

Use of ichnology in basin environment reconstruction: an example from the Lower Permian Pietra Simona Mb. (Southern Alps, Italy)

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SUMMARY - *Use of ichnology in basin environment reconstruction: an example from the Lower Permian Pietra Simona Mb. (Southern Alps, Italy)* - In the light of a more complete lithostratigraphic revision, the Lower Permian Pietra Simona Member (PS) a Member of the Dosso dei Galli Conglomerate (DGC) is described in detail with the aim to emphasize the significance of trace fossil analysis and the use of ichnology in the delineation of specific facies and environments. In its type-area (central Southern Alps sector), this unit occurs in the lower-middle part of the DGC in Val Dasdana (Collio Basin) and in the upper portion of the same formation in lower Val Camonica (Boario Basin). This last location hosts the PS type-section: it consists of about 280 metre-thick succession of prevailing dark wine-red fine sandstones-to-siltstones. Volcaniclastic fine-to-medium-grained deposits are frequently interspaced throughout the reference sections and two metre-thick crystalline tuff episodes occur at their top. The Pietra Simona is characterized by peculiar and pervasive burrowings which are here assigned to *Paleophycus tubularis* and *Planolites montanus*: the former characterizes the Val Camonica section and the latter the Val Dasdana outcrops. These two differing invertebrate ichnospecies can be related to the *Mermia* and the *Scoyenia* ichnofacies, characterizing benthic activity in low-energy continental environments. Their occurrence, coupled with facies-analysis of the investigated sections, lead us to propose a more precise environmental reconstruction and depositional setting of the discussed Permian unit.

RIASSUNTO - *L'uso dell'icnologia nella ricostruzione paleoambientale di un bacino: un esempio dal Membro della Pietra Simona, Permiano inferiore (Alpi Meridionali, Italia)* - Nel quadro di una più ampia revisione litostratigrafica, il presente lavoro ha lo scopo di rivedere in dettaglio il contenuto icnologico della Pietra Simona (PS), Membro del Conglomerato del Dosso dei Galli (CDG), e mettere in luce il contributo che le tracce fossili possono dare nella ricostruzione di facies e paleoambienti. Nell'area tipo (Sudalpino centrale), l'unità viene rinvenuta nella porzione medio-inferiore del CDG in Val Dasdana (Bacino di Collio) e nella parte superiore della stessa formazione nella Val Camonica meridionale (Bacino di Boario). In quest'ultima località fu descritta la sezione-tipo, rappresentata da una successione potente circa 280 m di prevalenti arenarie medio-fini e siltiti di colore rosso vinato scuro. Depositi vulcanoclastici medio-fini appaiono frequentemente intercalati nell'unità e due livelli metrici di tufi cristallini sono presenti alla sua sommità. La Pietra Simona è da sempre nota per le sue tipiche e pervasive bioturbazioni ("budellature" *Auctt.*), che vengono qui attribuite a *Paleophycus tubularis* e *Planolites montanus*: la prima caratterizza la successione della Val Camonica, mentre la seconda è tipica della Val Dasdana. Queste due icnospecie ricadrebbero nelle icnofacies *Mermia* e *Scoyenia*, caratteristiche di ambienti continentali a bassa energia. Tale attribuzione, insieme all'analisi di facies nelle sezioni investigate, ha consentito di approfondire le conoscenze sugli ambienti deposizionali di questa unità permiana.

Key words: Southern Alps, ichnofacies, Lower Permian, stratigraphy, paleoenvironments

Parole chiave: Sudalpino, icnofacies, Permiano inferiore, stratigrafia, paleoambienti

1. INTRODUCTION AND SCOPE OF THE WORK

The Pietra Simona (PS) represents in the central Southern Alps (Lombardy) a well-known siliciclastic unit, which was formalized (Assereto & Casati 1965) as a Member of the Lower Permian Dosso dei Galli Conglomerate (DGC; Cassinis 1969). For such a reason, it was recently included in the list of "Traditional stratigraphic units" of the Italian Stratigraphic Commission (Berra & Albini *et al.* 2006).

After 40 years from the last studies which dealt on it, and in the light of a forecoming more detailed work on lithostratigraphy, facies analysis and paleogeographic significance of such unit, the subject of this work is to emphasize the Pietra Simona ichnological content and the use of ichnology

in the delineation of specific facies and environments. To accomplish this task, the Darfo-Boario Terme (Val Camonica) type-section (Assereto & Casati 1965) and the Val Dasdana parastratotype (Cassinis 1969) were revisited and described in detail (Lombardi 2006).

2. HISTORICAL BACKGROUND AND GEOLOGICAL/STRATIGRAPHICAL SETTING

The term Pietra Simona was introduced into literature by Curioni in 1855, who gave this name to an ornamental and building stone which has been used in Val Camonica area since the XIV century. After that, and before the formalization of

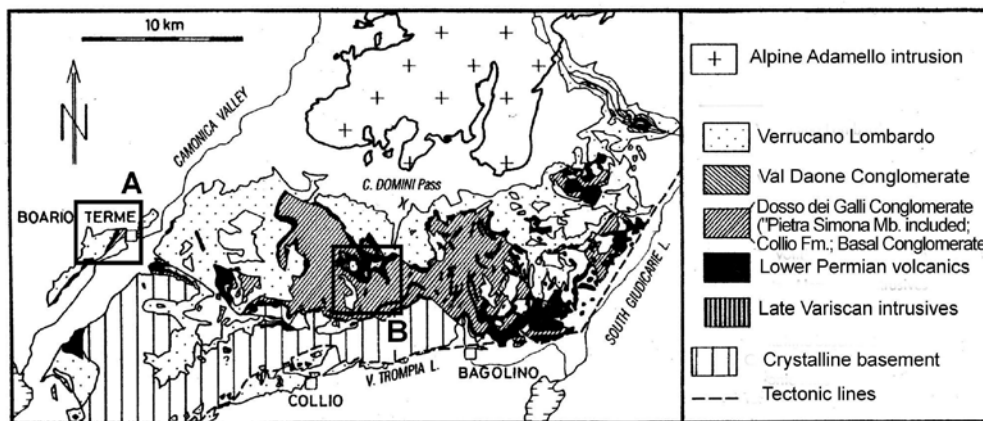


Fig. 1 - Location of stratotype- and parastratotype section of Pietra Simona Mb, respectively in Val Camonica (A) and Val Dasdana (B) (map after Cassinis *et al.* 2000, mod.).

Fig. 1 - Ubicazione dello stratotipo e del parastratotipo del Membro della Pietra Simona, rispettivamente in Val Camonica e in Val Dasdana (carta ripresa da Cassinis *et al.* 2000, mod.).

the unit (Assereto & Casati 1965), these siliciclastic deposits were cited by various authors without a clear stratigraphic significance (see Cassinis & Schirolli in press).

In the type-area (Fig. 1), the Pietra Simona Member represents an etheropic lithofacies of the Dosso dei Galli Conglomerate and, with respect to this coarse-grained formation, it crops out in different stratigraphic positions (Figs 2, 3). In lower Val Camonica (Luine archaeological Park, N of Boario town, A in Fig. 1), the PS attains its maximum thickness (277 m) and occurs in the uppermost portion of DGC, whereas in Val Dasdana (thickness of para-stratotype, 120 m; B in Fig. 1), upper Valle della Grigna and Val Caffaro, it characterizes the lower part of the DGC. Eastwards, the PS thickness decreases to a few meters to the Giudicarie sector and it also thins out towards the S of the Val Dasdana locality (Boni & Cassinis 1973).

In the former locality (Val Camonica), the PS lies over the upsection coarse-grained lithologies of Dosso dei Galli Conglomerate, while in the latter one (Val Dasdana) it is deposited, at places, on the upper member of Collio Formation or on the lower member of DGC (Boni & Cassinis 1973).

In both sequences the depositional history is characterized by mm to metric cycles of pretty homogeneous micaceous fine sandstones to clayey-siltstones, whose main petrographical composition is represented by quartz (15-40%), lithic fragments (mainly "porphyrs", 5%), feldspars (20-50%) and micas (15%) (Ogniben 1953). In the finest lithologies the white mica crystals contribute for the 35-45% and the cement component rises to 40-50%.

The true siliciclastic deposits are frequently interspaced by medium- to fine-grained pyroclastic/volcaniclastic intervals (Fig. 4d) as a witness of coeval volcanic activity; two metric crystalline tuff layers occur at the unit top in the Boario section (Assereto & Casati 1965) and about a 5 metre-thick tuff episode in the Val Dasdana parastratotype (Cassinis 1969).

According to Ori *et al.* (1988), the PS was irregularly deposited in an alluvial-to-lacustrine setting characterizing the mid-upper Collio Basin fill, regards as sandy zones lateral to the main cones of the medium- to very coarse grained DGC alluvial fans or inactive areas on the fans.

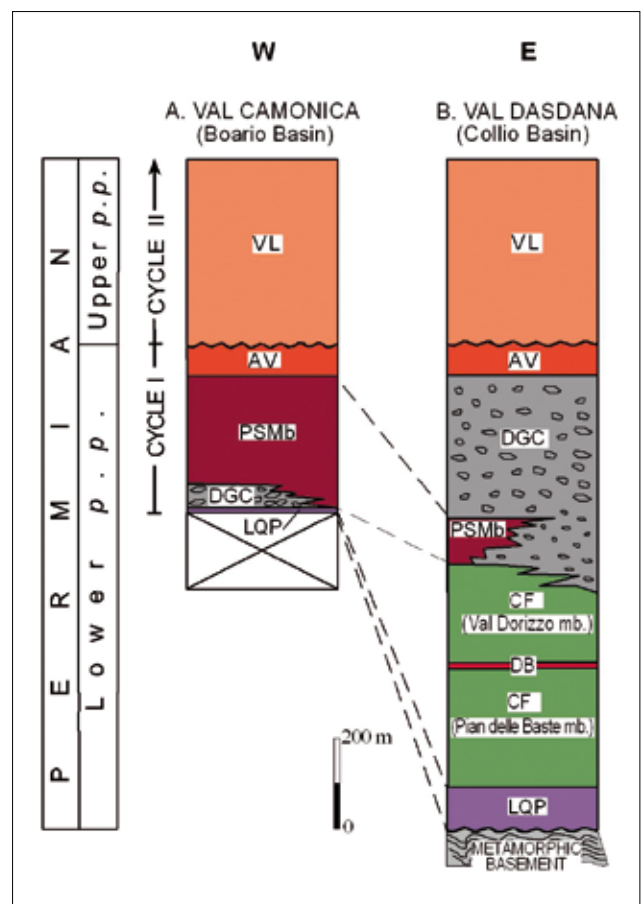


Fig. 2 - Representative sections of Val Camonica (Boario section A) and Val Dasdana (Collio section B) and stratigraphic position of Pietra Simona Mb within the Dosso dei Galli Conglomerate. LQP= "Lower Quartz Porphyrs" Auct.; CF= Collio Formation; PS= Pietra Simona Member; DGC= Dosso dei Galli Conglomerate; AV= Auccia Volcanics; VL= Verrucano Lombardo.

Fig. 2 - Sezioni stratigrafiche rappresentative dei bacini di Boario e Collio e posizione della Pietra Simona Mb. all'interno del Conglomerato del Dosso dei Galli. LQP= "Porfidi Quarziferi inferiori" Auct.; CF= Formazione di Collio; PS= Membro della Pietra Simona; DGC= Conglomerato del Dosso dei Galli; AV= Vulcaniti di Auccia; VL= Verrucano Lombardo.

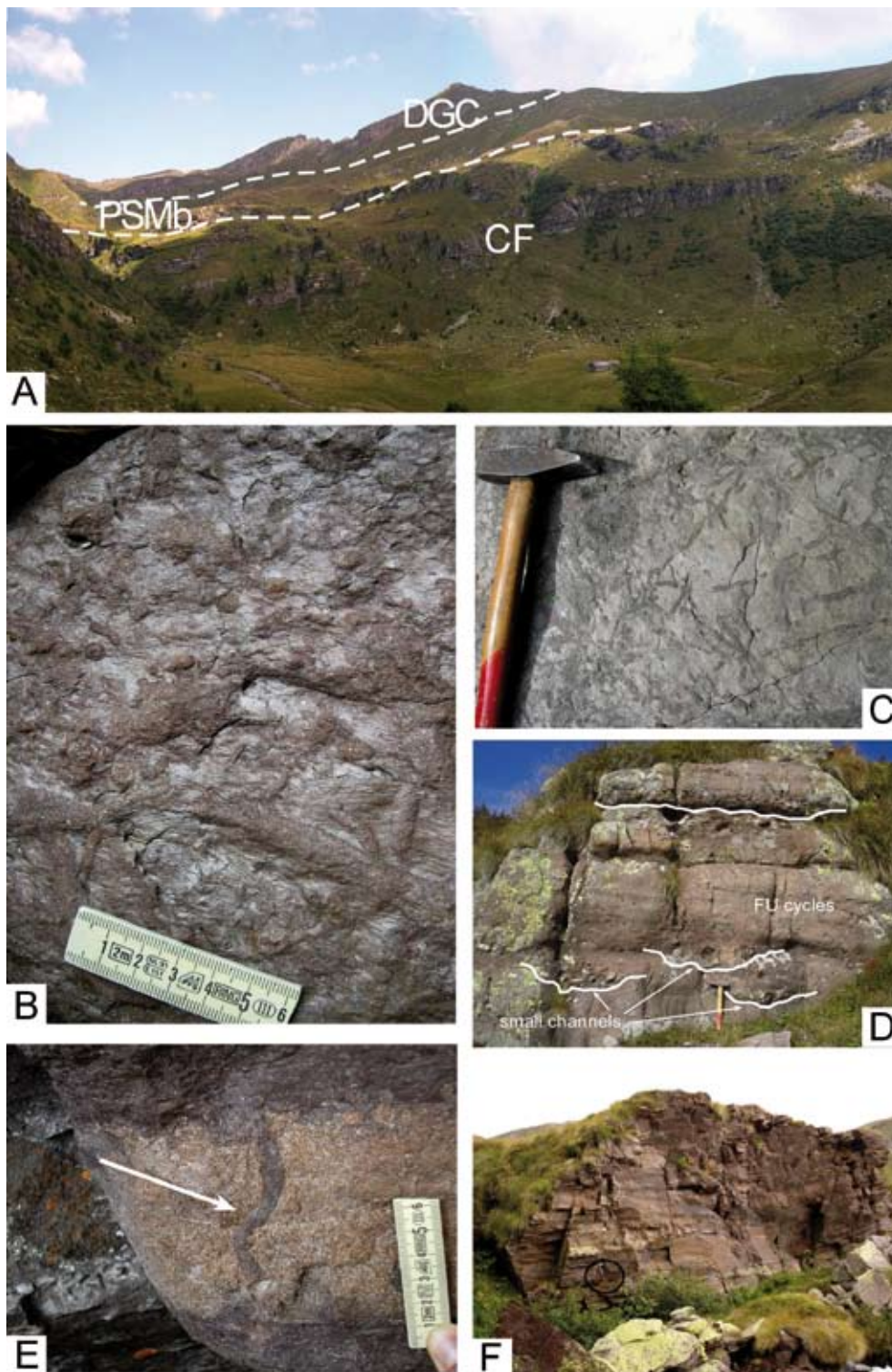


Fig. 3 - Pietra Simona facies and ichnological content in Val Dasdana parastratotype (Brescian Prealps). A. Panoramic view of lower Val Dasdana (CF= Collio Formation – Val Dorizzo Mb.; PSMb= Pietra Simona Mb.; DGC= Dosso dei Galli Conglomerate); B, C. close-up on *Planolites montanus* ichnospecies; D. channellized and graded medium- to coarse-grained deposits in the lower-middle part of the section; E. single infauna burrowing inside a medium-grained sandstone layer; F. horizontal bedding in fine- to medium-grained wine-red deposits in the lower part of the section (hammer for scale).

Fig. 3 - Facies e contenuto icnologico della Pietra Simona nel parastratotipo della Val Dasdana (prealpi bresciane). A. Vista panoramica della bassa Val Dasdana (CF= Formazione di Collio – membro della Val Dorizzo.; PSMb= Membro della Pietra Simona.; DGC= Conglomerato del Dosso dei Galli); B, C. particolari della icnospecie *Planolites montanus*; D. depositi medio-grossolani, canalizzati e gradati, nella porzione medio-inferiore della sezione; E. singola bioturbazione (infauna) all'interno di uno strato di arenaria; F. laminazione piano-parallela nei depositi medio-fini rosso-vinati nella parte inferiore della sezione (martello come scala).

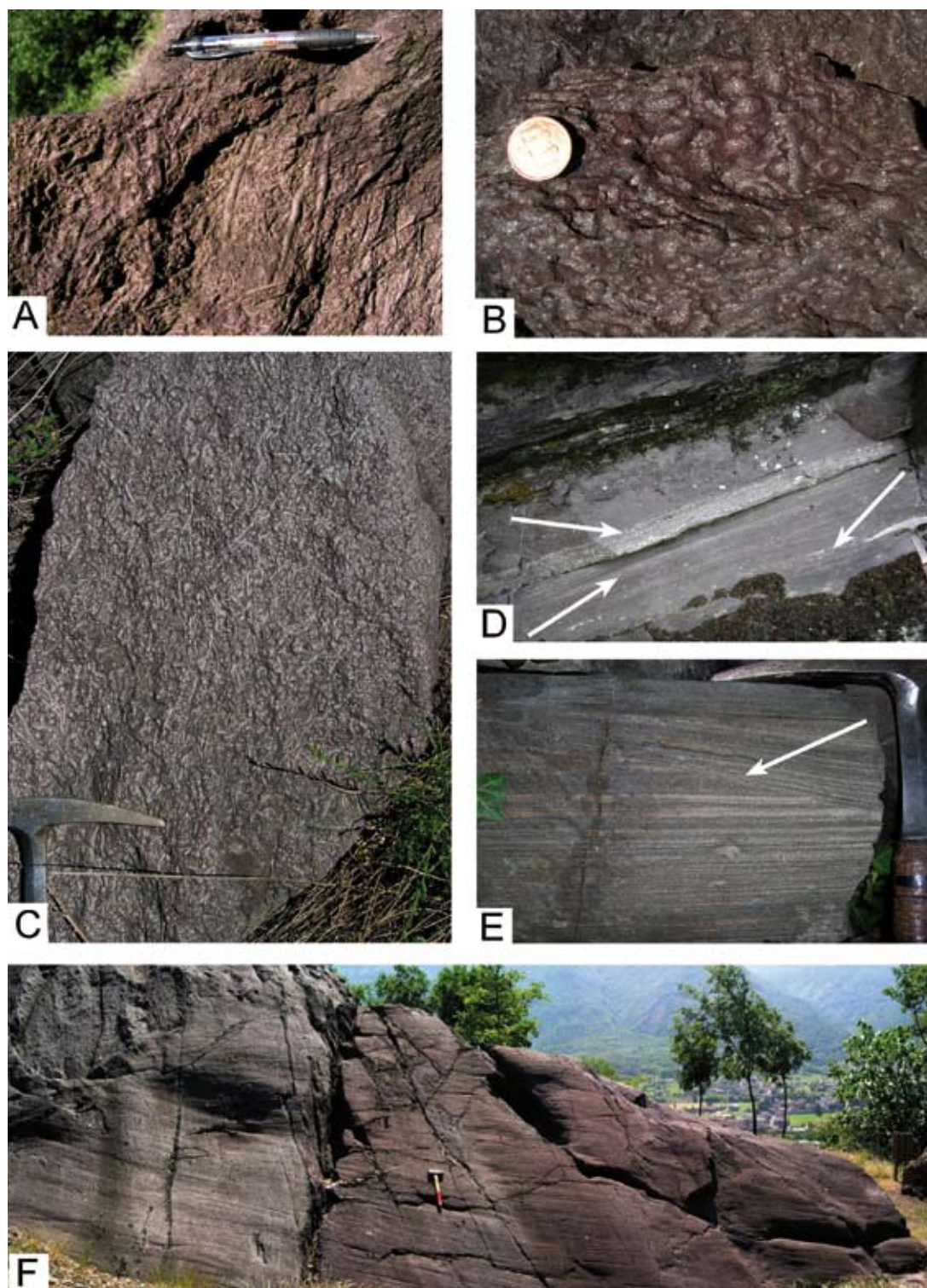


Fig. 4 - Pietra Simona facies and ichnological content in Val Camonica type-section (Luine Park, Darfo-Boario). A, B, C. different aspects and close-ups of *Paleophycus tubularis* at different levels of the section; D. fine-grained FU and CU graded volcaniclast deposits (arrows); E. lacustrine ritmites cross-cutted by an erosional surface (arrow); F. panoramic view of cross-laminated reddish siltstones in the mid-upper part of type section.

Fig. 4 - Facies e contenuto icnologico del Membro della Pietra Simona nella sezione tipo della Val Camonica (Parco di Luine, Darfo-Boario). A, B, C. differenti aspetti e particolari di Paleophycus tubularis in diversi livelli della successione; D. depositi vulcanoclastici fini e gradati (positivamente e negativamente, frecce); E. ritmiti lacustri e superficie erosiva (freccia); F. panoramica delle siltiti rosso-scure con laminazioni incrociate nella parte medio-superiore della sezione.

Apart from its ichnological content, this stratigraphic unit is, to-date, barren of fossils, therefore its age is deduced from the stratigraphic position: absolute datings (U-Pb on zircon) were recently performed on volcanic units above (“Auccia Volcanics”) and below the unit (“Lower Quartz Porphyries”), and gave respectively 279.8 ± 1.1 and 283.1 ± 0.6 Ma (Schaltegger & Brack 2007). Thus the Pietra Simona deposition should be generally constrained into the mid-late Early Permian (Artinskian).

3. ICHNOSPECIES AND ICHNOFACIES

A peculiarity of the PS, also evidenced by the oriented disposition of mica laminas, is the intricate pattern of bioturbations (“röhrige Wülste” of Salomon 1908 or “budellature” *auctt.*), which repeatedly occur all throughout the section and have produced the nearly complete disruption of the strata. These feeding traces (Fodichnia), due very likely to annelids, are here determined (Buatois pers. comm.) as pertaining to 1) *Paleophycus tubularis* Hall 1849 (Figs 4a, 4b, 4c) represented by horizontal and vertical, unbranched, straight to curved lined tubules with up to 15 cm in length and up to about 1 cm in diameter, filled with sediments typically identical to those of the surrounding matrix, and to 2) *Planolites montanus* (Figs 3b, 3c, 3e?) made up of simple horizontal/vertical, unlined burrows, up to 10 cm in length and up to 0,5 cm in diameter, infilled with sediments having textural and fabricational characters unlike those of the host rocks.

As indicated by Pemberton & Frey (1982), who revised *Paleophycus* ichnotaxonomy, this ichnospecies represents passive infilling of open dwelling burrows of predaceous or suspension-feeding organisms, and can be clearly distinguished from *Planolites* by having lined walls and burrow similar to the host rock.

Even though the lacking of most of the typical forms found associated, the PS invertebrate ichnospecies permit to identify, in the considered sections, two different ichnofacies, characterizing benthic activity in low-energy environments: the *Mermia* and the *Scoyenia* ichnofacies (Buatois & Mangano 1995, 1998), which are frequent in Carboniferous and Permian red beds.

The *Mermia* association (Buatois & Mangano 1995) occurs in very fine-grained sandstones and siltstones in lacustrine successions ranging in age from the Carboniferous to the Recent and records the establishment of a diverse, mobile, deposit-feeding soft-bodied epifauna. The ichnofacies is dominated by grazing trails typically, although locomotion traces are also present within the assemblage; neither dwelling structures nor back-filled meniscate burrows occur.

The *Scoyenia* ichnofacies (firstly proposed by Seilacher 1967, then revised by Frey *et al.* 1984 and later on by Buatois & Mangano 1995), also recorded in continental facies from the Devonian to the Tertiary, was identified in the Val Dasdana section due to the recurrent presence of *Planolites montanus* ichnospecies (Figs 3b, 3c).

4. FROM ICHNOFACIES AND FACIES ANALYSIS TO AN ENVIRONMENTAL RECONSTRUCTION

According to Buatois and Mangano (1995, 1998, 2004) the *Mermia* ichnofacies points to a permanently submerged, well-oxygenated, open and perennial lake environment. Pickerill (1992) indicates, for an ichnological assemblage (*Paleophycus* ichnocoenosis) comprising the ichnospecies *Paleophycus tubularis*, a nearshore, siliciclastic-dominated lacustrine facies. Nevertheless, as pointed out by Buatois & Mangano (1995), the *Paleophycus* ichnocoenosis is not associated with features indicative of sub-aerial exposure and thus can be regarded as aquatic in origin. Facies-analysis in the Boario sections, which is dominated by the monospecific presence of *Paleophycus tubularis*, is in tune with this interpretation, since no evidence of desiccation horizons was observed. Differently, the *Scoyenia* ichnofacies reflects marginal lacustrine substrates, periodically inundated or desiccated (e.g. Pemberton & Frey 1982; Buatois & Mangano 1998). The former ichnofacies characterizes the Val Camonica sector, while in the Val Dasdana area both ichnofacies occur, thus indicating a less stable, transitional terrestrial setting, with ephemeral-to-perennial lake systems.

On the basis of the stratigraphic relationships and facies analysis in the two main outcrop areas and thanks to the ichnofacies interpretation (Fig. 5), it is possible to draw the following paleoenvironmental scenario:

- A. the Val Dasdana sector (Collio Basin, section B, Figs 1-2) sector likely represented an alluvial-to-marginal and ephemeral lacustrine environment, in the lateral/distal areas of the coarse-grained DGC alluvial fans. Particularly in the Val Dasdana (even though, episodically also in the Boario section), the prevalently fine-to medium siliciclastic deposition (Fig. 3f), is interspaced by medium- to fine-grained channelized, stream-flow conglomerates (Fig. 3d); these decimetre- to some metre-thick lenses, made up of basement-sourced and porphyry clasts up to 10 cm, generally show fair lateral persistence. Along this section, repeated indications of sub-aerial exposure (mud-cracks) are in tune with the above-cited environments and this interpretation is coupled with the presence of vertebrate tracks in the basal part of the profile.
- B. Differently, the Val Camonica area (Boario Basin, section A, 1 and 2) area was the site of a deeper and long-lived lacustrine basin surrounded by an alluvial plain environment. This interpretation is supported both by facies analysis which documents a low energy depositional setting for the bulk of the succession and by the pervasive presence throughout the section of *Paleophycus tubularis* ichnospecies which indicates the presence of a perennial to semi-perennial lake-system in this area.

In the lower part of the section slightly carbonaceous clayey siltstones, together with varicoloured fine sandstones

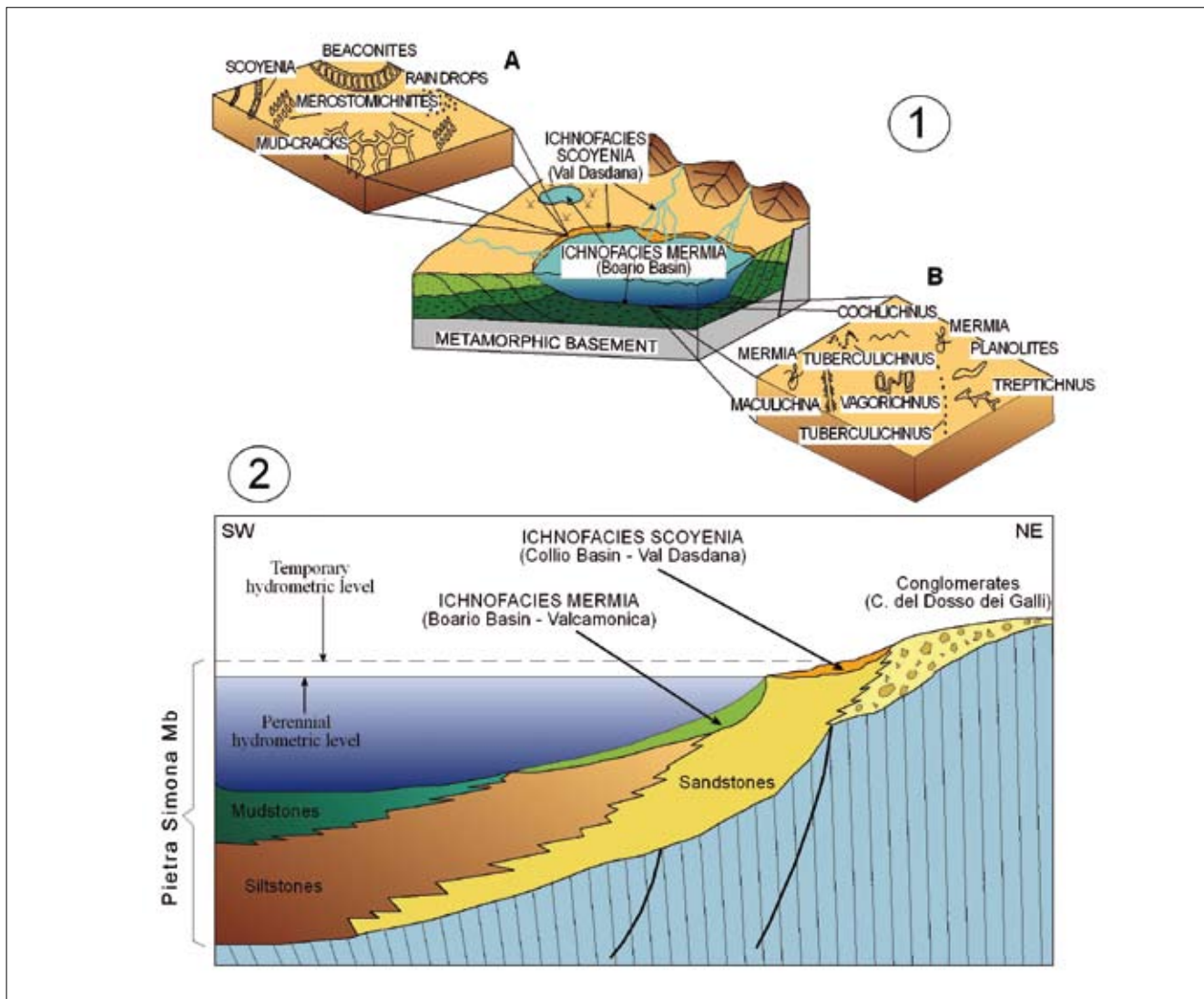


Fig. 5 - 1. Ichnofacies model of depositional paleoenvironments (partly reprised from Buatois and Mangano 2004, mod.) of Pietra Simona Mb. in Val Dasdana and Boario sectors with schematic reconstructions of Scoyenia (A) and Mermia (B) ichnofacies (from Buatois & Mangano 1998, redrawn); 2. Simplified paleobathymetric SW-NE profile with hipotized Lower Permian paleoenvironments of Pietra Simona and Cgl. Del Dosso dei Galli in Val Camonica (Boario Basin) and Val Dasdana (Collio Basin) sections.

Fig. 5 - 1. Modello delle icnofacies e degli ambienti deposizionali (da Buatois & Mangano 2004, mod.) della Pietra Simona in Val Dasdana e nel Bacino di Boario e schematica ricostruzione delle icnofacies Scoyenia (A) e Mermia (B) (da Buatois & Mangano 1998, ridis.). 2. Profilo paleobatimetrico SO-NE, semplificato e ipotetico, dei paleoambienti che caratterizzavano la Pietra Simona e il Conglomerato del Dosso dei Galli in Val Camonica (Bacino di Boario) e in Val Dasdana (Bacino di Collio) nel Permiano inferiore.

and siltstones, thinly laminated and with frequent dissolution cavities (max diameter up to 15 cm). These last are interpreted as former limestone nodules which would indicate the presence of local lacustrine carbonate facies characterizing the lake margins.

Apart from the intensely bioturbated intervals, sedimentary structures are evident all throughout the unit and, among these, even, ripple cross-laminations (both wavy and current ripples were observed), through-cross beddings (Fig. 4f) and lacustrine ritmites (Fig. 4e). These facies are interpreted as pertaining to alluvial plain to marginal or shallow-water lake settings, while the strongly bioturbated facies, more

and more frequent from mid section to its top, are characteristic of deep water lacustrine environment. Buatois & Mangano (1998) stated that strong biogenic disruption of primary bedding in subaqueous lacustrine deposits are not reported, to-date, from the Permian but only from the Triassic or even from the Cretaceous. This is not completely true because, apart from the subject discussed in this work, complete bioturbation of the sediment was described (Schneider & Roßler 1995) from the Rotliegend in the Vorerzgebirge basin (Härtensdorf and Leukensdorf fms) and from the Saale basin (Tambach fm.). These last authors discuss the total bioturbation of the sediment in relation to time of ex-

position of the surface of the sediment. According to other authors (H. Walter, pers. comm.) the degree of bioturbation could also depend on the degree of salinity (on playa environments for instance).

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