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A new Early Permian ichnocoenosis from the "Gruppo vulcanico atesino" (Mt. Luco, Southern Alps, Italy)

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SUMMARY - *A new Early Permian ichnocoenosys from the "Gruppo vulcanico atesino" (Mt. Luco, Southern Alps, Italy)* - The "Gruppo vulcanico atesino" (GA) belongs to the Lower Permian and reaches an areal extent of 2000 km^2 between the Periadriatic Lineament to NW and the Valsugana Line to the South, in the central Southern Alps. It consists of a continental volcano-sedimentary succession formed in an environment strongly conditioned by a contemporary tectonic activity. Geological mapping has revealed sedimentary levels laid down in small basins, preserved at different stratigraphical levels inside the volcanic succession. The deposits of one of the basins (Luco Basin) yielded a new, moderately well-preserved, Early Permian vertebrate ichnofauna. The ichnocoenosis includes three ichnotaxa ascribed to reptile trackmakers (cf. *Amphisauropus*, *Dromopus lacertoides*, *Dromopus* cf. *D. didactylus*) and one (cf. Batrachichnus) ascribed to amphibian. The radiometric age interval of the volcanites (Mt. Luco Fm.) that include the footprints-rich levels (Luco Basin) is between 279.6±1.5 My and 278.4±1.5 My. The ichnocoenosis here described results older than the Tregiovo ichnocoenosis and younger than the Collio Basin one. Consistently, it increases the confidence on the interval of occurrence of the Early Permian ichnoassemblage known in the region.

RIASSUNTO - *Una nuova icnoassociazione del Permiano inferiore dal "Gruppo vulcanico atesino" (M. Luco, Alpi Meridionali, Italia)* - Il "Gruppo vulcanico atesino" (GA) è riferito al Permiano inferiore e si estende nelle Alpi Meridionali su un'area di più di 2000 km^2 compresa tra il Lineamento Periadriatico a NW e la Linea della Valsugana a sud. Consiste in una successione vulcano-sedimentaria messasi in posto in un ambiente fortemente controllato dalla tettonica. Recenti lavori di cartografia geologica hanno masso in evidenza, a livelli diversi della successione, livelli sedimentari relativi a piccoli bacini. I depositi di uno di questi bacini (Bacino di Monte Luco) hanno restituito una icnofauna a vertebrati moderatamente preservata . L'icnoassociazione è composta da tre ichnotaxa attribuibili a rettili (cf. *Amphisauropus*, *Dromopus lacertoides*, *Dromopus* cf. *D. didactylus*) e uno (cf. Batrachichnus) attribuibile ad anfibi. L'intervallo cronologico delle vulcaniti che includono il Bacino del Monte Luco è compreso tra 279.6±1.5 Ma and 278.4±1.5 Ma. L'icnoassociazione qui descritta risulta più antica di quella della Formazione di Tregiovo e più recente di quella dei bacini di Collio. Per questo essa integra e affina la distribuzione cronostratigrafica delle icnofaune del Permiano inferiore conosciute nelle Alpi Merdionali.

Key words: Early Permian, ichnology, Southern Alps
Parole chiave: Permiano inferiore, icnologia, Alpi Meridionali

1. INTRODUCTION

In the central Southern Alps (Alto Adige/Südtirol), the whole Permian succession consists in two tectono-sedimentary cycles. The first involves infill of small intermountain grabens, or half grabens and is dominated by alluvial fan and lacustrine sediments. The second cycle, which begins above a marked unconformity, consists of fluvial, coastal sabkha and shallow marine carbonates (Italian IGCP-203 Research Group 1986; Cassinis *et al.* 1988; Krainer 1993; Massari *et al.* 1994).

The "Gruppo vulcanico atesino" (GA), mainly constituted by volcanic rocks, belongs to the lower cycle and reaches an areal extent of 2000 km^2 between the Periadriatic Lineament to NW and the Valsugana Line to the South (Fig. 1). The volcanic succession is related to a continental environment, strongly conditioned by a contemporary tectonic activity. The volcanites are made by dominant deposits of pyroclastic flow, with subordinate domes and lavas. They reach about 2500 meters of maximum thickness and lay throughout an unconformity either on the metamorphic basement or on continental basal conglomerates.

Clastic sediments are preserved into different stratigraphical levels inside the volcanic succession (Avanzini *et al.* 2007); they were deposited into small lakes, formed by volcano-tectonic processes within the GA, as sheet floods and debris flows. The deposits of one of these lacustrine basins (Luco Basin), consisting mainly of micaceous siltstones layers intercalated with stromatolitic carbonates, crop out along the eastern side of the Mt. Luco (Tisens, Bolzano/Bozen) and yielded a new, moderately well-preserved Early Permian vertebrate ichnofauna.

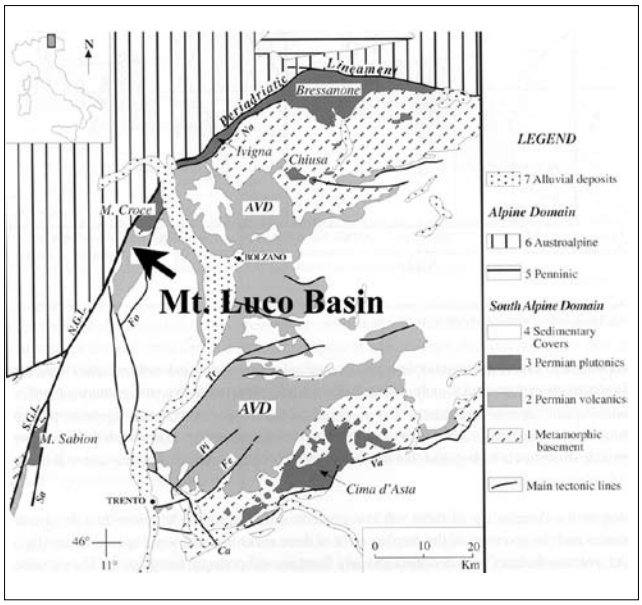

Fig. 1 - Location Map of the "Monte Luco". AVD= "Gruppo vulcanico atesino", S.G.L.= South Giudicarie Line, N.G.L.= North Giudicarie Line, Va= Valsugana Line.
Fig. 1 - Localizzazione del Monte Luco. AVD= "Gruppo vulcanico atesino", S.G.L.= Linea delle Giudicarie Sud, N.G.L.= Linea delle Giudicarie Nord, Va= Linea della Valsugana.

2. GEOLOGICAL SETTING

Several intervals of sedimentary rocks are present within the GA attesting to periods of volcanic quiescence. Fluvial-lacustrine sediments ("Tregiovo beds") cropping out near to the top of the GA were first described by Giannotti (1963) from a small volcano-tectonic sub-basin nearby of Mt. Luco (Tregiovo Basin) and were later studied by a number of workers (Avanzini *et al*. 2007). These studies showed that the "Tregiovo Beds" constitute a fining-upward succession of conglomerate and sandstones at the base, grading into fine-grained and laminated mudstones, stromatolitic carbonate and chert. *Dromopus didactylus* (Moodie 1930) footprints were reported from the Tregiovo Basin by Conti *et al*. (1997).

While the intervolcanic sediments are fairly well studied in the Tregiovo Basin, similar intervolcanic sediments are poor documented from other areas of the GA (Krainer & Spötl 1998; Avanzini *et al*. 2007). Recently mapped outcrops of both side of the Adige Valley between Bozen and Meran expose intevolcanic sediments macroscopically similar to "Tregiovo Beds", although significantly older (i.e. Guncina Fm. and Mt. Luco epiclastic units *sensu* Avanzini *et al*. 2007). The lacustrine interval here described is the oldest in the region. It consists of siliciclastic rocks ranging in grain size from conglomerates to siltstones. Discrete carbonate layers occur in the middle part of succession. Three facies association were recognised corresponding to different stages within the overall fining upward trend, showing also lateral interfingering (Fig. 2).

Lithozone a

Conglomerates occur in the lower portion of the Mt. Luco Basin. They are massive, poorly sorted and mostly matrix-supported. The matrix consists of fine to coarse-grained sandstone. Quartzite clasts, sub-rounded to rounded, entirely derive from metamorphic rocks of the South-Alpine Metamorphic Basement (Carboniferous). We interpret these conglomerates as matrix supported debris flow, deposited on alluvial fan or alluvial plain environments.

The basal lithofacies association shows a gradual upward transition into a several meters thick sandstone interval. Most sandstones are horizontally laminated, while cross bedded channel fills and small scale current ripples are less abundant. This interval is interpreted as sheet-flood deposits formed in the distal part of alluvial fans.

In this lithozone only scattered and poorly preserved specimens of *Dromopus* isp. have been recognised.

Lithozone b

The following lithozone is made-up of laminated limestones interbedded with dark gray, laminated silt and mudstones. Limestone beds are composed of alternating thin layers of algal laminites, dark micritic limestone, siltstone-mudstone, chert and rare caliche crusts. In some limestone layers small V-shaped cracks up to few millimetres deep and filled by calcite cements, are present. Limestone beds are locally brecciated *in situ*. Deposition of monotonous laminated mudstones and laminated cherty carbonate beds most likely occurred in a lacustrine environment, interfingered with alluvial silt and sandstone of the alluvial fans (Krainer & Spötl 1998). In analogy with modern lakes in semiarid setting (Renault & Tiercelin 1994), it is probable that these small lakes were meromittic or chemically stratified. The deep portion of the basin was probably occupied by dense saline water, whereas the upper part was presumably oxic and variably rich in biota. Algal laminites probably formed in this shallow water environment. Evidence of emersion includes shrinkage features and rare caliche crusts indicating pedogenic overprint during subaerial exposure. Several footprint rich layers and different ichnotaxa have been identified in this portion of the succession.

Lithozone c

The middle-upper part of the succession shows a gradual upward transition into a several tens of meter thick sandstone and conglomerate interval, very similar to the basal one. This interval is interpreted as sheet-flood and debris flow deposits formed during flash floods in a terminal stage of the basin evolution. Only footprints ascribed to *Dromopus* isp. are rarely preserved in the finest levels of this lithozone.

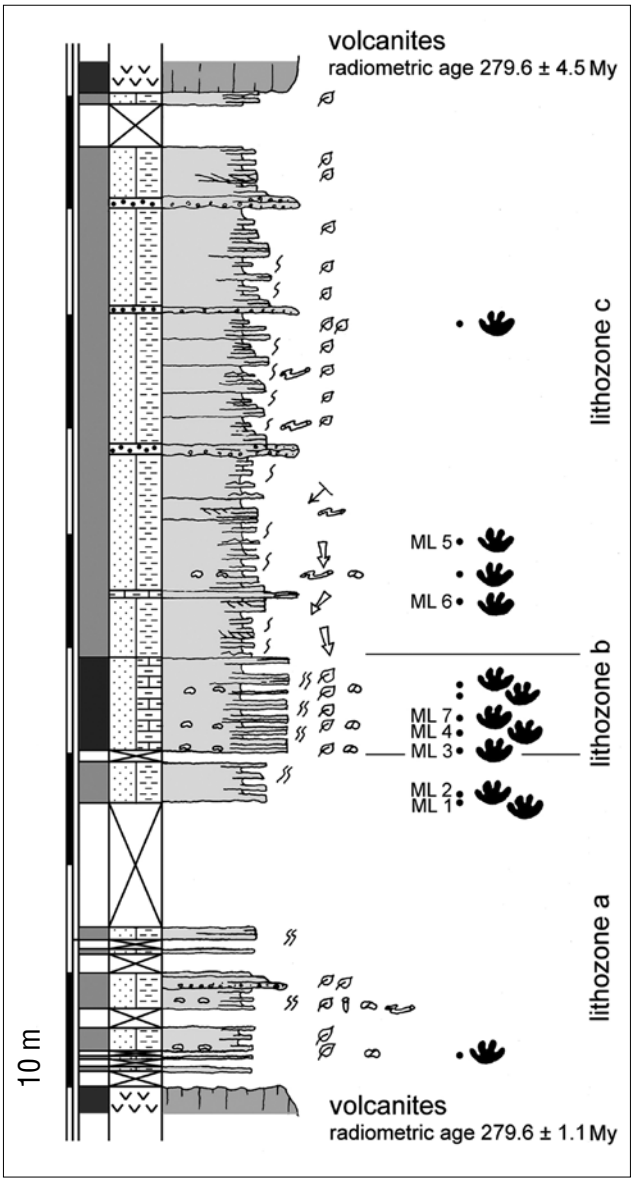

Fig. 2 - Stratigraphic log of the Mt. Luco Basin.
Fig. 2 - Colonna stratigrafica del Bacino del Monte Luco.

3. SYSTEMATIC ICHNOLOGY

The ichnocoenosis includes four ichnotaxa ascribed both to reptile and amphibian trackmakers, more specifically three of them were ascribed to reptiles (cf. *Amphisauropus* Haubold 1970, *Dromopus lacertoides* (Geinitz, 1861), *Dromopus* cf. *D. didactylus* (Moodie, 1930)) and one to amphibians (cf. *Batrachichnus* (Geinitz, 1861)). The ichnocoenosis therefore includes several of the ichnotaxa recognized within the first cycle sediments of the Alpine Permian sequence.

Ichnogenus *Amphisauropus* Haubold 1970 (Fig. 3d)

Description: semiplantigrade pentadactyl footprint, broader than long (width: 5.5 cm; length: 5 cm). Digits tips are rounded. Functional prevalence on digits I and II. The distal part of the digits are better impressed. Digit IV is the longest, digit V not clearly impressed.

Discussion: *Amphisauropus* is a well known track from Lower Permian red beds in Europe (Haubold 1973, 1996; Haubold & Lucas 2001). The Wolfcampian ichnofaunas of the south-west of the U.S.A. are taxonomically very similar to those of in the Rotliegende (Mossman & Place 1989) and *Amphisauropus* is there reported from the Robledo Mountains (Lucas *et al*. 2001).

In the Southern Italian Alps, *Amphisauropus* is a common ichnogenus with the two ichnospecies *A. latus* Haubold 1970 and *A. imminutus* Haubold 1970 in the Lower Permian Collio Formation (Ceoloni *et al*. 1987; Nicosia *et al*. 2005).

Ichnogenus *Dromopus* Marsh, 1894

Dromopus lacertoides (Geinitz, 1861) (Fig. 3c)

Description: Semiplantigrade to digitigrade pentadactyl footprint, near homopodous tracks with digit length increasing from I to IV. The digits are slender and gently curved, the distal phalanges curve inward. Pes digit V is relatively long and straight with variable curvature toward digit IV. Digits show claw marks. Manus prints are sometimes closely overstepped by the pes. The pes axis is usually directed outward, whereas the manus axis is directed inward.

Discussion: Despite their still unresolved ichnotaxonomic status (i.e. *D. agilis vs. D. lacertoides*), it is clear that *Dromopus* is the most common Early Permian lacertoid tracktype (Haubold 1996, 2000). *Dromopus lacertoides* is also common in the Collio Fm. (Ceoloni *et al*. 1987; Conti *et al*. 1991; Santi & Krieger 2001; Santi 2003, 2005)

Dromopus cf. *D. didactylus* (Moodie, 1930) (Figs 3a,3b)

Description: Semiplantigrade to digitigrade pentadactyl tracks, with digit length increasing from I to IV, very similar to *D. lacertoides*. The distinctive characteristic of this ichnospecies is the lack of the proximally sole pad and the proximally position of the pedal digit V.

Discussion: many misconceptions about the ichnotaxonomy of Permian lacertoid tracks are based on the large number of extramorphological varieties (Haubold *et al*. 1995a). The preservation characters of the Mt. Luco specimens allowed the preservation of the long expected variety of tracks. Tri- and didactyl pedal print are mixed in a variable pattern with more complete manus tracks. In originally wet muddy substrate, the pes tracks may totally disappear or preserve only the few digit tips. In other specimens the number of digits in both manus and pes is reduced. *D. didactylus* commonly appears with a characteristic didactyl preservation, but it appears clear that didactylity does not represent a ichnotaxonomic character, sufficient to discriminate species. Some of the best preserved Mt. Luco specimens show the lack of the pro-

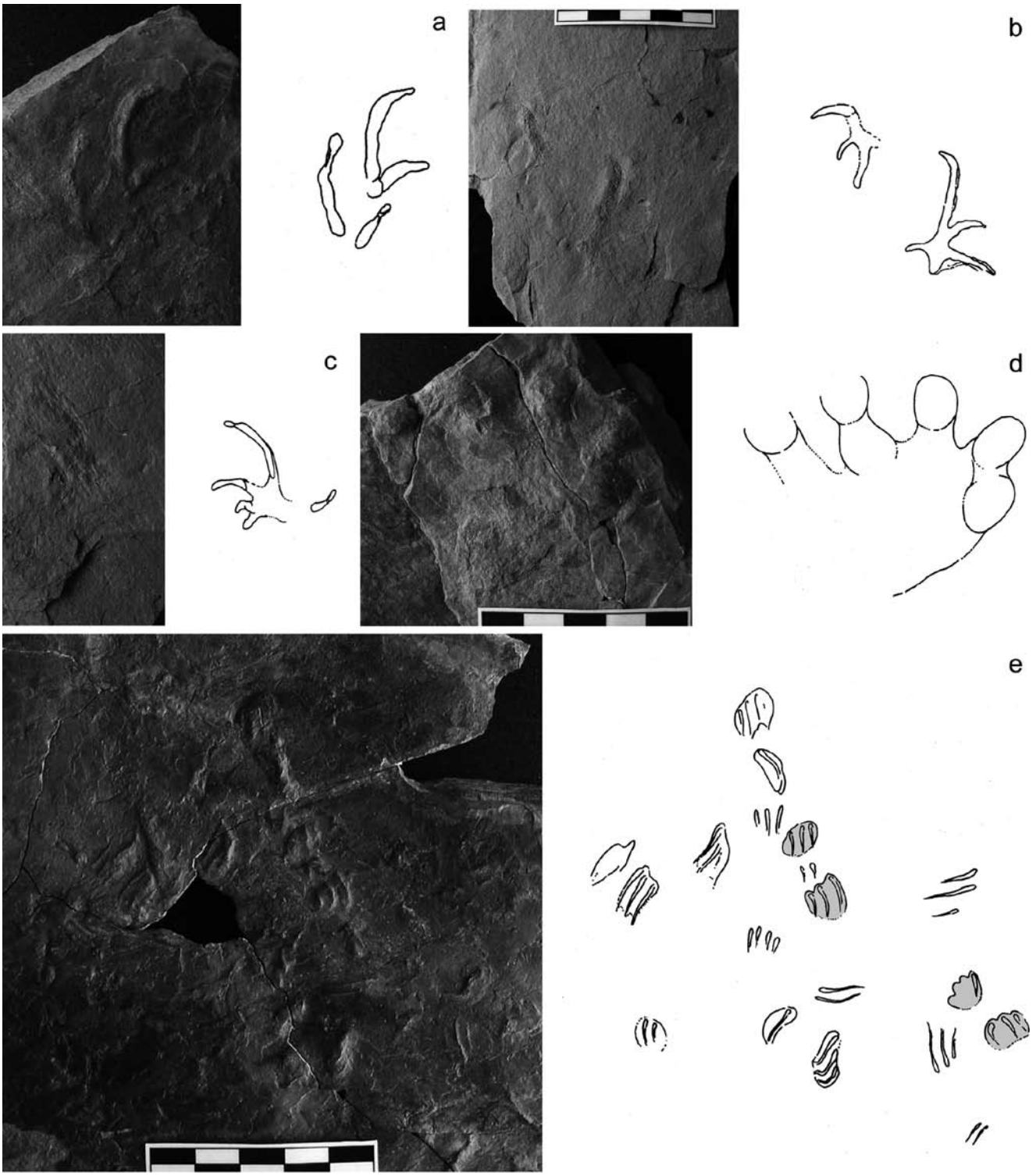

Fig. 3 - The tetrapod footprint from the Mt. Luco basin. a. and b. *Dromopus* cf. *D. didactylus* (Moodie, 1930), c. *Dromopus lacertoides* (Geinitz, 1861), d. cf. *Amphisauropus* Haubold 1970, e. cf. *Batrachichnus* Woodworth, 1900.
Fig. 3 - Orme di tetrapodi dal bacini del Monte Luco. a. e b. Dromopus *cf.* D. didactylus *(Moodie, 1930), c.* Dromopus lacertoides *(Geinitz, 1861), d. cf.* Amphisauropus *Haubold 1970, e. cf.* Batrachichnus *Woodworth, 1900.*

ximally sole pad and a proximally pedal digit V. On the basis of these characters where prudentially attributed to *Dromopus* cf. *D. didactylus*.

The presence of *D. didactylus* is commonly reported for the European red beds and for Late Pennsylvanian - Early Permian sedimentary units of the Robledo Mountain (Haubold *et al*. 1995b).

In Southern Alps *D. didactylus* is reported in the Val

Trompia Basin in association with other ichnotaxa, while in Tregiovo Basin it is the exclusive ichnotaxon (Conti *et al*. 1989; Nicosia *et al.* 2005).

Ichnogenus *Batrachichnus* Woodworth, 1900 (Fig. 3d)

Description: Ichnites of a very small quadruped. Trackway pattern characterized by pace angulation of around 80-90°. Pes plantigrade to semiplantigrade, pentadactyl. Digits I to III closely grouped together with increasing length, digit IV is the longest, digit V set posteriorly and laterally. Manus semiplantigrade, tetradactyl, smaller than the pes, digits increasing in length from I to III, digit IV outwardly diverging.

Discussion: The Mt. Luco specimens are attributed to cf. *Batrachichnus*, but due the poor preservation a sure attribution results impossible. The specimens show a transition from plantigrade, pentadactyl tracks, to that of a characteristic digitigrade undertrack. Some specimens exhibit an extreme of undertrack effects, sometimes in combination with overstepping of the manus by the pes.

Batrachichnus salamandroides (Geinitz, 1861) is a common ichnospecies in the Collio Fm. both of the Orobic and Trompia basins.

4. AGE AND MEANING OF THE ICHNOFAUNA

The ichnotaxa recognised within the sediments of the first tectono-sedimentary cycle of the Alpine Permian sequence constitute a relatively rich ichnoassociation (Avanzini *et al*. 2001). It was tentatively considered as a "Faunal Unit" under the name of "Collio Faunal Unit", further subdivided in two "Faunal subunits" named as "Pulpito Faunal subUnit" and "Tregiovo Faunal subunit" (Conti *et al.* 1997). To each of them was also ascribed a biochronological value with the names of "Collio Faunal Age" ("Rabejac Faunal subAge" and "Tregiovo Faunal SubAge"). The ichnoassociation is mainly based on data as recorded in the Collio Basin (Collio Fm.; Cassinis 1966; Cassinis & Doubinger 1991b), in which several footprint-bearing levels were recognised along a nearly 700 m thick sedimentary succession (Geinitz 1869; Curioni 1870; Berruti 1969; Ceoloni *et al.* 1987; Conti *et al.* 1991). The ichnocoenosis includes reptile footprints (?*Camunipes cassinisi* Ceoloni *et al.* 1987, *Varanopus curvidactylus* Moodie 1929, *Amphisauropus latus* Haubold 1970, *Ichniotherium cottae* (Pohlig, 1885) Pohlig 1892, *Dromopus lacertoides* (Geinitz 1861), *D. didactylus* (Moodie 1930)) and less frequent amphibian footprints (*Batrachichnus salamandroides* (Geinitz 1861), Haubold 1996).

This set of data was compared with data coming from sediments cropping out in other localities of the Eastern Southern Alps and in the Tregiovo Basin (Conti *et al.* 1997).

The Tregiovo fauna differs in showing a monotypic ichnoassociation in which only *Dromopus didactylus* is well represented.

The volcanic products interbedded in the Collio Basin gave an U/Pb age among 283±1 My and 281±2 My (Schaltegger & Brack 1999), while recent radiometric investigation of Tregiovo Formation yielded an age between 276.9±2.3 My and 277.0±2.0 My (Avanzini *et al*. 2007). Using floristic data (Cassinis & Doubinger 1991a) for correlation, and constraining the ages of the base and the top by radiometric data, it results that the time interval in which this Permian ichnofauna is widespread in Northern Italy is limited between about 283 My BP, at the base, and 277 My BP at the top (Schaltegger & Brack 1999; Avanzini *et al*. 2007).

The radiometric age interval of the volcanites that include the footprints-rich levels here described (Luco Basin) is between 279.6±1.1 My (Ryodacitic Lavas at the base) and 279.6±4.5 My (Andesite Lavas at the top).

Consistently, the here described ichnocoenosys, referable to an age of about 279-280 My (Artinskian *p.p.* - Kungurian *p.p.*), results younger than the association of the Collio and Orobic basins and more ancient than the Tregiovo Basin one. From a biochronological point of view, the ichnoassemblage well corresponds to the "Pulpito Faunal subunit" ("Collio Faunal Unit") and to the "Rabejac Faunal subAge" ("Collio Faunal Age") *sensu* Conti *et al.* (1997). This is confirmed by the radiometric ages, increasing therefore the confidence on the interval of occurrence of the Early Permian ichnoassemblage in the region.

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