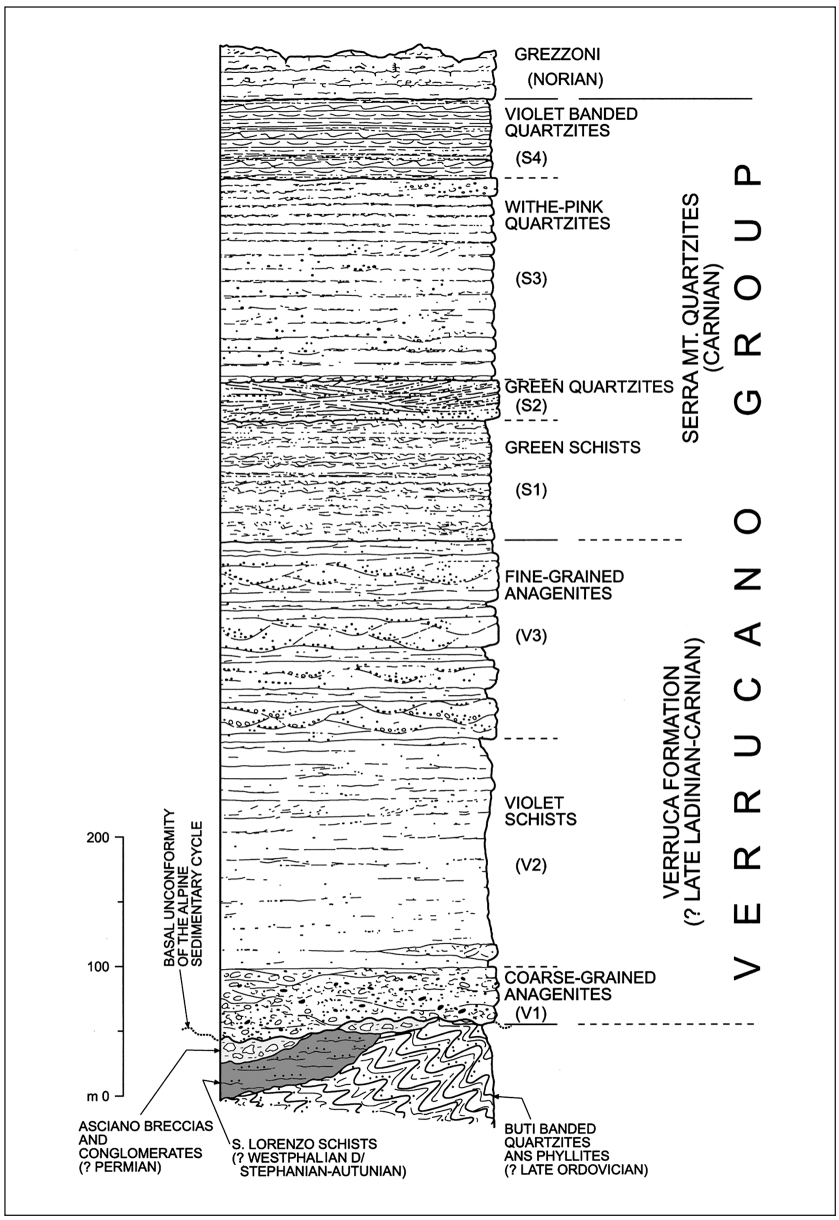

Fig. 4 - Stratigraphic column of the Paleozoic-Carnian succession of the Pisani Mountains (redrawn from RAU & TONGIORGI, 1974).
– Colonna stratigrafica della successione Paleozoico-Carnica dei Monti Pisani (da RAU & TONGIORGI, 1974, modificato).

Taking into account the presence of continental fossils in the lowermost (Villa Massagli site), the middle (Valentona-Monte Togi-Traina/Colletto outcrops), and the upper part (Monte Vignale-Via Pari and Sasso Campanaro) of the San Lorenzo Schists (see RAU & TONGIORGI, 1974; LANDI DEGL'INNOCENTI *et alii*, this volume), the finding of crinoids and bryozoa in the Montuolo outcrop is an evidence of a marine transgressive event in the lower part of the formation. The presence of two distinct main lithologies with different, albeit poor and poorly preserved, fossil associations in the two fossiliferous sites of the Montuolo outcrops, provides further and more detailed information about the depositional environment during this transgressive episode. The metasiltstone facies with disarticulated and randomly-oriented fossils is indicative of higher-energy conditions with respect to the energy level testified by the phyllite with fenestellid bryozoa, a delicate form whose state of preservation indicates a low-energy setting. Both facies could be as a whole diagnostic of the distal part of a deltaic setting, receiving relatively coarser terrigenous inputs and shelly material during storms and major river floods, whereas fine-grained sediments were deposited during normal conditions or in more distal, offshore environments.

Finally, the findings of Montuolo indicate strong paleoenvironmental analogies between this part of the San Lorenzo Schists and the coeval, coastal-neritic Iano Schists and Sandstones cropping out near Volterra (COSTANTINI *et alii*, 1998) and the Rio Marina Formation in the Elba Island (PANDELI *et alii*, 1994; BORTOLOTTI *et alii*, 2001 and references therein) both including marine fossils similar to those of the Montuolo site (e.g. *Fenestrella* cfr. *F. veneris* in SACCO, 1913; DE STEFANI, 1914).

Thus, the depositional environment of the lower part of the San Lorenzo Schists can be related to a transitional environment, ranging from a wide coastal plain environment to a neritic setting. On the contrary, the middle-upper part of this formation, only characterized by continental fossils, shows evidences of regressive conditions, probably as a consequence of the increase of the silici-

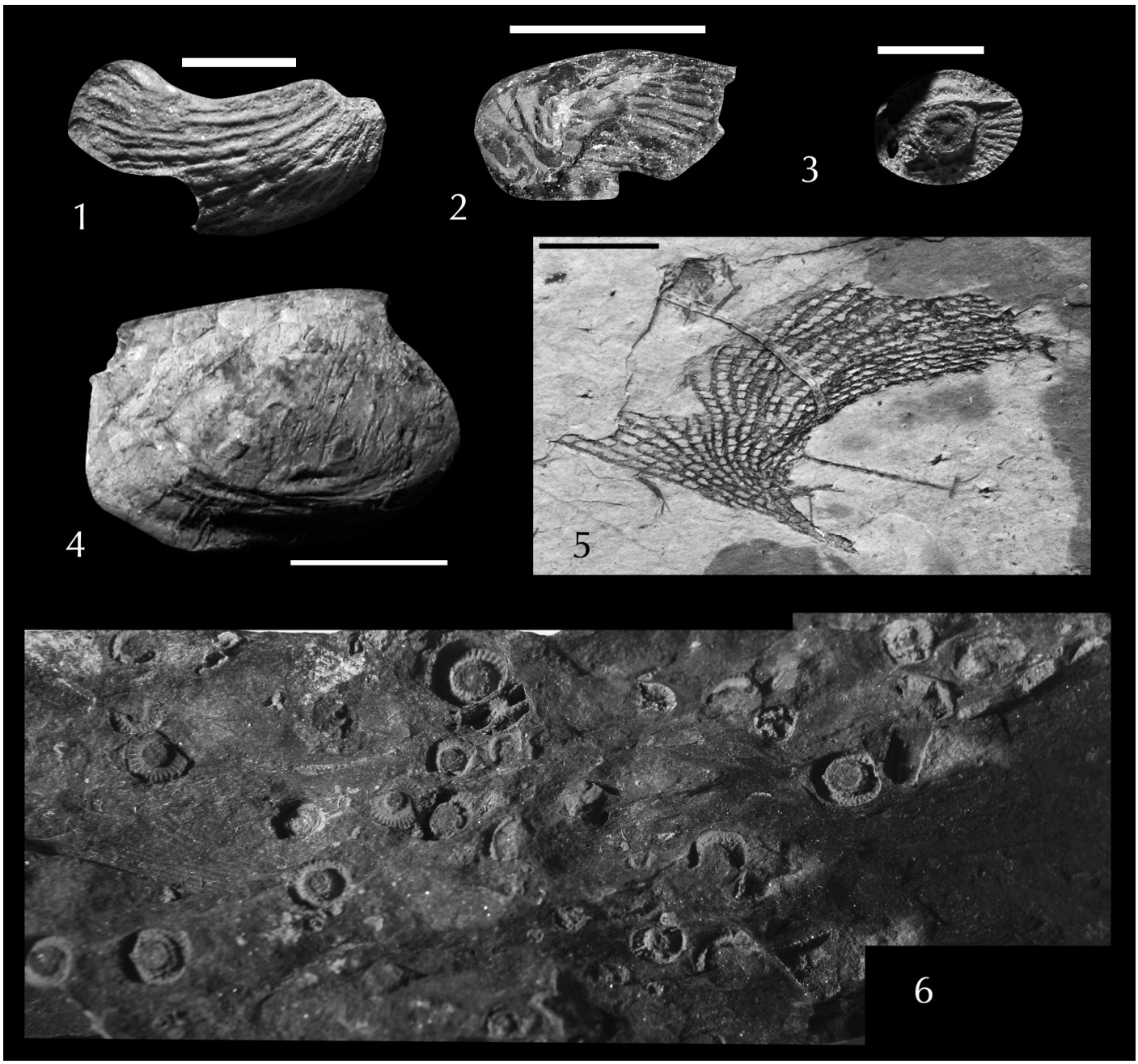

Plate 1 - Fig. 1 - «problematica 1», (pedicle?) valve, IGF14132E (scalebar 0.5 cm); Fig. 2 - «problematica 2», (pedicle?) valve. IGF14131E (scalebar 1.0 cm); Fig. 3 - Crinoid isolated columnal IGF14133E (scalebar 0.5 cm); Fig. 4 - Undetermined bivalve, right valve IGF14130E (scalebar 1.0 cm); Fig. 5 - Fenestrate bryozoa, IGF14134E (scalebar 1.0 cm); Fig. 6 - Metasiltite slab with disarticulated columnals and fragments of crinoids IGF14129E (largest dimension 18.5 cm).
– Fig. 1 - «problematica 1», valva (peduncolare?), IGF14132E (unità di misura 0.5 cm); Fig. 2 - «problematica 2», valva (peduncolare?). IGF14131E (unità di misura 1.0 cm); Fig. 3 - Articoli isolati di crinoide IGF14133E (unità di misura 0.5 cm); Fig. 4 - Bivalve indeterminato, valva destra IGF14130E (unità di misura 1.0 cm); Fig. 5 - Briozoo finestrato, IGF14134E (unità di misura 1.0 cm); Fig. 6 - Campione di metasiltite con articoli e frammenti di crinoidi IGF14129E (dimensione massima 18.5 cm).

clastic input connected to the onset of of the Variscan landscape rejuvenation due to the Saalian extensional event (Rau & Tongiorgi, 1974, 1976; Pandeli *et alii*, 1994; Pandeli, 2002 and references therein).

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