

## Norian dinosaur footprints from the “Strada delle Gallerie” (Monte Pasubio, NE Italy)

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**SUMMARY** - *Norian dinosaur footprints from the “Strada delle Gallerie” (Monte Pasubio, NE Italy)* - An association of 11 dinosaurian footprints from the Dolomia Principale formation of the Monte Pasubio is described and figured. It was found, preserved as convex hyporelief, on the roof of the 12th gallery of the “Strada delle Gallerie”, dug in 1917, during the First World War. The association consists of three main morphotypes and other scattered prints. Morphotype A together with some isolated footprints is assigned to sauropodomorpha trackmakers; morphotypes B and C to small and large theropods, respectively. This association, more than being the first record of dinosaurian footprints on the Prealpi Vicentine, is the first found *in situ* in the Dolomia Principale Fm. This allowed conodont biostratigraphic investigation that confirmed the Norian age of the trampled layer.

**RIASSUNTO** - *Orme di dinosauro noriche della “Strada delle Gallerie” (Monte Pasubio, NE Italy)* - Viene descritta e illustrata un’associazione di 11 impronte di dinosauri rinvenuta sul Monte Pasubio all’interno della formazione della Dolomia Principale. Le impronte sono state ritrovate, conservate come calchi naturali, sulla volta della 12<sup>a</sup> galleria della “Strada delle Gallerie”, scavata dal genio militare nel 1917, durante la Prima Guerra Mondiale. L’associazione è costituita da tre morfotipi e da altre orme isolate. Il morfotipo A viene attribuito a dinosauri sauropodomorfi, mentre i morfotipi B e C a teropodi rispettivamente di piccole e grandi dimensioni. Questa associazione, oltre ad essere la prima segnalazione di impronte dinosauriane nelle Prealpi Vicentine, è anche la prima ad essere stata ritrovata *in situ* all’interno della Dolomia Principale. Questo ha consentito indagini biostratigrafiche tramite conodonti che hanno confermato l’età Norica dello strato, in accordo con le informazioni icnologiche.

*Key words:* Monte Pasubio, dinosaurs footprints, Upper Triassic, Dolomia Principale, conodonts

*Parole chiave:* Monte Pasubio, impronte di dinosauri, Triassico superiore, Dolomia Principale, conodonti

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### 1. INTRODUCTION

During the First World War, in order to repel Austro-Hungarian attempts to advance toward the Venetian plain, the Italian command garrisoning the Pasubio Massif found necessary to build a safe mule-track to connect the main road through Bocchetta Campiglia to Schio and Vicenza and the Porte del Pasubio. The task was assigned to the 33<sup>o</sup> Compagnia Minatori of the 5<sup>o</sup> Reggimento Genio that had to negotiate a drop of 712 metres, going through cliffs, overhanging faces and canyons (Pieropan 1978). The track, created in 1917, consists of a large path originally cut by means of 50 tunnels, numbered from Bocchetta Campiglia (Fig. 1). Hereby the name of the track, “Strada delle Gallerie”, that is now often frequented by hikers.

During an excursion, one of the authors (M.A.) noticed on the roof of the 12th gallery (dedicated to cap. Leopoldo Motti) a number of bulges immediately attributed to dinosaur footprints preserved as natural casts.

The ichnites lay within the Dolomia Principale Fm., an Upper Triassic tidal formation present everywhere in the Southern Alps.

Many dinosaurian footprints have already been found and described from this unit, (M. Pelmetto: Mietto 1988; Tre Cime di Lavaredo: Mietto 1990; Prealpi Carniche: Dalla Vecchia & Mietto 1998; Altopiano di Puez: Leonardi & Mietto 2000), but this is the first record on the Prealpi Vicentine, the only one found *in situ*, and not in fallen boulders.

### 2. LOCALITY AND GEOLOGICAL SETTING

The Pasubio Massif is set in the north-western region of the Prealpi Vicentine and develops mainly in the Trento territory. It shares its geological history and stratigraphic succession with the southernmost Recoaro region (locally called Recoarese).

It can be reached from Schio (Vicenza) by the Val Leogra road (SP 46 del Pasubio), or from Rovereto (Trento) by the Vallarsa Road (SP 46 del Pasubio). At about 17 km from Schio, in Ponte Verde, a secondary road to Posina begins. At Colle Xomo (1058 m) the road, known as the “Strada degli Scarubbi”, leads to a parking area at of Bocchetta Campiglia (1216 m) where the “Strada delle Gal-



Fig. 1 - A 1917 picture taken at the entrance of Galleria 10.  
Fig. 1 - Foto del 1917 all'entrata della Galleria 10.

lerie" begins. It climbs the south-eastern and southern faces of Monte Forni (2023 m), to the Passo di Fontana d'Oro (1875 m), and then continues on beneath the ridge of Mount Cimon del Soglio Rosso (2040 m) and ends at the Porte del Pasubio (Fig. 2).

Geologically, the southern face of the Pasubio Massif consists of the Dolomia Principale Fm., that here sits directly on the Upper Ladinian altered and pedogenized volcanites, as a transgressive conglomerate (De Zanche & Mietto 1977; De Vecchi *et al.* 1986).

In other places on the Recoarese, where the volcanic cover has been removed, the Dolomia Principale Fm. lies unconformably directly on the palaeokarstic surface of the Lower Ladinian Calcare del Monte Spiz Fm. (De Zanche & Mietto 1977; 1988).

Elsewhere, under the Dolomia Principale Fm, lays the Travenanzes Fm. (Gruppo di Raibl *sensu* De Zanche & Mietto 1977; Barbieri *et al.* 1980).

In the Cerbaro section (Tretto Schio), De Zanche & Mietto (1988) defined the base of the Dolomia Principale Fm. as Carnian. Based on sequence-stratigraphic data, this interpretation was later extended to the whole Southern Alps (De Zanche *et al.* 1993; Gianolla *et al.* 1998).

The upper boundary between the Dolomia Principale and the Monte Zugna Fm. (Calcari Grigi *Auct.*) has been defined at Cima Marana (Recoaro) using brachiopod faunas. This allowed the association of this lithostratigraphic horizon with the Rhaetian-Hettangian boundary (Mietto 1977).

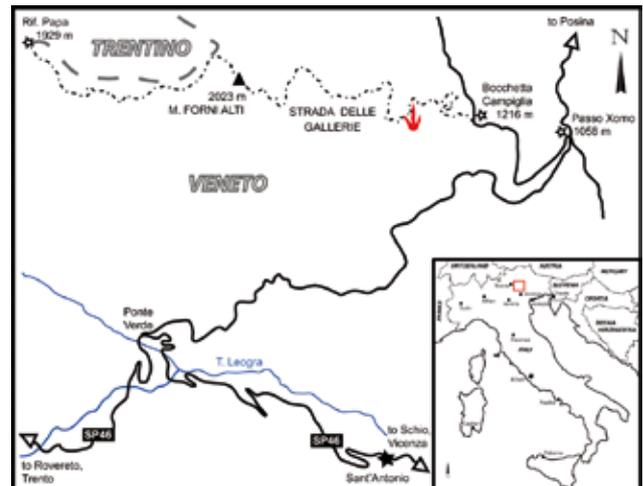


Fig. 2 - Location Map of the "Strada delle Gallerie" and the footprint site.

Fig. 2 - Localizzazione geografica della "Strada delle Gallerie" e del sito ad orme.

In the Recoarese area the Dolomia Principale Fm. has a reduced (900 metres) thickness and consists of a sequence of peritidal-subtidal cycles (Bosellini & Hardie 1988).

The "Strada delle Gallerie" path starts from the lower part of the Dolomia Principale, where a yellowish flamed aphanitic dolostone outcrops. Above this, begins the massive bioturbated and fossil-rich dolostone, typical of subtidal facies.

The trampled surface lays about 500-550 m above the base of the formation (Fig. 3), at the base of a subtidal layer that constitutes the lower portion of a typical peritidal cycle (Bosellini 1967).

Above this unit starts the peritidal sequence that consists of several-meter-thick peritidal cycles, almost always topped by thick stromatolitic intervals.

### 2.1. Age of the trampled layer

A rock sample of Dolomia Principale (ca. 4.5 kg), collected immediately below the trampled surface, has been worked for conodont investigations in order to better understand the age of the ichnological association. Unexpectedly we recovered an advanced *Epigondolella praeslovakensis* Kozur, Masset & Moix 2007 (in Moix *et al.* 2007) transitional to *Mockina slovakensis* Kozur 1972 characterized by a slightly bifurcated keel, along with a real *Mockina slovakensis* Kozur 1972 (Fig. 4).

Recently, Moix *et al.* (2007) revised the *Mockina slovakensis* population using paleontological and biostratigraphic criteria and recognized a new species, that is *Epigondolella praeslovakensis* Kozur, Masset & Moix from which *Mockina slovakensis* Kozur directly descended. Moreover, because of this revision based on their material and data from literature, Moix *et al.* (2007) deduced the age of the two species, concluding that *Epigondolella praeslovakensis* is middle

to late Alaunian (middle Norian) in age and that a conodont assemblage composed only of *Mockina slovakensis* is assigned to the Sevatian (upper Norian), even if its FAD is latest

Alaunian (Channell *et al.* 2003). Thus, the co-occurrence of advanced *Epigondolella praeslovakensis* and *Mockina slovakensis* is latest Alaunian in age (Moix *et al.* 2007).

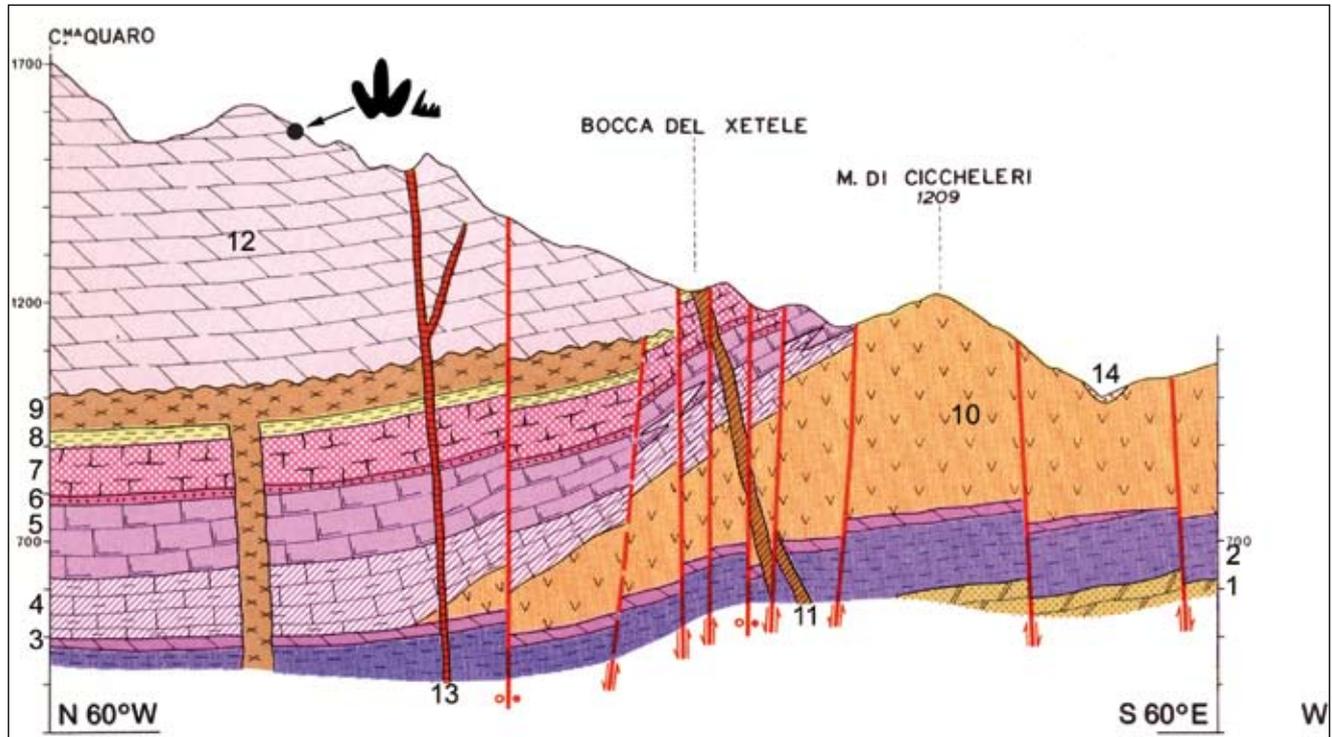
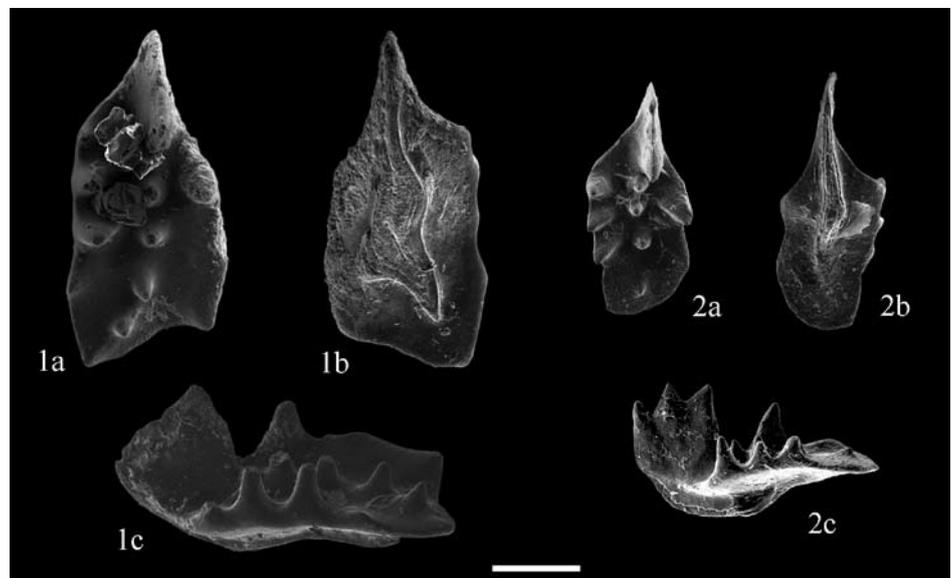


Fig. 3 - Geological profile through the "Strada delle Gallerie" path. (De Vecchi *et al.* 1986, modified). 1. Bellerophon Fm. (Upper Permian); 2. Werfen Fm. (Lower Triassic); 3. Dolomia del Serla Inferiore Fm.; 4. Gracilis and Voltia Fms. (Aegean-Bithynian); 5. Calcare di Recoaro Fm.; 6. Conglomerato del Tretto Fm. (Illyrian); 7. Calcare di M. Spiz (Illyrian); 8. Nodosus Fm. (Illyrian - Lower Longobardian); 9. Longobardian volcanites; 10. subvolcanic products (Longobardian); 11. Rhyolitic dikes (Longobardian); 12. Dolomia Principale Fm. (Tuvalian - Rhaetian); 13. Basaltic dikes (Upper Paleocene - Oligocene); 14. Debris.

Fig. 3 - Sezione geologica attraverso la "Strada delle Gallerie" (De Vecchi *et al.* 1986, modificata). 1. Fm. a Bellerophon (Permiano Superiore); 2. Fm. Werfen (Triassico Inferiore); 3. Dolomia del Serla Inferiore; 4. Fm. a Gracilis e Strati a Voltia (Aegeano-Bitnico); 5. Calcare di Recoaro; 6. Conglomerato del Tretto (Illirico); 7. Calcare di M. Spiz (Illirico); 8. Fm. a Nodosus (Illirico - Longobardico inferiore); 9. Vulcaniti longobardiche; 10. prodotti subvulcanici (Longobardico); 11. Dicchi Riolitici (Longobardico); 12. Dolomia Principale (Tuvalico - Retico); 13. Dicchi basaltici (Paleocene superiore - Oligocene); 14. Coperture detritiche.

Fig. 4 - SEM micrographs of conodonts in the Dolomia Principale Formation of the "Strada delle Gallerie", Monte Pasubio. 1a-c. *Epigondolella praeslovakensis* Kozur, Masset & Moix, Dolomia Principale Fm., sample "SG"; 2a,b. *Mockina slovakensis* (Kozur), Dolomia Principale Fm., sample "SG". Scale bar 100  $\mu$ m.

Fig. 4 - Microfotografia SEM dei conodonti rinvenuti nella Dolomia Principale della "Strada delle Gallerie", Monte Pasubio. 1a-c. *Epigondolella praeslovakensis* Kozur, Masset & Moix, Dolomia Principale., campione "SG"; 2a,b. *Mockina slovakensis* (Kozur), Dolomia Principale., campione "SG". Scala 100  $\mu$ m.



### 3. METHODS

Because of the position of these tracks on the roof of the gallery, and the irregular and slippery floor, a classical survey was very difficult. Thus it was done with photographic techniques and using a photo editing software (*Fotoraddrizzamento 1.2*©). A picture of each footprint was taken, together with a reference square. Then the pictures were treated with *Fotoraddrizzamento 1.2*©, that restored them to the original proportion using the reference square. Because of its position, very close to the boundary of the slab, where only a high angled photo was possible, footprint “SG- IX” was recorded using a transparent plastic overlay. The comparison between the two methods shows up any inconsistencies, so the reliability of this method is checked.

Then, once treated, the footprints were scaled, measured and redrawn.

All the prints were left *in situ* and named with the prefix SG (Strada delle Gallerie): e.g., SG-I, SG-XI.

### 4. ICHNOLOGICAL DESCRIPTIONS

The track surface is situated on the roof of the 12th tunnel (Galleria Cap. Motti: about 1550 m a.s.l), overlooking a window. The impressed surface measures 4.5 metres in length and 2.5 in width, and dips northward at 20° (Fig. 5).

The trampled slab reveals 11 dinosaurian footprints, generally poorly preserved, both of bipedal and quadrupedal trackmaker. Usually they occur in convex hyporelief, but in some cases they are broken, so that, due to the fracture, the footprints look like an impression rather than a cast.

Two groups of footprints, that include different morphotypes, can be recognized: tetradactyl and tridactyl (for labels see Tab. 1 and Fig. 6).

#### 4.1. Tetradactyl footprints

##### Morphotype A

Morphotype A includes three pedal prints (SG-IV, SG-VIII, SG-IX). In SG-VIII and SG-IX not all the digits occurs because of the poor preservation.

“SG- IV” is the biggest of the group and of all footprints on the trampled surface. It is a digitigrade tetradactyl footprint, probably more than 30 centimetres long and 35 wide. The four straight and deep digits impressions are anteriorly oriented. Digits appear completely separated along their length and almost parallel. The distal end of digit III is the most anteriorly extended and digit I is the shortest.

“SG- VIII” appears as three not very thick, elongated and wide bulges even though measurement is difficult. It has been attributed to this group, because of its affinity in shape and size to “SG- IV”.

“SG- IX” shows a quite wide and long III digit, with posterior hypex. Both digits II and IV are wide and long. The

interdigital angles are extremely low so that the digits look almost parallel. No claws or pad impression are visible.

Two further isolated tetradactyl footprints (SG-I and SG-VI) cannot be assigned to the previous group: “SG- I” is the only impression showing a possible manus-pes couple. The pes is apparently tetradactyl, with short straight anteriorly directed digits (L: 14.5 cm, W: 23 cm). Digit I is the longest, while digits II-IV are shorter and almost separated along their axis. Digit IV lies posteriorly with respect to the digits II-III. The proximal (plantar) part of the foot is not impressed but an elliptical structure, possibly related by the proximal region of the foot is recognisable. Basing on the position of digit I, the footprint has been considered as right.

Manual print is wider (10 cm) than long (8 cm) (see Fig. 6), and seems tridactyl and mesaxonic with a marked heteropody. The shape is slightly crescentic and no clear digit impressions occur, mostly because of the bad preservation. It lies anteriorly and externally with respect to the pes.

“SG- VI” shows three poorly preserved digits, parallel and slightly bent inward. It is slightly longer than wide (L: 20 cm, W: 18 cm). Probably they represent a partially preserved tetradactyl digitigrade footprint in which only digits I, II and III are preserved. Digit IV could correspond to a hollow present near digit III and due probably to breaking of the slab. Digit III is dominant while digit II and IV (the hollow) are slightly shorter. The distal portion of digits III and II are deeper than those of digit I suggesting a reduced weight bearing role of digit I.

#### 4.2. Tridactyl footprints

Tridactyl footprints can be divided in two groups, according to the criteria described below (Tab. 1).

##### Morphotype B

It includes three footprints (SG- II, SG- III, SG- V) and presents medium-small dimensions (around 20 cm in length). It is a markedly longer than wide print (L/W = 1.6), with a long digit III and a narrow II-IV divarication angle. Digits are slender and digit III is the longest in each footprint. No clear claw mark is present, but all the three footprint digit traces have pointed ends.

“SG- II” is the worst preserved of this morphotype. It shows clearly only digit III which is long and narrow. Digits II and IV are slightly impressed, and no hypices are evident. One elongated and pointed impression in the distal part could be possibly related to the metatarsal impression or to digit I.

“SG- III” has the narrower digit impression, probably due to sediment re-flowing, but is the most complete footprint of the morphotype. No clear pad impression is present, even though the outline of digit III suggests the occurrence of some slight pad morphology.

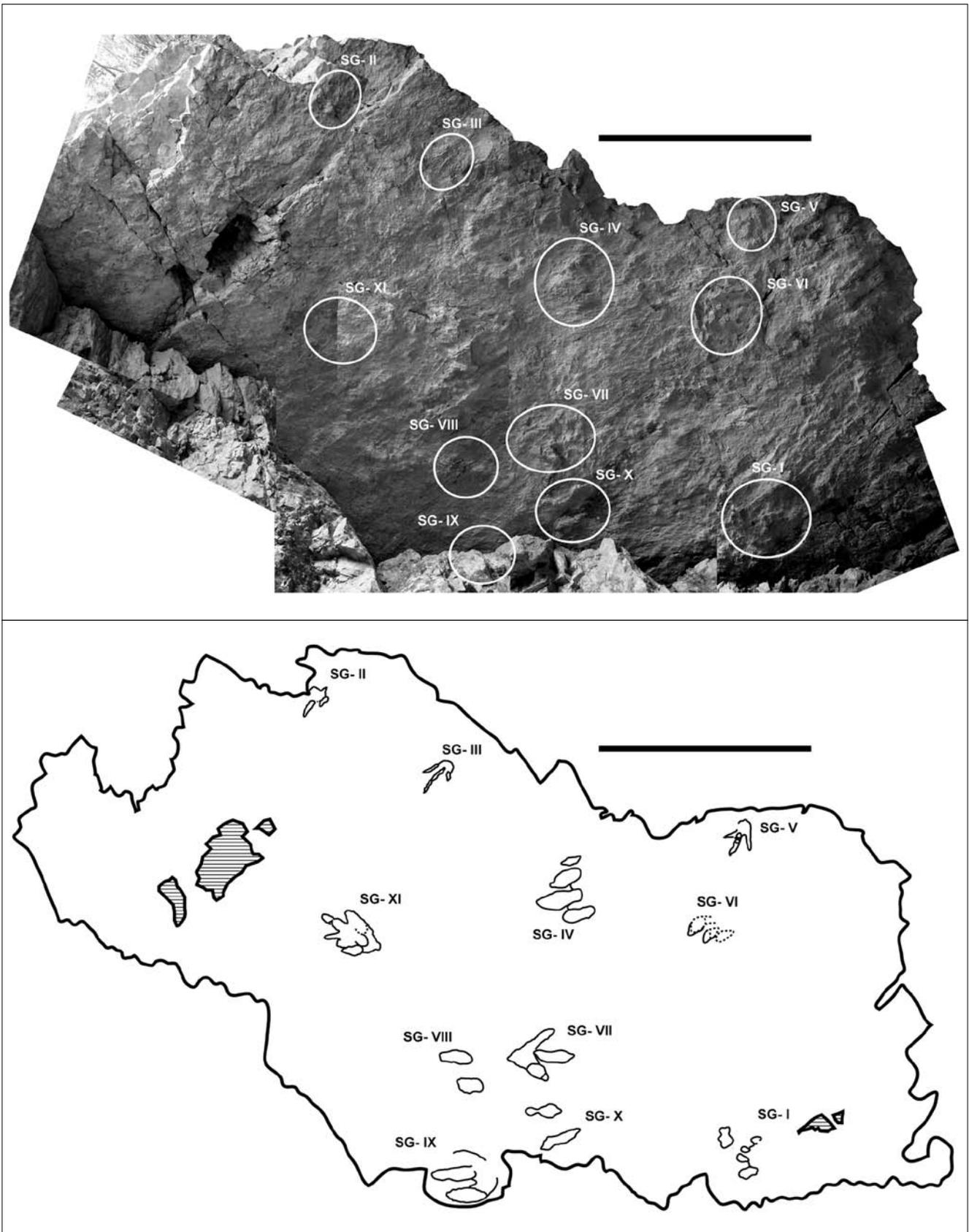


Fig. 5 - Picture of the trampled surface in the 12<sup>th</sup> Gallery and interpretative drawing of footprints. Scale bar 1 m.  
Fig. 5 - Foto della superficie con le orme nella Galleria 12 e disegno interpretativo della stessa. Scala 1 m.

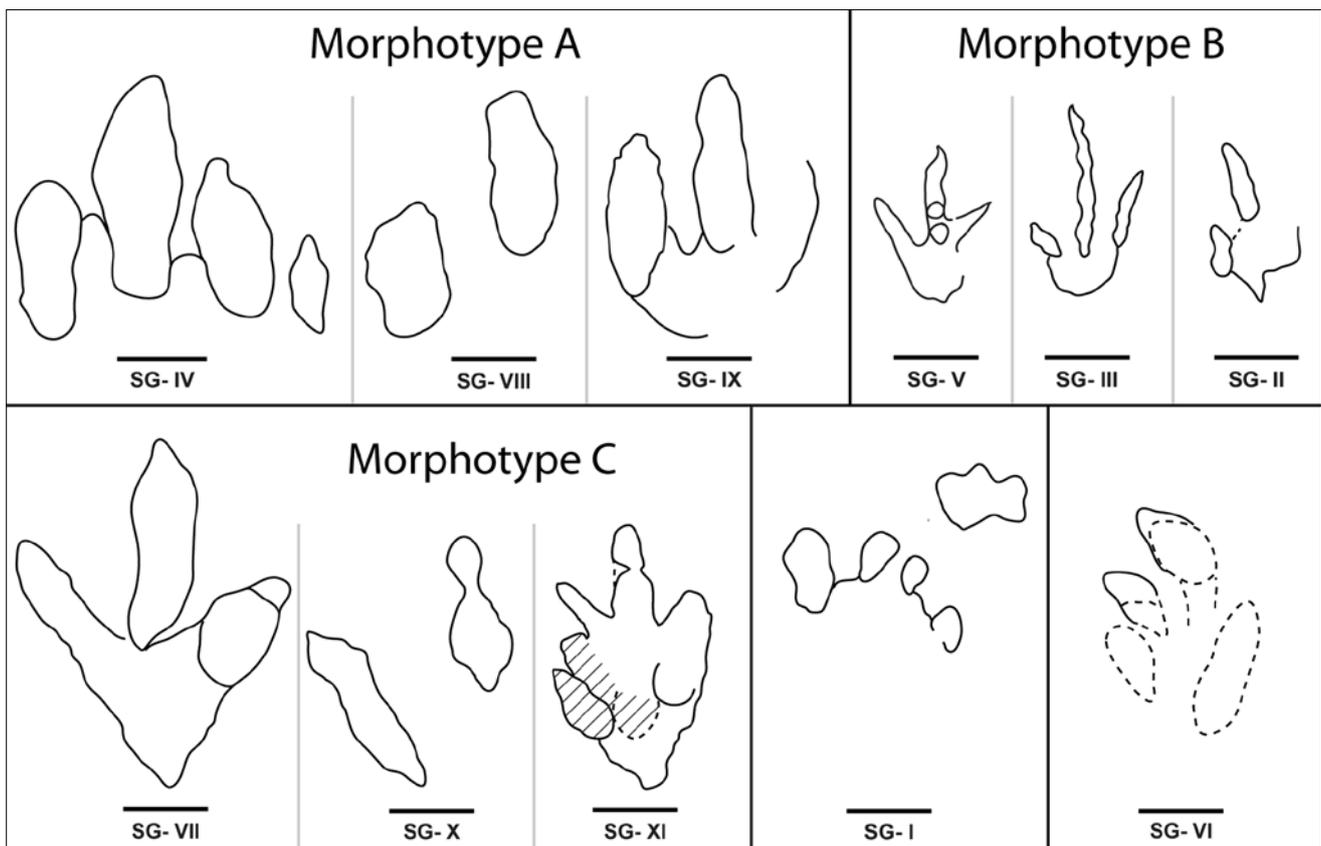


Fig. 6 - Dinosaur footprints of the "Strada delle Gallerie". Scale bar 10 cm.

Fig. 6 - Le orme di dinosauro della "Strada delle Gallerie". Scala 10 cm.

"SG- V" appears to have a clear impression of digits III and IV, while II is only slightly visible.

A sub-triangular heel is present. Two pads impression seems to occur on the digit III, but the poor preservation doesn't allow us to determine this with certainty.

#### Morphotype C

Morphotype C includes the three larger footprints: SG-VII, SG- X and SG- XI (L more than 30 cm, and W more than 18 cm). Only a few of them are well preserved.

Footprint "SG- VII" was broken so that only the digit II trace has clear relief with one recognisable pad impression. The remaining parts of the footprint are poorly outlined. The "heel" has a pointed shape.

"SG- X" shows only two digit impressions, probably II and III. It is quite wide and slightly bent. Probable pad impressions are visible in the proximal part of digit III, that taper distally.

Footprint "SG- XI" is composed of the over-impression of two footprints of different sizes. The first is a medium-sized tridactyl footprint, with a possible metatarsal impression that can be assigned to this morphotype. Because of the impression of the second smaller tridactyl footprint any other detail cannot be recognized.

#### 5. ICHNOTAXONOMY

The poor preservation of most the footprints, doesn't allow us to make a detailed ichnotaxonomical evaluation. Nevertheless in some of these tracks diagnostic characteristics are preserved, so it is possible to suggest some tentative attributions.

Among tetradactyl footprints, morphotype A, and especially "SG- IV", because of the apparent bipedal gait and the occurrence of four long subparallel digits, can be assigned tentatively to a sauropodomorph-like track very close to the ichnogenus *Pseudotetrasauropus* Ellenberger 1972.

"SG- I" shows a peculiar morphology that suggests that it is a quadrupedal sauropodomorph trace. The extremely poor preservation prevents further taxonomical classification.

The shape of SG- VI does not show the typical features of a tridactyl print. If the hollow near digit III really corresponds to a broken digit, the footprint could results a tetradactyl digitigrade print very similar to *Evazoum* Nicosia & Loi 2003, close in shape to those that were recently identified in the Travenanzes Fm. of the Adige Valley (D'Orazi Porchetti *et al.* 2008).

Among tridactyl footprints, morphotype B, with an elongated digit III and the narrow interdigital angles, can

Tab. 1 - Measures of the footprints from Monte Pasubio (SG). In centimetres (degrees for angular parameter). L= print length; W= print width; I/II/III/IV l= I/II/III/IV digit length; I/II/III/IV w= I/II/III/IV digit width; II/III/IV fdl= II/III/IV free digit length; I-IV= interdigtal angle between digits I and IV; II-III= interdigtal angle between digits II and III; III-IV= interdigtal angle between digits III and IV; II-IV= interdigtal angle between digits II and IV; ( )= approximate measurement; —= data not measured because of the poor preservation.

Tab. 1 - Misure delle impronte del Monte Pasubio (SG). In centimetri (gradi per i parametri angolari). L= lunghezza dell'impronta; W= larghezza dell'impronta; I/II/III/IV l= lunghezza diti I/II/III/IV; I/II/III/IV w= larghezza diti I/II/III/IV; II/III/IV fdl= lunghezza dito libero dei diti II/III/IV; I-IV= angolo interdigtale tra i diti III e IV; II-III= angolo interdigtale tra i diti II e III; III-IV= angolo interdigtale tra i diti III e IV; II-IV= angolo interdigtale tra i diti II e IV; ( )= misure approssimative; —= dato non misurabile a cause della cattiva conservazione.

	L	W	I l	I w	II l	II w	III l	III w	IV l	IV w	I-IV°
SG- I pes	15.1	20.3	10.3	5.1	6.3	3.5	4.7	3.0	3.1	3.8	—
SG- VI	27.2	18.3	9.9	4.4	10.4	4.8	15.2	6.1	16.5	4.9	(51)
<i>Morphotype A</i>											
	L	W	I l	I w	II l	II w	III l	III w	IV l	IV w	
SG- IV	31.5	36.9	11.8	4.6	19.4	8.7	26.7	9.2	18.8	7.5	
SG- VIII	—	(29.5)	—	—	—	—	19.8	7.7	15.8	8.6	
SG- IX	31.6	25.3	—	—	16.4	6.9	21.4	6.2	—	—	
<i>Morphotype B</i>											
	L	W	II fdl	II w	III fdl	III w	IV fdl	IV w	II-III°	III-IV°	II-IV°
SG- II	(19.3)	(11.3)	—	2.4	(9.4)	2.3	—	—	—	—	—
SG- III	22.5	14.9	4.8	1.9	18.0	1.9	9.4	1.6	16	14	30
SG- V	18.3	13.4	—	—	10.2	2.0	7.7	2.0	(26)	25	(51)
<i>Morphotype C</i>											
	L	W	II fdl	II w	III fdl	III w	IV fdl	IV w	II-III°	III-IV°	II-IV°
SG- VII	41.7	32.5	(10.6)	7.7	(24.6)	6.8	(16.4)	4.6	(30)	32.0	(62)
SG- X	29.6	—	—	—	18.8	5.9	(12.3)	5.7	—	(28.0)	—
SG- XI	(30.5)	19.0	(5.3)	5.0	(12.5)	4.3	7.6	2.4	22.0	31.0	53.0

be generically attributed to cf. *Grallator* Hitchcock 1858. But, for some of the footprints of this group (i.e. SG-V) an attribution to an *Atreipus*-like footprint also seems possible. The very bad preservation of the material excludes further inferences.

We are confident that morphotype C, shows close similarities with ichnogenus *Eubrontes* Hitchcock 1845.

## 6. CONCLUSIONS

Despite the small dimension of the surface, and the bad preservation of the footprints, a varied ichnoassociation is present, with the occurrence of both large and small theropod and sauropodomorph tracks. It shows great similarities with

the Late Triassic ichnoassociation from other localities of the Southern Alps. Large theropods are present in the Dolomia Principale Fm. of the Tre Cime di Lavaredo (Mietto 1990), at the Dolomites (Leonardi & Mietto 2000) and Carnia (Dalla Vecchia & Mietto 1998) localities, while small theropod and prosauropod footprints occur in Carnia (Dalla Vecchia & Mietto, 1998) and the Dolomites (Mietto, 1988).

The “Strada delle Gallerie” ichnoassociation differs from the Carnian Monte Pelmetto and Adige Valley ichnofaunas (Mietto, 1988) in lacking the so-called “basal ornithischian” and crurotarsan ichnites (Leonardi & Mietto, 2000; D’Orazi Porchetti & Nicosia 2007, D’Orazi Porchetti *et al.* 2008).

As described before, the Dolomia Principale Fm. spans the Carnian to the Rhaetian. So, in the whole formation, we

could possibly recognise the faunal turnover described by Klein & Haubold (2007) consisting in the replacement of the Carnian *Atreipus* – *Grallator* dominated ichnofaunae (*Atreipus* – *Grallator*-*Brachychirotherium* biochron) by Norian *Eubrontes* – *Grallator* dominated (*Eubrontes* – *Grallator*-*Brachychirotherium* biochron) ichnocoenosis.

Worldwide, *Brachychirotherium* appears in the Middle Triassic (Karl & Haubold, 2000) and occurs in North America up to the Triassic-Jurassic boundary (Szajna & Hartline 2003; Olsen *et al.* 2002) and so has limited chronostratigraphic value. *Pseudotetrasauropus*, *Tetrasauropus*, *Evazoum Kalosauropus* and *Atreipus* are common in the Carnian-Norian of South Africa, North America, Italy and France (Klein *et al.*, 2006). *Grallator* is widely distributed between the Carnian and Lower Jurassic, with occurrences in Germany, Great Britain, Switzerland, France, Sweden, Greenland, North America and *Eubrontes* is typical of the Norian-Lower Jurassic interval (Lucas *et al.* 2006).

The occurrence of large tridactyl footprints attributed to *Eubrontes* in the “Strada delle Gallerie ichnoassociation, seems consistent with the uppermost Middle Norian age of the site (*Eubrontes* – *Grallator* biochron *sensu* Klein & Haubold, 2007). This is confirmed by the latest Middle Norian (latest Alauian) age indicated by conodonts.

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