



Lower Permian invertebrate ichnocoenosis from the Orobic Basin, northern Italy

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ABSTRACT - The Lower Permian invertebrate palaeoichnofauna from the Collio Formation (Orobic Basin, North Italy) has been enriched by the new finding of arthropods (*Bifurculapes* isp., cf. *Heteropodichnus variabilis* Walter, 1983 and *Eisenachichnus* isp.), probable gastropods (*Paleobullia* isp.), possible myriapod traces, and also an undetermined trail. The ichnoassociation including *Medusina atava* (Pohlig, 1892) Walcott, 1898 is also, as well as the vertebrate ichnocoenosis, very similar to the one which existed in the neighbouring countries of France and Germany, thus showing a great uniformity in the geographic distribution of the fauna. The invertebrate ichnocoenosis composition shows: (a) a dominance of surface traces and not infaunal burrows, (b) low biodiversity, (c) a lack of monospecificity. The ichnodiversity and taxonomic composition suggest a terrestrial-freshwater origin.

RIASSUNTO - [Icnocenosì ad invertebrati del Permiano inferiore del Bacino Orobico (Italia settentrionale)] - Il Permiano inferiore del Sudalpino (Nord Italia) è testimoniato da una successione di terreni continentali ricchi in icnofossili di vertebrati ed invertebrati; solo la Formazione di Collio, al momento, risulta fossilifera. Nonostante sia da tempo conosciuto il Permiano del Bacino Orobico (Lombardia) non ha ricevuto una grande attenzione e solo recentemente gli studi sulla icnofauna si sono approfonditi. La paleoicnofauna della Formazione di Collio del Bacino Orobico, del Permiano inferiore oltre alla presenza di anfibi e rettili ("*Batrachichnus*" salamandroides (Geinitz, 1861) Haubold, 1996, cf. "*Batrachichnus*" salamandroides (Geinitz, 1861) Haubold, 1996, *Camunipes cassinisi* Ceoloni, Conti, Mariotti, Mietto e Nicosia, 1987, *Amphisauropus imminutus* Haubold, 1970, *A. latus* Haubold, 1970, cf. *A. imminutus* Haubold, 1970, *Varanopus curvidactylus* Moodie, 1929, *Dromopus lacertoides* (Geinitz, 1861) Haubold, 1971, ?*Ichnoterium cottae* (Pohlig, 1885) Pohlig, 1892) è arricchita da diversi invertebrati quali artropodi (*Bifurculapes* isp., cf. *Heteropodichnus variabilis* Walter, 1983 ed *Eisenachichnus* isp.), probabili gasteropodi (*Paleobullia* isp.), tracce di possibili miriapodi ed anche di piste di cui non è ancora stato possibile identificare l'autore con sicurezza ed infine anche da *Medusina atava* (Pohlig, 1892) Walcott, 1898. Quest'ultima è presente solo nella parte superiore della Formazione di Collio i cui sedimenti sono una possibile testimonianza di ambienti di playas. Rispetto all'icnocenosì ad invertebrati del Bacino della Val Trompia non è ancora stata rinvenuta *Medusina limnica* Müller, 1978. Questa icnoassociazione è molto simile a quelle presenti sia in Francia sia in Germania dimostrando una grande uniformità nella distribuzione spaziale della fauna. Da questi primi dati sull'icnoassociazione ad invertebrati si può dedurre: a) una dominanza di impronte di organismi camminatori e non scavatori, b) una bassa biodiversità, c) mancanza di monospecificità. Questa icnoassociazione suggerirebbe un'origine continentale di acqua dolce.

INTRODUCTION AND PREVIOUS WORKS

The "Collio Formation" (Early Permian in age), with good continuity, crops out over almost the entire South-Alpine domain (northern Italy); its beds are a rich source of fossils, mainly vertebrate footprints. At present these provide an important biochronological tool (Conti et al., 1997; Avanzini et al., 2001; Cassinis et al., 2002; Cassinis & Santi, 2001, 2005). The plant remains (macrofloras, spores and pollens) have also assumed a similar, very meaningful chronostratigraphic role (Cassinis & Doubinger, 1992; Pittau, 1999; Visscher et al., 1999; Cassinis & Santi, 2001). The biodiversity of the Lower Permian is completed by invertebrate traces, even if studies focused on them are rare. Berruti (1969) indicated bivalve discoveries (*Anthracoisidae*) from the Collio Formation in the Trompia Basin (Brescia Province, Lombardy, North Italy), Conti et al. (1991) demonstrated in the Brescian "Collio" the presence of freshwater jellyfish (*Medusina limnica* Müller, 1978) along with crustaceans ("*Estheria*") and *Tambinia spiralis* Müller, 1956.

Only in recent years studies on the invertebrate trails of the Orobic Basin (Lombardy, North Italy), west of

the Trompia Valley, have been carried out (Alessandrello et al., 1988; Santi & Krieger, 2001; Ronchi & Santi, 2003).

This note aims to introduce the new findings from the Collio Formation cropping out in the Orobic Basin (Figs. 1-2), to enlarge our knowledge of the invertebrate ichnocoenosis in the Lower Permian.

STRATIGRAPHIC SETTING

At the end of the Palaeozoic, the Hercynian orogenesis originated a succession of pull-apart basins from W to E, linked to a transtensional tectonic activity. The major basins are the Orobic Basin and, east of this, the Trompia Basin. Other very small troughs (Tione Basin, Tregiovo Basin), because of their significant ichnocoenoses, are also considered as important (Conti et al., 1997, 1999).

The Permian succession in the Orobic Basin, as in the whole South-Alpine domain, is organised by two tectono-sedimentary cycles separated by a clear regional angular unconformity (Italian IGCP Group 203, 1986; Cassinis et al., 1988, 1999) (Fig. 3). Cycle I

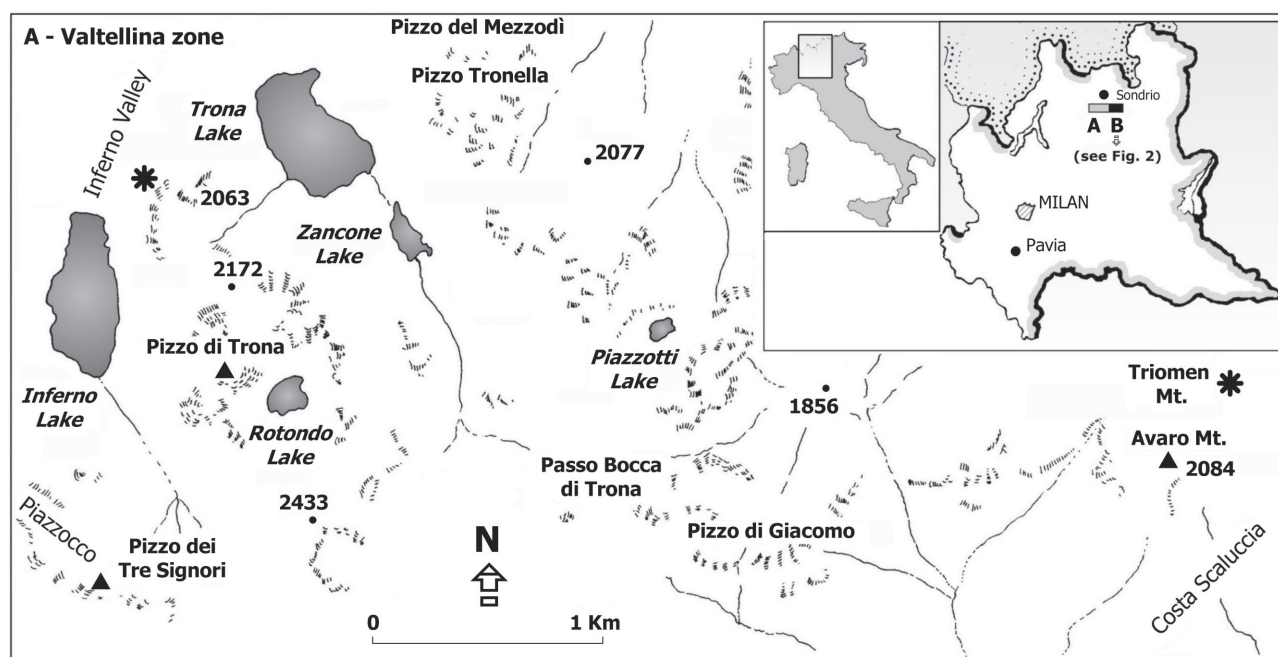


Fig. 1 - Geographical position of the Valtellina area and Brembana Valley in Lombardy (North Italy) with (asterisks) the main fossiliferous zones.

(?Westphalian B/C-Lower Permian) is characterised by a volcano-sedimentary succession that consists of: “Basal Conglomerate”, cropping out discontinuously over the whole Orobic Basin and missing in the Trompia Valley; “Collio Formation”, and “Ponteranica Conglomerate”. The “Collio Formation” is composed of a volcanic unit (discontinuous) and a sedimentary one (“Collioschichten” *sensu* De Sitter & De Sitter-Koomans, 1949), locally lying above the “Basal Conglomerate” or, more frequently, on the crystalline basement. The sedimentary unit typical of the lacustrine environment, is mainly composed of sandstones, pelites and shales, and locally presents some conglomeratic intercalation. In the literature the highest stratigraphical part is known as “Scisti di Carona” (De Sitter & De Sitter-Koomans, 1949), comprising sandstones, pelites and volcanoclastic breccias laid down in lakes of arid or semi-arid environments. The “Ponteranica Conglomerate”, a fluvial conglomeratic lithosome (Casati & Gnaccolini, 1967; Gianotti et al., 2001, 2002), interfingers with the Collio Formation. According to Cassinis et al. (2002) this sedimentary cycle (Cycle I) is probably Sakmarian up to Artinskian in age.

The second sedimentary cycle (Cycle II) is mainly defined by a reddish conglomeratic lithosome known as the Verrucano Lombardo that ends the Permian sedimentation. Based on the palaeontological record the second cycle is referred to the Upper Permian (Broglia Loriga et al., 1988; Massari et al., 1988, 1994; Kozur, 1989), although Massari & Neri (1994) consider it to continue into the Lower Anisian. The two cycles are thus separated by a gap, which length is still debated: the hiatus could be placed between the Lower and Upper Permian or at the base of the latter (Cassinis et al.,

2000), and quantified as 5-10 My (Harland et al., 1990; Odin & Odin, 1990; Menning, 1995). Nevertheless, according to more recent data (Cassinis & Neri, 1999) the gap was between 14 and 27 My or, in agreement with Cassinis et al. (2002), restricted to 24-25 My; this has been inferred from strongly different evolutionary stage between the two ichnofaunas mirrored by the change in the ichnoassociations of the Lower Permian with respect to the ones of the Upper Permian in the South-Alpine domain (Conti et al., 1999; Cassinis et al., 2002).

In agreement with Cassinis (2003), here the continental Permian “Lower” and “Upper” subdivisions are adopted. The question of the use of a two- or three-fold subdivision of the Permian System for continental successions has been debated for a long time. A detailed discussion concerning the dating of the Permian continental beds in the South-Alpine region was recently carried out by Cassinis (2003), Cassinis & Ronchi (2001), Cassinis et al. (2002), and Cassinis & Santi (2005). The traditionally adopted Permian subdivision in the South-Alpine area is “Lower Permian” (from about the Asselian to Kungurian) and “Upper Permian” (from the Ufimian to Tatarian, according to the Cis-Ural/Russian Standard Scale); sometimes the latter includes the Middle Permian, corresponding approximately to the Guadalupian Series (Menning, 2001; Cassinis, 2003). It is based on the palaeontological data from macroplants, palynomorphs, tetrapod footprints, and radiometric and palaeomagnetic investigations. Therefore, the stratigraphical resolution is rather poor compared with the marine equivalents; so the absence of detailed data and of wider correlations for the continental beds prevents the use of the three-

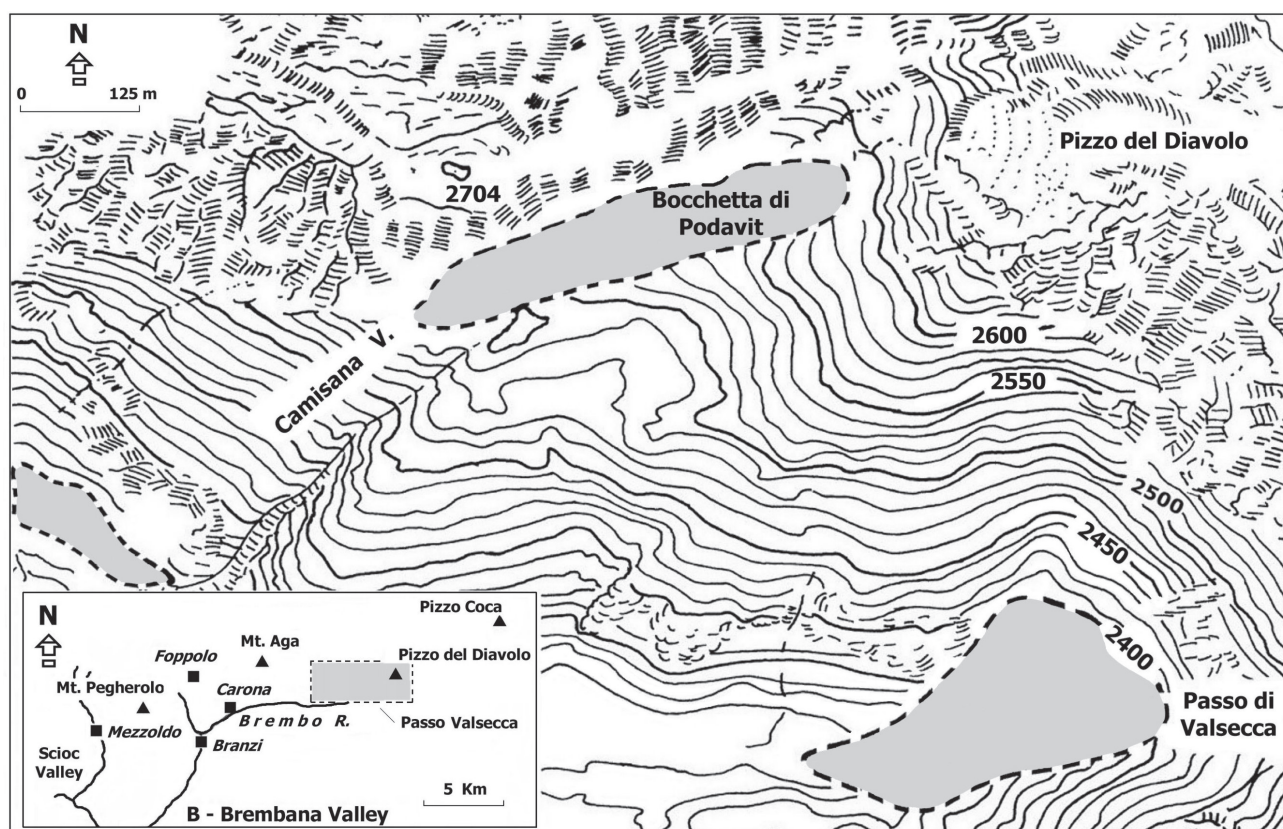


Fig. 2 - Geographical position of the Brembana Valley and the main zones rich in invertebrate ichnofossils neighbouring Pizzo del Diavolo.

fold subdivision of the Permian System into “Lower”, “Middle” and “Upper”. Only where the lateral transition between the continental and marine deposits is evident (i.e. between the “Arenaria di Val Gardena” and the “Bellerophon Formation”, Upper Permian in the

Dolomite region) can the use of the marine stages be justified.

In Lucas’s opinion (pers. comm.) the “Middle Permian” should include the Ufimian and Kazanian, whereas only the Tatarian should really be “Upper

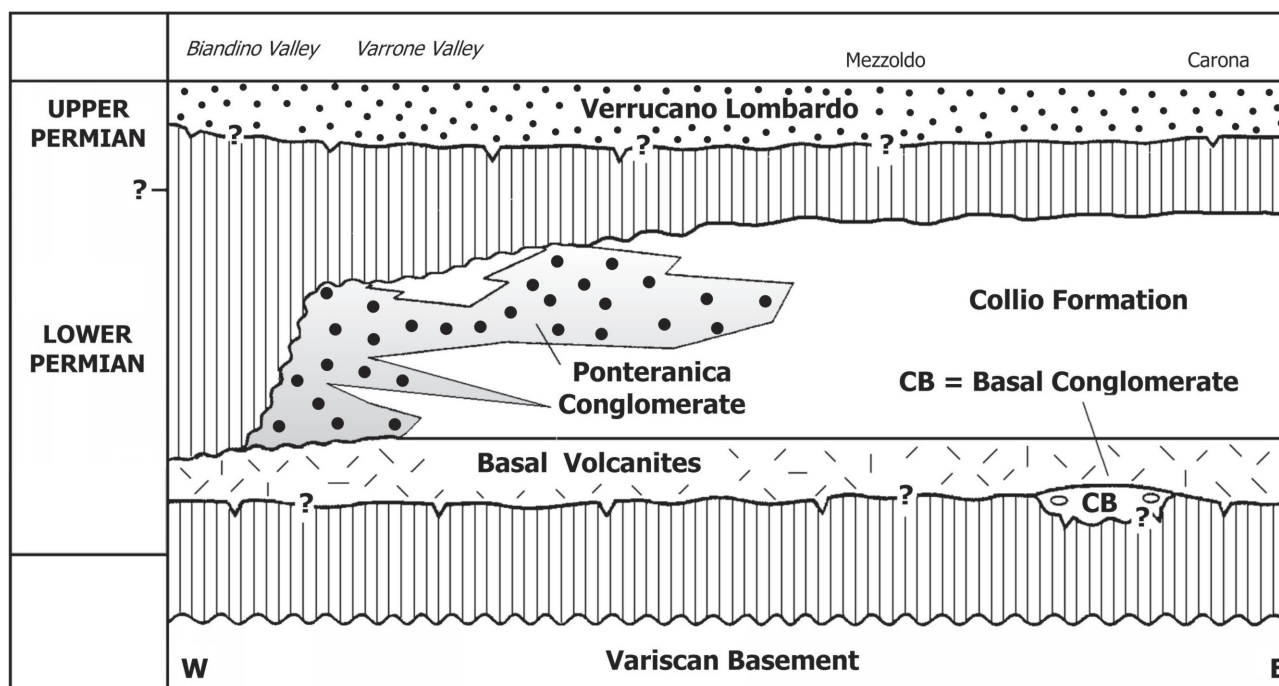


Fig. 3 - Stratigraphic scheme of the Permian in the Orobic Basin (after Cassinis et al., 2000, mod.).

Permian". It would be better to use the marine timescale terms (Roadian, Wordian, Capitanian, Wuchiapingian, etc.) rather than the old Russian terms.

Therefore, the chronostratigraphy here adopted (Cisuralian and Russian stages) for the Early Permian matches with the international subdivision of the Permian System. Dating the continental beds with the post-Kungurian Russian terms (which, in Lucas's opinion -pers. comm.- are only the regional stages) is more difficult for the reasons advanced. Fig. 4 shows the different scales of the Permian stratigraphy.

MATERIALS

Fossils come from the Collio Formation only; neither the Ponteranica Conglomerate nor the Verrucano Lombardo Formation are fossiliferous. The Collio Formation can be subdivided into two informal, lithologically similar parts (sandstones, siltstones and pelites and less frequently conglomerates), but chromatically different: the lower unit black-green, the upper one red-wine. In the Valtellina area the transition between the two units is clear and the upper one crops out with good continuity. Toward the east in the Brembana Valley and in the most of the Orobic Basin, only the lower unit crops out. A great amount of vertebrate footprints and trackways (Amphibians and Reptiles: "*Batrachichnus*" *salamandroides* (Geinitz, 1861) Haubold, 1996, cf. "*Batrachichnus*"

salamandroides (Geinitz, 1861) Haubold, 1996, *Camunipes cassinisi* Ceoloni, Conti, Mariotti, Mietto & Nicosia, 1987, *Amphisauropus imminutus* Haubold, 1970, *Amphisauropus latus* Haubold, 1970, cf. *Amphisauropus imminutus* Haubold, 1970, *Varanopus curvidactylus* Moodie, 1929, *Dromopus lacertoides* (Geinitz, 1861) Haubold, 1971, *Ichniotherium cottae* (Pohlig, 1885) Pohlig, 1892) have been gathered in the whole Collio Formation of the Orobic Basin (Nicosia et al., 2000; Santi & Krieger 2001), together with a paucity of macroflora (i.e. *Cassinisia orobica* Kerp, Penati, Brambilla, Clement-Westterhof & Van Berger, 1996 for its particular fossilization - Kerp et al., 1996; Visscher et al., 1999 - and rare silicified wood remains of difficult classification), and different invertebrate traces complete the fossiliferous picture.

Recently the invertebrate ichnocoenosis has been enriched by the freshwater jellyfish remains (*Medusina atava* (Pohlig, 1892) Walcott, 1898) from the "red" Collio Fm (Ronchi & Santi, 2003; Santi, 2004). These new findings assume a key role in our overview of the climatic shift (Ronchi & Santi, 2003).

New invertebrate traces and trails have been recently discovered and are here examined. They are stored in the Museo Civico di Scienze Naturali "E. Caffi" (Bergamo) and in the Dipartimento di Scienze della Terra of Pavia University. The invertebrate ichnotaxonomy is still problematic; an evaluation of useful terminology for the ichnosystematics, and also discussion of the ichnospecies concept among invertebrates, was

		SCPS 2000		U.S.A. stages	RUSSIA stages	My	TETHYS stages	CHINA stages
P E R M I A N	UPPER	L O P I N G I A N	CHANGXINGIAN	251			DORASHAMIAN	CHANGXINGIAN
			WUCHIAPINGIAN				D Z H U L F I A N	WUCHIAPINGIAN
			OCHOAN	?				
	MIDDLE	G U A D A L U P I A N	CAPITANIAN	CAPITANIAN	TATARIAN	267 272	MIDIAN	MAOKOUIAN
			WORDIAN	WORDIAN	KAZANIAN		MURGHABIAN	
			ROADIAN	ROADIAN	UFIMIAN	274	KUBERGANDIAN	CHIHSIAN
	LOWER	C I S U R A L I A N	KUNGURIAN	LEONARDIAN	CATHEDRALIAN	KUNGURIAN	BOLORIAN	
			ARTINSKIAN		HESSIAN	ARTINSKIAN	YAKHTASHIAN	
		W O L C A M P I A N	SAKMARIAN		LENOXIAN	SAKMARIAN	SAKMARIAN	
			ASSELIAN		NEALIAN	ASSELIAN	ASSELIAN	

Fig. 4 - Permian stratigraphy (SCPS = Sub-Commission of Permian Stratigraphy) (after Vachard & Argyriadis, 2002, mod.).

Ichnogenera-ichnospecies	labels
<i>Bifurculapes</i> isp.	Bif 1
<i>Bifurculapes</i> isp.	Bif 2
cf. <i>Heteropodichnus variabilis</i>	Het 1
<i>Eisenachichnus</i> isp.	Sec 1
<i>Dendroidichnites elegans</i>	De/2 de
<i>Dendroidichnites elegans</i>	De/3 de
<i>Dendroidichnites elegans</i>	10121
<i>Paleobullia</i> isp.	Palb 1
Myriapods	My 1
Undetermined traces	S 1665/8
Undetermined traces	S 1664/9
Undetermined traces	S 1664/44

Tab. 1 - List of the ichnogenera and/or ichnospecies with corresponding label.

proposed by Braddy (1995b). Arthropod traces are currently in need of revision, and several authors tend to over-split ichnotaxa (Braddy, pers. comm.). On this basis, I considered the systematic nomenclature mainly according to the studies by Walter (1983) and Demathieu et al. (1992), and the trackmaker identification according to Demathieu et al. (1992) and Braddy (2001). The measures were taken on the basis of Trewin's (1994) scheme. Ichnofossils were labelled with an acronym comprising the ichnogenus abbreviations followed by a progressive number or alternatively, only by a number (Tab. 1).

SYSTEMATIC ICHNOLOGY

a) ARTHROPOD TRAILS

Ichnogenus *Bifurculapes* Hitchcock, 1858

Bifurculapes isp.
(Figs. 5-6)

1992 *Bifurculapes* isp. DEMATHIEU, GAND & TOUTIN-MORIN, p. 37, Figs. 7-5, Figs. 10B-D.

2001 *Bifurculapes* isp. DURAND, p. 13, Fig. 8.

2003 *Bifurculapes* isp. SANTI, p. 112, pl. 1, Fig. A.

Material - Bif 1, Bif 2.

Description - Well-impressed and regular walking-trail, characterised by two regular and parallel rows each composed of two sets of very closed forked prints each jointed to the base; only rarely the external little prints open towards the outer side of the trail. Tab. 2 shows the principal parameters measured on the trails. The trackways are attributed to an homopodous trackmaker.

Discussion - Trace disposition, and their general organisation of the morphology indicate the ichnogenus *Bifurculapes* Hitchcock, 1858. In comparison with what has been drawn by Häntzschel (1975), the "orobic"



Fig. 5 - *Bifurculapes* isp. Brembana Valley, Orobic Basin. Specimen Bif 1 (Museo Civico di Storia Naturale "E. Caffi", Bergamo).

fossils present little external prints not completely disposed towards the outer side of the trail, but in general the trace features are very similar to the Triassic ichnotype. The "Collio" trails are partially similar to the ones described by Demathieu et al. (1992, Fig. 10B-D) from Gonfaron (France) and according to the authors the trackmaker could be cautiously considered an insect, or better a triopsid. Similar trails referring to other invertebrates (e.g. *Permichnium* Guthörl, 1934, *Lithographus* Hitchcock, 1858) are considered by Braddy (2001) as insect traces. To date, this ichnogenus is unknown in the Permian of Germany and North America.

Concerning the difficulties of nomenclature, Walter (pers. comm. 2004) suggests that the here-reported *Bifurculapes* could be approximated to *Secundumichnium alternas* Walter, 1983 (according to the Walter's 1983 nomenclature).

PARAMETERS	Bif 1	Bif 2
Length	149.6	163.8
External width	44.2	26.0
Internal width	11.05	8.45
Track angle right °	32°	40°
Track angle left °	30°	45°
Interseries dist. right °	18.02	9.14
Interseries dist. left °	16.15	10.32

Tab. 2 - Measures (in mm) of the trails of the *Bifurculapes* isp. specimens. Points identify mean values.



Fig. 6 - *Bifurculapes* isp. Brembana Valley, Orobic Basin. Specimen Bif 2 (Museo Civico di Storia Naturale "E. Caffi", Bergamo).

Ichnogenus *Heteropodichnus* Walter, 1983

cf. *Heteropodichnus variabilis* Walter, 1983
(Fig. 7)

1983 *Heteropodichnus variabilis* WALTER, p.151, table II, Figs. 8-9, table III, Figs. 1-2.

Material - Het1.

Description - The incomplete trail is a hypo-relief and it is defined by an external and internal part; the

first is a series of ray-disposed commas, while the second comprises only a light couple of commas, linked by a thin impressed circular "structure". External commas are longer (in average 1.81 mm long) and asymmetrical compared with the internal ones, implying heteropody. The external streaking couples show an evidently positive rotation like the internal ones. Trail is 24 mm long and 18 mm wide.

Discussion - The slab comes from the upper unit of the Collio Formation near to Mt. Mincucco (Valtellina area); together with the invertebrate trail an incomplete couple right *manus-pes*, digitigrade of probably *Dromopus* isp. is printed. The hand is characterised by the digit impressions of the II-III and IV, and by digit II-III for the *pes*; the last is overlapped to the hand. Trail development is short; nevertheless it has some features very similar to the ichnospecies *Heteropodichnus variabilis* Walter, 1983 (Walter, 1983, table II, Figs. 8-9) from the Upper Palaeozoic of Germany (Hornburger Schichten, Blättertonhorizonte rHr2't). These features namely the two-folds comma-like disposition of the external and internal prints, the light presence of the circular "structure", and the trace disposition that should close it to holoichnotypus, appear confused. Notwithstanding these imprecise features, the general morphology of the walking-trail indicates *H. variabilis*, and in my opinion this trail should be classified as cf. *Heteropodichnus variabilis* Walter, 1983.

Ichnogenus *Eisenachichnus* Kozur, 1981

Eisenachichnus isp.
(Fig. 8)

Material - Sec 1.

Description - Linear sequence of elongated and curved elements forming different walking-trails that sometimes cross. The main printed trail has a width on average around a centimeter, while is 50.7 mm in length. The single prints (in average around 1 mm in length)

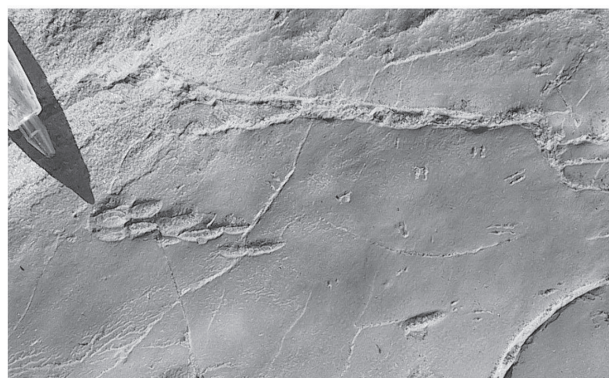


Fig. 7 - cf. *Heteropodichnus variabilis* Walter, 1983. Mincucco Mt., Valtellina area, Orobic Basin. Slab n. Het1.



Fig. 8 - *Eisenachichnus* isp. Brembana Valley, Orobic Basin, specimen Sec 1 (Museo Civico di Storia Naturale "E. Caffi", Bergamo).

are claw-like and arranged in the direction of locomotion. They are arranged parallel to each other.

Discussion - Trace disposition and their particular curved morphology recollect the components of the *Eisenachichnus* Kozur, 1981. In the past, trails with this general morphology were attributed to the ichnogenus *Secundumichnus* Walter, 1983 a junior synonym of *Eisenachichnus* (Kozur & LeMone, 1995). Three ichnospecies formed this ichnogenus: *E. tenellus* Walter, 1983, *E. biprintus* Walter, 1983, *E. alternans* Walter, 1983 found in the Permian of Germany. In comparison to the holoichnotypus of *E. alternans*, the imprints here analysed seem miss the alternate row disposed on the right and left sides of the track. The difference among the other ichnospecies is just the disposition of this second row, which in *E. alternans* is "alternated" to the first, and in *E. tenellus* and *E. biprintus* are disposed side by side. Without this key taxonomic feature it is impossible to determine the ichnospecies. Alessandrello et al. (1988) found similar traces in the Lower Permian strata of the Collio Fm in Scioc Valley, an area close to the Brembana Valley. They classified them as *Terricolichnus permicum* Alessandrello, Pinna & Teruzzi, 1988 considering them as planarian locomotion prints. Until now these traces are unknown in the Permian deposits of France, but are present in N. America (Kozur & LeMone, 1995). The reigning confusion over the systematic

classification of the invertebrate traces demands wider analysis.

Ichnogenus *Dendroidichnites* Demathieu, Gand & Toutin-Morin, 1992

Dendroidichnites elegans Demathieu, Gand & Toutin-Morin, 1992
(Fig. 9)

- 1992 *Dendroidichnites elegans* DEMATHIEU, GAND & TOUTIN-MORIN, p. 37, Figs. 10H-K.
- 1995a *Dendroidichnites elegans* Demathieu, Gand & Toutin-Morin - BRADDY, p. 101, Fig. 1E.
- 2001 *Dendroidichnites elegans* Demathieu, Gand & Toutin-Morin - SANTI & KRIEGER, p. 59, Fig. 8, pl. IV, Fig. d.
- 2002 *Dendroidichnites elegans* Demathieu, Gand & Toutin-Morin - GIANOTTI ET AL., p. 69, Fig. 13.
- 2003 *Dendroidichnites elegans* Demathieu, Gand & Toutin-Morin - RONCHI & SANTI, p. 755, Fig. 3H.
- 2003 *Dendroidichnites elegans* Demathieu, Gand & Toutin-Morin - SANTI, p. 113, pl. 1 Fig. c.

Material - De/2 de, De/3 de, 10121.

Description - Trails are characterised by large lateral "comma-like" imprints with curved extremities separated by a large central canal having some longitudinal strips arranged conformably to the trail direction. These prints are well-impressed, 60 mm long and 13 mm wide, vanishing in its final portion, and with an angle between the "commas" between 50° and 78° (spec. De/2 de). The morpho-dimensional diagnostic features for the specimen 10121 are: length slightly more than 50 mm, width of 16.5 mm, angle between the opposite "commas" about 70°.

Discussion - The described specimens show strong affinities with the ones referred to *Dendroidichnites elegans* by Demathieu et al. (1992) and Braddy (1995). Moreover, Walter (pers. comm., 2004) thinks that the imprint labelled Cas/2de could belong inside the ichnogenus *Permichnium*, *Secundumichnium* (junior synonym of *Eisenachichnus*), *Heteropodichnus* or *Heterotripodichnus*. This because: "At the border of the trace very clearly you can observe comma-like single imprints. The problem is only the thick drag mark in the middle of the trackway. It seems to me that the animal had problems in the movement on the substrate." (Walter, pers. comm., 2004). However, my opinion is in contrast with the Walter's comments because observing the morphological variability of *D. elegans* shown by Demathieu et al. (1992), and in particular the Fig. 10I, this specimen could well be ascribed to this ichnospecies. In Demathieu's opinion (pers. comm.) this ichnospecies of *Dendroidichnites* should be a synonym of *Mirandaichnium irregulare* Holub & Kozur, 1981. At present, lacking of further data about this arthropod traces prevent a detailed analysis on this problem, hence I preferred to maintain the ichnospecies *D. elegans* because in the recent literature it is still usually cited (i.e. Durand et al., 2002), hoping that in the future, a focused ichnotaxonomical analysis might be elaborated.

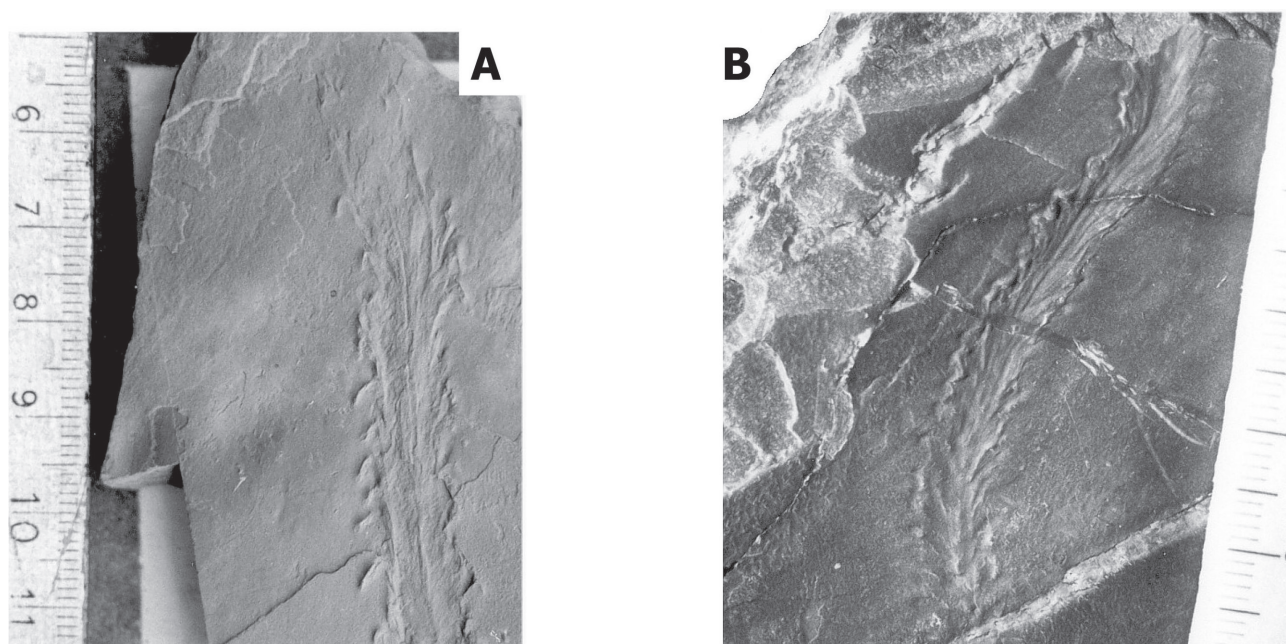


Fig. 9 - *Dendroidichnites elegans* Demathieu, Gand and Toutin-Morin, 1992. Orobic Basin. A - Specimen De/2 de (Valtellina area) (Dipartimento di Scienze della Terra, Pavia University). B - Specimen 10121 (Brembana Valley), (Museo Civico di Storia Naturale "E. Caffi", Bergamo).

b) GASTROPOD TRAILS

Ichnogenus *Paleobullia* Göttinger & Becker, 1932

Paleobullia isp.
(Fig. 10)

Material - Palb 1.

Description - Prints consist of subcircular to quadrangular-shaped elements with regular dimensions of about 2 mm in diameter. The disposition of the elements is enlarged.

Discussion - The single component organisation is very particular and unlike any traces known from the literature. Likenesses between these "Orobic" prints and those described by Demathieu et al. (1992) from the Gonfaron Permian layers imply we should re-enter them in the ichnogenus *Paleobullia* Göttinger & Becker, 1932. In contrast to the French prints, those from the "Orobic" Basin seem to have less regular trail development, although the dimensions are well inside the range (1-5 mm) indicated by the French authors. In the literature, different ichnogenera show some morphological features similar to *Paleobullia*, such as *Gordia* Emmons, 1844. In contrast to *Paleobullia*, the *Gordia* ichnogenus shows long, slender and smooth traces, neither regularly meandering nor sinusoidal (Häntzschel 1975; Demathieu et al., 1992). In the Orobic prints the lack of these features support the attribution to *Paleobullia*. These traces are usually referred to gastropods; the former is linked to sediment agglutination by the mucus secreted by the foot.

c) DOUBTFUL TRACES

? Myriapods
(Fig. 11)

Material - Myl.

Description and discussion - In the slab from the upper part of the Collio Formation (cropping out in the Gerola-Inferno Valleys), two tetrapod footprints of *Amphisauropus imminutus* Haubold, 1970 are impressed; a large number of fine, not organised, but randomly distributed points are observed. Demathieu et al. (1992, Fig. 12A), studying the Permian deposits of France, pointed out that a similar distribution of points belongs to an unidentified myriapod trackmaker; also a three-point grouping, if found in some traits of the trail, should indicate ichnogenus *Danstiaria*. Contrary to what is advanced by these authors, in this slab a similar organisation is not present.

d) UNDETERMINED TRAILS

Undetermined trails
(Fig. 12)

1992 Traces non nommées DEMATHIEU, GAND & TOUTIN-MORIN, p. 40, Fig. 12D.

Material - S 1665/8, S 1664/9, S1664/44.

Description - Three trails with curvilinear trends, sometime rectilinear, consisting of three continuous and



Fig. 10 - *Paleobullia* isp. Brembana Valley, Orobic Basin. Specimen Palb 1 (Museo Civico di Storia Naturale "E. Caffi", Bergamo).

parallel grooves (two external) conformably disposed to the movement axe. The central one crosses the smoother areas.

Discussion - In the literature similar trails are documented by Demathieu et al. (1992), referred to the Permian of Gonfaron. These authors did not identify either the ichnogenus or the ichnospecies; in fact they refer to them as "*traces non nommées*". Therefore some known ichnogenus could be used as comparison elements, i.e. *Bunyerichnus* Glaessner, 1969 (Häntzschel, 1975). This last is defined by imprints characterised by different morphological elements in comparison with those studied here, namely, through areas between the grooves characterised instead by segments perpendicular to the central axis. The ichnogenus *Protichnites* Owen, 1852 can also be related to these prints, but differs in the presence of bifid or trifold rows not observable in the "Orobic" ones, which could also be compared to *Diplopodichnus biformis* Brady, 1947 (Braddy, pers. comm., 2003). Lastly, another possible ichnogenus should re-enter in the so-called "group" *Subphyllochorda* Götzinger & Becker,

1932. The morphological description by Häntzschel (1975) indicates: "*bandlike, trifold, with varied longitudinal markings; on both sides of the median ribbon characteristic narrow carinate ridges common*" (p. 106, Fig. 66, 2d-e). What was described by this author could well correspond to the "Orobic" trails. Is possible that these traces might be approximated to *Ophidichnium* from Triassic of the eastern border of the Massif Central of France (Demathieu, pers. comm).

CONCLUSIONS

The discovery of new invertebrate traces and trails from the Collio Formation cropping out in the Valtellina and Brembana valley (Orobic Basin, North Italy) certainly enriches the Lower Permian ichnocoenosis coming from this sector of the South-Alpine domain. Traces and trails belong to *Bifurculapes* isp., cf. *Heteropodichnus variabilis* Walter, 1983 and *Eisenachichnus* isp. (Tetrapodichnia), *Paleobullia* isp. (Gastropods), unidentified myriapods, and other undetermined traces.

Until now, rare invertebrate traces of *Medusina atava* (Pohlig, 1892) Walcott, 1898 have been discovered only in the Collio Formation of the Orobic Basin (Ronchi & Santi, 2003; Gianotti et al., 2002; Santi, 2004). Ichnoassociation paucity is a fact already known for the "lower Collio" and becomes more evident in the upper part. Referring to the South-Alpine domain, this evidence could be a consequence of combined tectonic and climatic actions. In large parts of Western Europe, Early Permian times were characterised by a climatic shift from warm conditions, with alternating wet and dry seasons, to semi-arid conditions, up to the very warm and hot conditions of the Late Permian. Lithofacies and biofacies changes suggest a regional and geologically rapid decrease of the rate of precipitation and the onset of oxidising climatic conditions during the mid-late Early Permian (Artinskian?, Kungurian?). In the Orobic Basin (at least in its western sectors) the dominant alluvial-to-lacustrine dark-coloured facies pass quite abruptly, towards the top of the succession, to reddish fine sediments. The dark deposits suggest that a higher groundwater level produced reducing conditions, while the red fine sediments indicate muddy playa conditions, with high evaporation rates and an oxic environment. The "deposition time compression" hypothesis was invoked to explain the high rate of sedimentation for

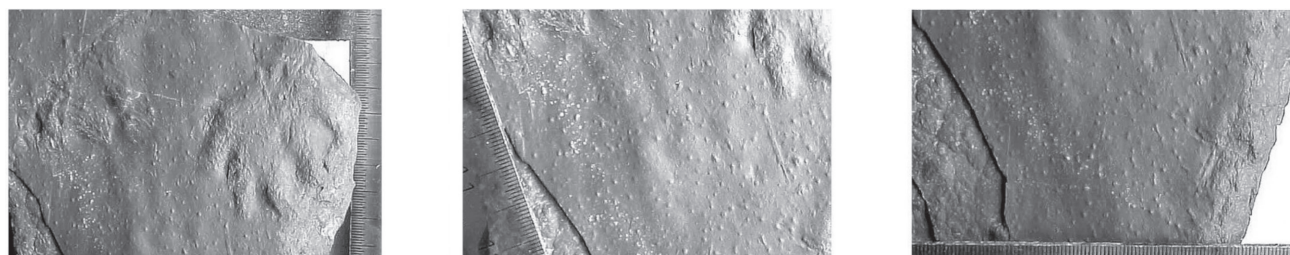


Fig. 11 - Doubtful traces (?Myriapods), Valtellina area, Orobic Basin. Slab n. My1 (Dipartimento di Scienze della Terra, Pavia University).

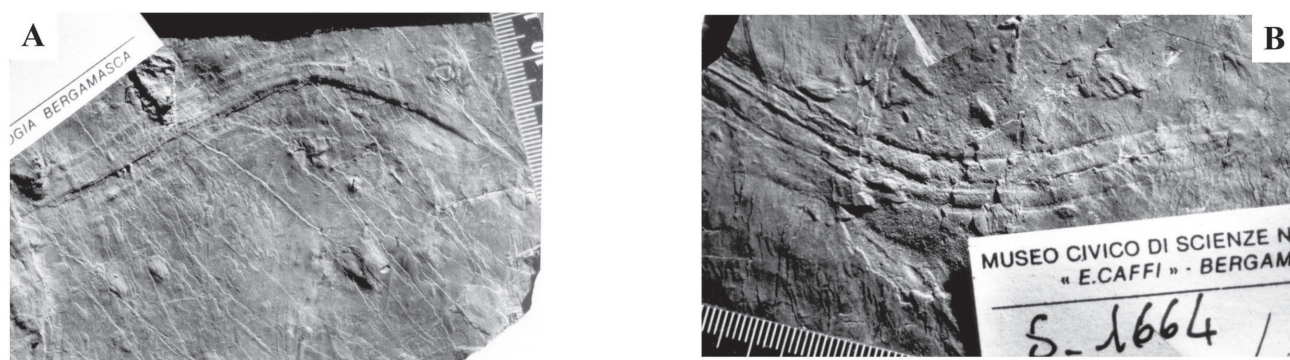


Fig. 12 - Undetermined traces. Brembana Valley, Orobic Basin. A - Specimen S 1665/8, B - Specimen S 1664/44 (Museo Civico di Storia Naturale "E. Caffi", Bergamo).

the Collio Fm in Trompia Valley (about 700 m in 4-5 My) which prevented the development of habitats suitable for the trackmakers (Nicosia et al., 2000). Tectonic activity prevented the development of a stable habitat, while the climatic variation did not allow the adaption of some species to the new and variable conditions of life.

From the data mentioned above, the invertebrate ichnocoenosis composition of the Orobic Basin shows: (a) imprints typical of fresh water; (b) a dominance of surface traces rather than infaunal burrows; (c) low biodiversity; (d) lack of monospecificity. The ichnodiversity and the taxonomic composition suggest a terrestrial-freshwater origin.

In comparison with the features shown by the tetrapod footprint distribution (great abundance of *Amphisauropus latus* Haubold, 1970 and *Dromopus lacertoides* (Geinitz, 1861) Haubold, 1971, less frequently *Varanopus curvidactylus* Moodie, 1929), the invertebrate trails and traces are rarer and no ichnospecies is dominant.

Invertebrate prints associated with the tetrapods (*Batrachichnus*, *Amphisauropus*, *Camunipes*, *Dromopus*, *Varanopus*) (Ronchi & Santi, 2003) should confirm a Sakmarian-Artinskian age.

The Lower Permian ichnocoenosis of the Orobic Basin, in its basic vertebrates and invertebrates components, is more similar to the ones from Central Europe (Walter, 1983; Demathieu et al., 1992; Gand et al., 1996; Kozur & LeMone, 1995 and references therein; Conti et al., 1999; Nicosia et al., 2000; Avanzini et al., 2001; Haubold, 1996; Durand, 2001; Haubold & Lucas, 2001a, b; Lucas, 2002). It is only partially similar to the Abo I unit (upper Sakmarian-Wolfcampian) showing the greatest uniformity and paucity in taxa, and different to those of the Coconino Sandstone (North America) (Braddy, 1995b; Kozur & LeMone, 1995; Haubold & Lucas, 2001a, b). These differences are probably linked to the different habitats: playa-lake facies for the first, dune sands for the Coconino Sandstone. Despite the ichnoassociations having the same facies, the evaluated differences between the European and American ichnocoenoses could be justified by the palaeogeographical positions of the respective zones during the Early Permian: the American Robledo Mountains were located in a semi-humid to semi-arid

girdle south of the Equator, while the European zone (South-Alpine and Central Europe) was in a semi-humid to semi-arid girdle north of the Equator (Kozur & LeMone, 1995). Ichnofossils listed here indicate an invertebrate fauna that although not yet completely understood, reflects an alluvial-plain or playa environment. The extremely wide vertical range of the ichnogenera (from Cambrian to Quaternary) does not allow their use for biostratigraphical purposes.

At present, there are not clear lines of evidence of the presence of ichnofossils within the Upper Permian layers in the Orobic Basin. The stratigraphic gap between the sedimentary cycles I and II, of uncertain age (lastly estimated as 14-25 My; Cassinis et al., 2002), should contain the last moments of an association addressed to the extinction, successively substituted by another assemblage with clearly modern features.

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