

## Updating the dinosaur tracksites from the Lower Jurassic Calcarei Grigi Group (Southern Alps, Northern Italy)

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**SUMMARY** - *Updating the dinosaur tracksites from the Lower Jurassic Calcarei Grigi Group (Southern Alps, Northern Italy)* - The discovery in 1989 of the Lavini di Marco tracksite (Lower Jurassic) gave rise to the search of other dinosaur footprint-bearing outcrops in the whole Southern Alps sector. As a result ten new Lower Jurassic ichnosites have been found since then in Trentino Alto-Adige and Veneto (North-eastern Italy), including two new sites described in this volume for the first time. The aim of this paper is to provide an updated summary of the Lower Jurassic dinosaur tracksites discovered to date in the Southern Alps. All the outcrops are lithostratigraphically referred to the Calcarei Grigi Group (Hettangian-upper Pliensbachian). Information about the geographic and geological setting, the age, the main features of the footprints, the most likely track makers and the relative bibliographic references are herein provided for each ichnosite.

**RIASSUNTO** - *Aggiornamento dei siti con orme dinosauriane attribuiti al Gruppo dei Calcarei Grigi, Giurassico inferiore (Alpi Meridionali, Italia settentrionale)* - La scoperta nel 1989 del sito dei Lavini di Marco (Giurassico Inferiore) ha dato il via alla ricerca di nuovi affioramenti con orme dinosauriane in tutto il settore delle Alpi Meridionali. Da allora dieci nuovi icnositi, anch'essi attribuibili al Giurassico inferiore, sono stati rinvenuti in Trentino Alto-Adige e in Veneto (Italia nord-orientale), inclusi due siti inediti descritti per la prima volta in questo volume. Lo scopo di questo articolo è di fornire un quadro sintetico e aggiornato dei siti con orme dinosauriane attribuiti al Giurassico inferiore, scoperti sino ad ora nelle Alpi Meridionali. Tutti gli affioramenti presi in esame sono litostratigraficamente riferibili al Gruppo dei Calcarei Grigi (Hettangiano-Pliensbachiano superiore). Per ogni icnosito sono forniti l'inquadramento geografico e geologico, l'attribuzione cronologica, i principali caratteri delle orme, i probabili trackmakers ed i relativi riferimenti bibliografici.

**Key words:** dinosaur tracks, Lower Jurassic, Calcarei Grigi Group, Trento carbonate Platform, Southern Alps

**Parole chiave:** orme di dinosauro, Giurassico inferiore, Gruppo dei Calcarei Grigi, Piattaforma carbonatica di Trento, Alpi meridionali

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### 1. INTRODUCTION

Dinosaur tracks and trackways are widespread in the Lower Jurassic of Southern Alps (Northern Italy, Fig. 1) and up to date eleven dinotracksites were discovered in this area (Lanzinger & Leonardi 1992; Leonardi & Avanzini 1994; Mietto & Roghi 1994; Avanzini 1997; Avanzini *et al.* 1997; Leonardi & Mietto 2000; Mietto *et al.* 2000; Avanzini 2001, 2002; Avanzini *et al.* 2001a, 2001b, 2001c, 2003, 2006, 2007a; Piubelli *et al.* 2005; Avanzini *et al.* 2008; Petti *et al.* 2008). All the outcrops belong to the Calcarei Grigi Group that is a Lower Jurassic shallow water carbonate succession well-exposed through the eastern sector of the Southern Alps (see Avanzini *et al.* 2007b for a review). In this region the Calcarei Grigi Group reaches a thickness of several hundred meters (more than 400 m in the central-western Trento Platform) and is composed of alternating subtidal, peritidal and supratidal deposits. The Calcarei Grigi Group is currently subdivided into four formations and one member (CARG project - Geological Map of Italy at the scale 1:50.000; Avanzini *et al.* 2007b; Fig.

2), namely from bottom to top: the Monte Zugna Formation (Hettangian-Sinemurian), the Loppio Oolitic Limestone (Middle to Late Sinemurian), the Rotzo Formation (Sinemurian *p.p.* -Pliensbachian), locally partially heteropic with the Tovel Member (Sinemurian-Pliensbachian), and the Massone Oolitic Limestone (Late Pliensbachian). Recently the Monte Zugna Formation has been further subdivided by Avanzini *et al.* (2006) into three informal units: a "Lower Subtidal Cyclic Unit", a "Middle Peritidal Unit" and an "Upper Subtidal Unit" (respectively LSCU, MPU and USU in Fig. 2).

From a palaeogeographic point of view, the Calcarei Grigi Group pertains to the Trento carbonate Platform, now extending north-south from Verona to Bolzano (NE Italy) and that during the Mesozoic covered an area of approximately 20.000 km<sup>2</sup>. This domain was characterized by shallow-water carbonate sedimentation through all the Early Jurassic and was bounded on the east by the Belluno pelagic basin and on the west by the Lombard pelagic basin through the so-called "Garda escarpment" (Fig. 3), a normal fault system active during the Jurassic and the

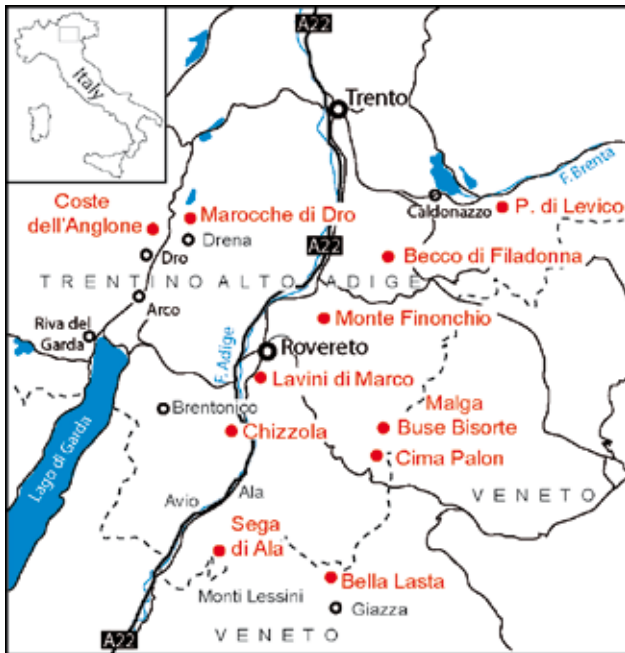


Fig. 1 - Location map of the Lower Jurassic dinosaur tracksites from Southern Alps.

Fig. 1 - Ubicazione geografica dei siti con orme dinosauriane delle Alpi Meridionali attribuiti al Giurassico Inferiore.

Cretaceous (Castellarin *et al.* 1993, 2005). As suggested by the palynological analysis of some track-bearing horizons (Avanzini *et al.* 2006), the climate of the Trento Platform area during the Early Jurassic varied from arid to humid conditions.

2. DINOSAUR TRACKS LOCALITIES

**Lavini di Marco** (*Pl. I a; Pl. II a; Pl. III a, e, f; h; Pl. IV 1-10; Pl. V 1, 2, 3*)

Discovered by Luciano Chemini in 1989  
 45°50'37.06"N, 11°02'04.79"E  
 707 m a.s.l.

The Lavini di Marco tracksite is located few kilometers south of Rovereto (Trentino-Alto Adige) and represents one of the most important European dinosaur footprint-bearing outcrops. It has been studied thoroughly by several authors since 1990 that carried out extensive ichnological, sedimentological and palynological researches (Lanzinger & Leonardi 1992; Leonardi & Avanzini 1994; Avanzini *et al.* 1997; Leonardi & Mietto 2000; Avanzini *et*

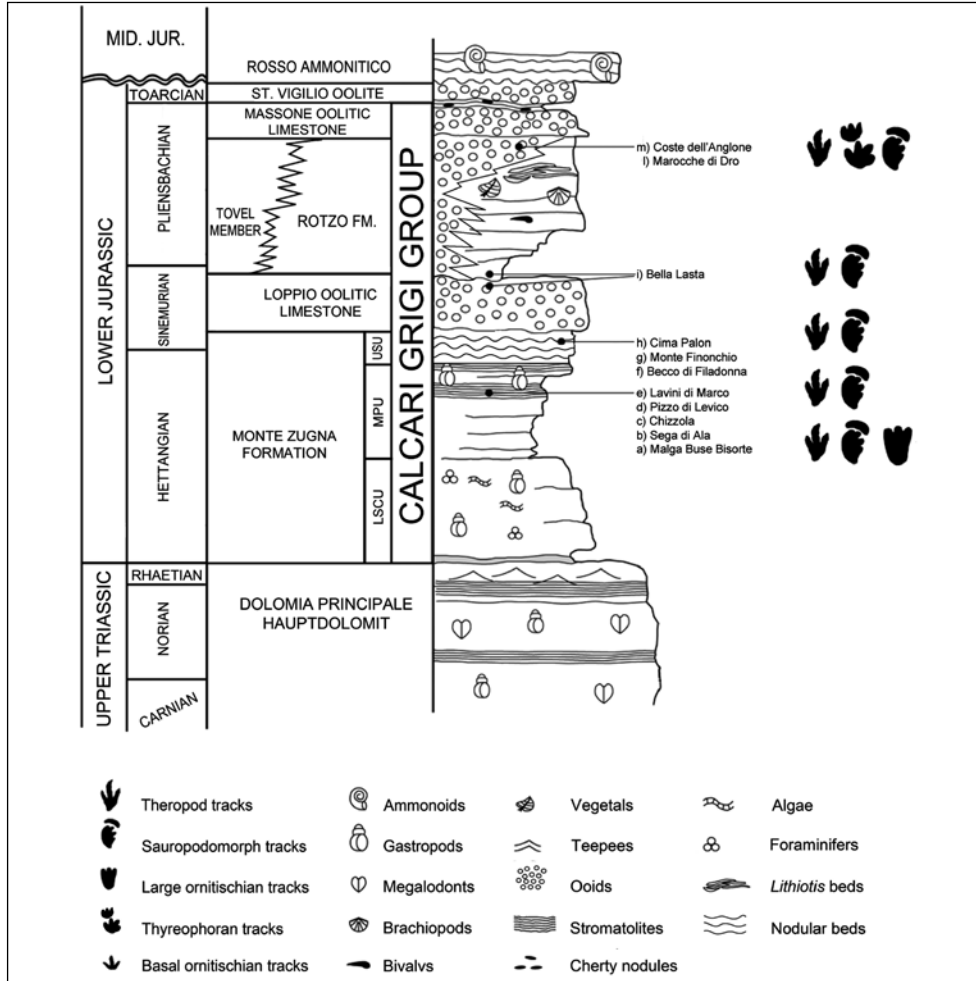


Fig. 2 - Lithostratigraphic succession of the Lower Jurassic Calcarei Grigi Group showing the stratigraphic positions of the different dinosaur tracksites.  
 Fig. 2 - Successione litostratigrafica del Gruppo dei Calcarei Grigi (Giurassico Inferiore) con la posizione stratigrafica dei siti con orme di dinosauro.

al. 2001b; Avanzini 2002; Avanzini *et al.* 2003; Piubelli *et al.* 2005; Avanzini *et al.* 2006).

#### Lithostratigraphy and age

The Lavini di Marco trampled horizons have been ascribed to the middle-upper part of the Monte Zugna Formation ("Middle Peritidal Unit" *sensu* Avanzini *et al.* 2006; Fig. 2) and cover approximately 300.000 m<sup>2</sup> of monoclinical surfaces (Piubelli *et al.* 2005). Seven dinoturbated levels have been recognized in a 7 meter-thick section. The richest level is made of alternating stromatolitic laminae and light gray, peloidal mudstones, dark gray bioclastic wackestones and reddish mudstones (Avanzini *et al.* 1997). The top of the stromatolitic layer is often pervasively dolomitized and typically white in color. All the track-bearing layers are Hettangian in age (Avanzini *et al.* 2006).

#### Description of the tracks

The ichnoassemblage is very rich and diverse. It comprises predominantly tridactyl footprints of small to medium-sized theropod dinosaurs that fall within the ichnogenera *Kayentapus* isp. Welles 1971, *Grallator* isp. Hitchcock 1858 and *Eubrontes* isp. Hitchcock 1845. *Kayentapus* isp. is the most common. Some of the tridactyl footprints are considered to belong to primitive ornithischians that had functionally tridactyl and clawed, theropod-like feet. Among them, *Anomoepus* isp. Hitchcock 1848 has also been recognized (Pl. III h; Avanzini *et al.* 2001b; Olsen & Rainforth 2003). Furthermore some of the tridactyl tracks are elongate, displaying the whole or partial impressions of the metatarsus and indicating a crouching posture of the dinosaur (Pl. IV 10; Avanzini *et al.* 2001b). In addition to tridactyl tracks there are many narrow-gauge trackways of medium-sized quadrupeds that may likely represent sauropodomorphs. Most of these trackways close resemble those of *Parabrontopodus* Lockley, Farlow & Meyer 1994 from the Upper Jurassic of Colorado (USA) and *Breviparopus* Dutuit & Ouazzou 1980 from the Upper Jurassic-Lower Cretaceous of Morocco both attributed to sauropodomorphs (Pl. V 2, 3). Among the quadrupedal trackways, it is worth to mention the ichnotaxon *Lavinipes cheminii* Avanzini, Leonardi and Mietto 2003 recently erected and described from this site (Pl. III a; Pl. V 1). This ichnotaxon has been attributed to basal sauropods, probably to individuals of the Eusauropoda clade Upchurch (1995).

#### Chizzola (Pl. III i; Pl. IV 18)

Discovered by Giuseppe Leonardi in 1994  
45°49'35.09"N, 10°59'58.77"E  
156 m a.s.l.

The Chizzola tracksite is located slightly south of the Lavini di Marco site and east of Brentonico along the road Mori-Avio. (Trentino-Alto Adige).

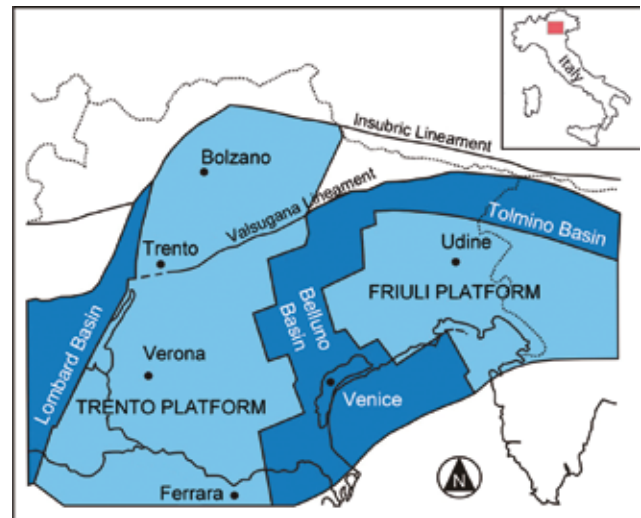


Fig. 3 - Palaeogeographic restoration of the central-eastern sector of Southern Alps during the Early Jurassic.

Fig. 3 - Ricostruzione paleogeografica del settore centro-orientale delle Alpi Merdionali durante il Giurassico Inferiore.

#### Lithostratigraphy and age

Dinosaur tracks at Chizzola were discovered in a road cut along the SP 22. The trampled horizon has been assigned to the middle-upper part of the Monte Zugna Formation ("Middle Peritidal Unit" *sensu* Avanzini *et al.* 2006; Fig. 2) and is Hettangian in age. It consists of a light-gray stromatolitic interval, dolomitized at the top (Avanzini *et al.* 1997). The footprints were destroyed due to the recent works of road widening in the area.

#### Description of the tracks

The Chizzola tracksite yielded three tridactyl footprints related to medium-sized theropods (ALCH 1, ALCH 2 e ALCH 3). The best preserved footprint (ALCH 1; Pl. III i; Pl. IV 18), partially eroded, is a left tridactyl track (33 cm in length) with stout digit impressions, claw traces and several phalangeal pad impressions on each digit. The impression of digit IV is pulled back with respect to the digit III, while the digit II is clearly outward rotated. Although ALCH 1 was initially assigned to *Eubrontes* isp. by Leonardi & Mietto (2000), its morphological features point out a close resemblance to *Kayentapus* isp. ALCH 1 is one of the largest footprints discovered up to now in the Calcarei Grigi Group.

#### Pizzo di Levico (Pl. I d; Pl. III g)

Discovered by Marco Avanzini in 2001  
45°58'44.07"N, 11°20'35.70"E  
1830 m a.s.l.

The Pizzo di Levico outcrop is situated about 6 km south-east of the Caldonazzo Lake (Trentino-Alto Adige).

*Lithostratigraphy and age*

The Pizzo di Levico tracksite belongs to the “Middle Peritidal Unit” (*sensu* Avanzini *et al.* 2006) of the Monte Zugna Formation (Fig. 2) and has been attributed to the Hettangian. This unit is also characterized by fully subtidal cycles or by evidences of sudden subaerial exposure of the carbonate bank (lack of laminated layers at the top of the cycle). In the latter case, the topmost of the cycle is intensively bioturbated, with evidences of palaokarst, red clay and silty dolostones. In the Pizzo di Levico stratigraphic section the footprint-bearing layer falls into one of these intervals, namely at the top of a reddish oolitic grainstone with intraclasts and black pebbles (Avanzini & Tomasoni 2002).

*Description of the tracks*

The specimen discovered at Pizzo di Levico is a tridactyl track (PL. III g) attributed to a small-sized theropod. It is likely an undertrack formed in the layer immediately below the true tracking surface (5 cm), constituted by a stromatolitic bindstones. Two clear phalangeal pad are impressed on the lateral digits which show faint claw traces. The impression of digit III is better preserved posteriorly, fading rapidly anteriorly, and not exceeding the length of the lateral digits. Owing to these feature, the track can be tentatively compared with the ichnogenus *Kayentapus* Welles 1971.

**Sega di Ala (Monti Lessini)**

Discovered by Marco Avanzini in 1993  
45°43'43.43"N, 10°58'05.79"E  
705 m a.s.l.

The Sega di Ala stratigraphic section is located few kilometres south-east of Ala, in the Lessini Mountains along the road Ala-Passo Fittanze (Trentino Alto-Adige).

*Lithostratigraphy and age*

Dinosaur trampled layer belongs to the middle-upper part of the Monte Zugna Formation (“Middle Peritidal Unit” *sensu* Avanzini *et al.* 2006; Fig. 2) and is Hettangian in age. It is composed by a set of stromatolitic layers which are followed by a structureless mudstone sealing the only preserved footprint and perfectly connected at the top to the undeformed surface (Avanzini 2001).

*Description of the tracks*

The track is clearly visible on a natural vertical section (Avanzini 2001), probably cut through the middle part of a tridactyl footprint of a medium-sized theropod dinosaur. The section is expressed as a gentle trilobate depression. The central lobe, corresponding to the impression of

digit III, is 3 cm depth, while the lateral ones (related to the impressions of digit II and IV) are shallower reaching 2 cm in depth.

**Becco di Filadonna (Pl. I c; Pl. III b)**

Discovered by Marco Avanzini in 1997  
45°55'39.92"N, 11°09'07.53"E  
1071 m a.s.l.

The ichnosite is located on a bedding surface outcropping on the slope of the Val Gola furrowing to the west the Becco di Filadonna massif, about ten kilometres south of Trento (Trentino-Alto Adige).

*Lithostratigraphy and age*

In the Becco di Filadonna ichnosite two dinoturbated layers have been recognized (Avanzini *et al.* 2006; Avanzini 1997). They have been ascribed to the middle and upper part of the Monte Zugna Formation (respectively “Middle Peritidal Unit” and “Upper Subtidal Unit” *sensu* Avanzini *et al.* 2006, Fig. 2)

In the “Middle Peritidal Unit” a tridactyl footprint is preserved in a dolomitized stromatolitic bindstone, Hettangian in age.

In the “Upper Subtidal Unit” dinosaur tracks are preserved at the top of two distinct stromatolitic layers, which are marker beds of this informal lithostratigraphic unit. They were exposed subaerially and stratigraphically follow bioturbated brown and dark grey wackestone/packstone, organized into thin (10-30 cm) nodular beds with low-angle lamination and/or flaser structures. In the Becco di Filadonna section, both the aforementioned stromatolitic levels are dinoturbated, while in other sections (Monte Pasubio sector), only the lowest is trampled (Avanzini 2001). These layers are Hettangian-early Sinemurian in age.

*Description of the tracks*

The track assemblage contains isolated, medium-sized, tridactyl tracks and large footprints generically attributable to quadrupedal dinosaurs (Avanzini 1997; Avanzini *et al.* 2006).

The tridactyl footprints can be tentatively ascribed to the ichnogenus *Eubrontes* Hitchcock 1845.

Some larger, poorly preserved manus-pes couples made by a quadruped individual are also documented. Owing to their narrow-gauge trackway they were identified as the ichnogenus *Parabrontopodus* Lockley, Farlow and Meyer 1994 and attributed to sauropod dinosaurs (Avanzini 1997).

**Monte Finonchio (Pl. I f; PL. V 6)**

Discovered by Marco Avanzini in 2007

45°54'38.36"N, 11°05'39.18"E  
760 m a.s.l.

Dinosaur tracks have been recently recognized on the western flank of the Monte Finonchio, just few kilometres north-east of Rovereto (Trentino-Alto Adige).

The *in situ* ichnological analysis at Monte Finonchio is hindered by the difficult accessibility of the outcrop, which is represented by a steeply dipping bedding plane (PL. I f). For this reason terrestrial laser scanner (TLS) has been used in order to obtain a model of the trampled area. The study and the interpretations of the footprints have been then performed directly on the 3D model (Avanzini *et al.* 2008).

#### *Lithostratigraphy and age*

The Monte Finonchio tracksite belongs to the "Upper Subtidal Unit" of the Monte Zugna Formation (*sensu* Avanzini *et al.* 2006; Fig. 2) and is late Hettangian-early Sinemurian in age. This unit connects the underlying peritidal deposits with the granular body of the Loppio Oolitic Limestone. It is characterized by a basal, grainy body overlain by brown and dark grey mudstone-wackestone organized into thin (10-30 cm) nodular beds containing scattered evidence of tractive sedimentary structures (parallel or low-angle laminations). Toward the top of the unit, the grainy fraction increases, represented by packstone and grainstone where ooids and peloids predominate.

Footprints are clearly observable on three superimposed carbonate layers; they were found at the top of a mudstone layer covered by a stromatolitic layer that was exposed subaerially and are now superimposed on dark grey wackestone/packstone beds.

#### *Description of the tracks*

The ichnoassemblage of Monte Finonchio comprises five large and poorly preserved *manus-pes* couples attributed to medium-sized sauropodomorph individuals (FIN 1, 2, 3, 4, 5; see Avanzini *et al.* 2008). Footprints are preserved as undertracks and are characterized by a strong heteropody, the *pes* prints being much larger than the *manus* prints (PL. V 6). The *pes* prints are elliptical in shape and are usually associated with sub-circular or sub-elliptical *manus* impressions. For the above mentioned features the Monte Finonchio tracks were tentatively ascribed to the ichnogenus *Parabrontopodus* Lockley, Farlow and Meyer 1994.

#### **Monte Pasubio (Cima Palon and Malga Buse Bisorte)** (Pl. II c)

Discovered by Marco Avanzini in 1996  
Cima Palon - 45°47'32.86"N, 11°10'32.86"E  
2187 m a.s.l.  
Malga Buse Bisorte - 45°48'47.39"N, 11°11'05.75"E  
1885 m a.s.l.

The Monte Pasubio is located about ten kilometres south-east of Rovereto. Two dinosaur track-bearing outcrops have been discovered in this sector (Avanzini 2001). The first one is situated west of Cima Palon, the second slightly to the north in Malga Buse Bisorte locality.

#### *Lithostratigraphy and age*

Dinosaur tracks from the Cima Palon (Dente Italiano) belong to the "Upper Subtidal Unit" of the Monte Zugna Formation (*sensu* Avanzini *et al.* 2006; Fig. 2). As already mentioned, this unit is made of nodular (thinly bedded) brown and dark grey, bioturbated mudstone-wackestone, and is marked by the occurrence of two separate stromatolitic levels. At the Cima Palon ichnosite, dinosaur footprints were found in the upper stromatolitic layer (Avanzini 2001).

Footprints preserved at Malga Buse Bisorte occur at the top of the lower stromatolitic layers of the "Middle Peritidal Unit" of the Monte Zugna Formation (*sensu* Avanzini *et al.* 2006). The Malga Buse Bisorte trampled-layer is ascribed to the Hettangian, while the Cima Palon ichnosite is Hettangian to Sinemurian in age.

#### *Description of the tracks*

The ichnoassemblage of Cima Palon ichnosite is represented by different tracks, found both on bedding plane of scattered limestone blocks and in natural section, where load cast deformation structures are evident in the stromatolitic bindstone (PL. V 6). They are sub-circular in shape (average diameter is about 30 cm) and preserved as true tracks. No trackways have been recognized. All the footprints are surrounded by evident raised rims, sometimes showing a collapse structure toward the deepest part of the hollow. The type of preservation prevents the identification of further anatomical details, allowing only a generic attribution to medium sized sauropodomorphs.

#### **Bella Lasta (Monti Lessini)** (Pl. I e; Pl. II e, f; Pl. III i; Pl. IV 19; Pl. V 7)

Discovered by Guido Roghi in 1992  
45°41'20.45"N, 11°06'29.52"E  
1568 m a.s.l.

The Bella Lasta site is located on the western flank of the Revolto Valley, between Passo Malera and Cima Trapola (Alti Lessini Veronesi), few kilometers north of Verona (Veneto) (Mietto *et al.* 2000).

#### *Lithostratigraphy and age*

The track-bearing layers are located near the boundary between the Loppio Oolitic Limestone and the lowermost Rotzo Formation (Fig. 2; Avanzini *et al.* 2006).

There are five trampled levels in 8.5 m of successive beds. The lower levels (VRBL 20, 25, 1 and 5) are mainly composed of oolitic grainstone (oolitic bars), formed by tidal currents in shallow marine environments. The uppermost footprint-bearing horizon (VRBL5) is composed of wackestone layers with pyrite nodules, reflecting a lagoonal environment. This surface is covered by a limestone with abundant bivalves and gastropods (thickness about 10 cm). The footprint levels are late Sinemurian in age.

#### *Description of the tracks*

The track record is represented by tridactyl prints of medium-sized theropods (Pl. II e; Pl. III i) and amorphous *manus-pes* couples likely attributable to sauropodomorphs (Pl. II f; Pl. V 7). The tridactyl tracks, which have been assigned to *Kayentapus* isp. (Mietto *et al.* 2000), show high interdigital divarication angles (II–IV > 70°) and short, robust impression of the digit III. Some of the track-bearing surfaces are intensively dinoturbated, making it difficult to recognize discrete trackways.

#### **Marocche di Dro** (Pl. I b; Pl. II b; Pl. V 4-5)

Discovered by Matteo Campolongo in 1999.  
45°59'01.44"N, 10°56'28.63"E  
300 m a.s.l.

The Marocche di Dro outcrop, in the Sarca Valley, consists of landslides that cover an area larger than 13 km<sup>2</sup> (Bassetti 1997). Footprints and trackways occur within the scattered limestone blocks, slightly north of Drena (Trentino Alto-Adige).

#### *Lithostratigraphy and age*

The trampled sediments have been ascribed to the upper part of the Calcarei Grigi Group (Tovel Member of the Rotzo Formation *sensu* Castellarin *et al.* 2005; Fig. 2), which consists of oolitic-bioclastic facies. The blocks on which footprints are preserved are made of light-grey to yellowish-grey packstone, with oolites, bioclasts, algal lumps, pellets, dasycladacean algae, foraminifera, litiolids and miliolids. The sedimentologic features of these deposits clearly suggest a subtidal tidal flat paleoenvironment in which mud banks and sand deposits, constituted by oolitic bars, occur close together. The tracks are commonly infilled and are late Sinemurian to Pliensbachian in age.

#### *Description of the tracks*

On the main block surface a quadrupedal dinosaur trackway (MDK1/1) is clearly recognizable (Pl. II b; Pl. V 4; Avanzini *et al.* 2001a, 2001c). The MDK1/1 trackway (Pl. V 4), characterized by partial to total primary overlap, wide gauge and low pace angulation, is comparable to the ones

attributed to basal ankylosauridae (McCrea *et al.* 2001), and close to the Cretaceous ichnogenera *Tetrapodosaurus borealis* Sternberg 1932 or *Metatetrapodus valdensis* Haubold 1971. The most probable track maker of the MDK1/1 trackway was a relatively small form of a basal thyreophoran similar to *Scelidosaurus* Owen 1860 from the Lower Jurassic of England.

The block MDK4 displays several eroded footprints showing infilling separated by laminae of red clay. Some *manus-pes* couples are preserved on the surface that area assumed to form a probable trackway (MDK4/1) of a quadrupedal dinosaur (Pl. V 5). The trackway is very different from MDK1/1, and fits better with prosauropods than sauropods.

#### **Coste dell'Anglone (Monte Brento)** (Pl. I g; Pl. II d; Pl. III c,d; Pl. IV 11-17)

Discovered by Ermanno Filippi & Massimo Maceri in 2007  
45°58'33.39"N, 10°54'37.02"E  
525 m a.s.l.

The Coste dell'Anglone ichnosite is located along the eastern slope of Monte Brento (Dro, Trentino Alto-Adige), in the central sector of the Southern Alps, slightly north of the Garda Lake. Hundreds of dinosaur tracks, mostly arranged in long trackways (up to 50 m in length; Pl. II d), have been recognized on a wide monoclinical surface dipping about 30° SE. New documentation technologies, as high resolution photogrammetry and active sensors (laser scanner), have been tested on this recently discovered tracksite (Petti *et al.* 2008).

#### *Lithostratigraphy and age*

The footprints bearing level belongs to the Tovel Member of the Rotzo Formation (Fig. 2), mainly subtidal and composed of metric oolitic and bioclastic grainstone and packstone beds, alternating with decimetric finely laminated beds of grey mudstone, with abundant miliolids and related to small supratidal ponds. The tracks come from one of these latter levels, composed of poorly fossiliferous dark grey stromatolitic and peloidal mudstone. The dinosaur trampled deposits have been ascribed to the late Sinemurian-Pliensbachian time interval.

#### *Description of the tracks*

To date thirteen trackways attributable to bipedal dinosaurs have been recognized (Avanzini *et al.* 2007a). Tracks are only tridactyl and exhibit different degrees of preservation (Pl. III c, d; Pl. IV 11-17). The different preservation quality of the tracks is probably due to the relative water content of the original substrate. Even if the ichnological analysis is still in progress, most of the footprints can be attributed to small and medium-sized theropods.

Most of the tracks exhibit digits III-IV more divaricated than II-III, well defined impressions of the metatarso-phalangeal pad of digit IV, and a low protrusion of the central digit beyond the line connecting the lateral digits. All these features allow to likely assign them to the ichnogenus *Kayentapus* isp. Other medium to large footprints (Foot length >25 cm) have a narrow pes and a relatively long digit III; thus, they are possibly assigned to the ichnogenus *Anchisauripus* Lull 1904.

### 3. CONCLUSIONS

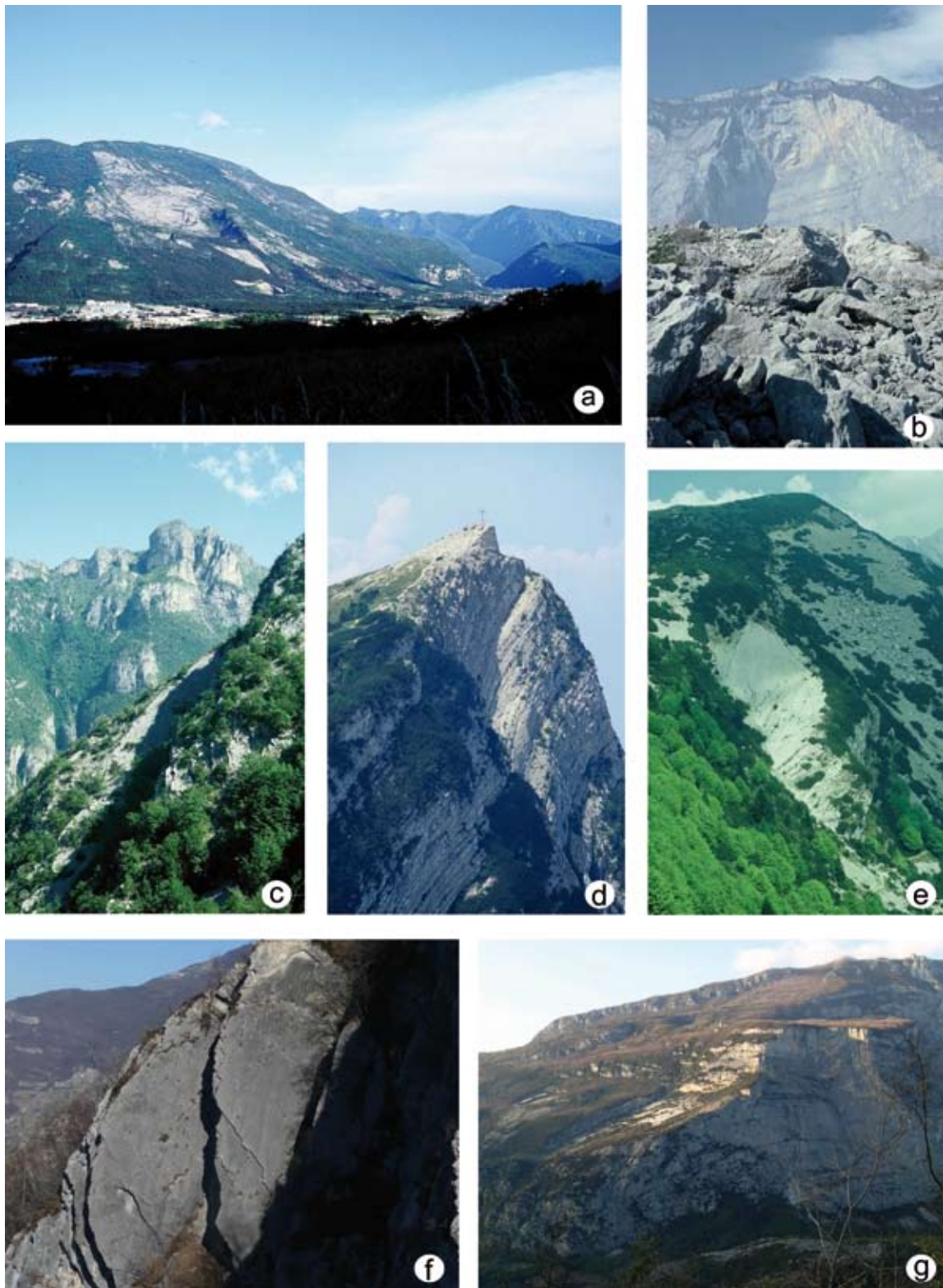
The discoveries of the Monte Finonchio and Coste dell'Anglone dinosaur tracksites bring to a total of eleven the ichnosites documented up to now in the Lower Jurassic (Hettangian-Pliensbachian) Calcarei Grigi Group. As a whole the outcrops display rich and diverse ichnoassemblages including forms assigned to different ichnogenera and ichnospecies. Among them *Grallator* isp., *Kayentapus* isp. and *Eubrontes* isp., attributed to small- to medium-sized theropods, are widespread in the whole unit. Quadrupedal trackways assigned to *Parabrontopodus* isp. and *Lavinipes cheminii*, both attributed to medium-sized sauropods, occur within the Hettangian-lower Sinemurian deposits. Other unnamed quadrupedal trackways, from the upper Sinemurian-Pliensbachian layers, have been tentatively attributed to basal ankylosauridae and to prosauropods.

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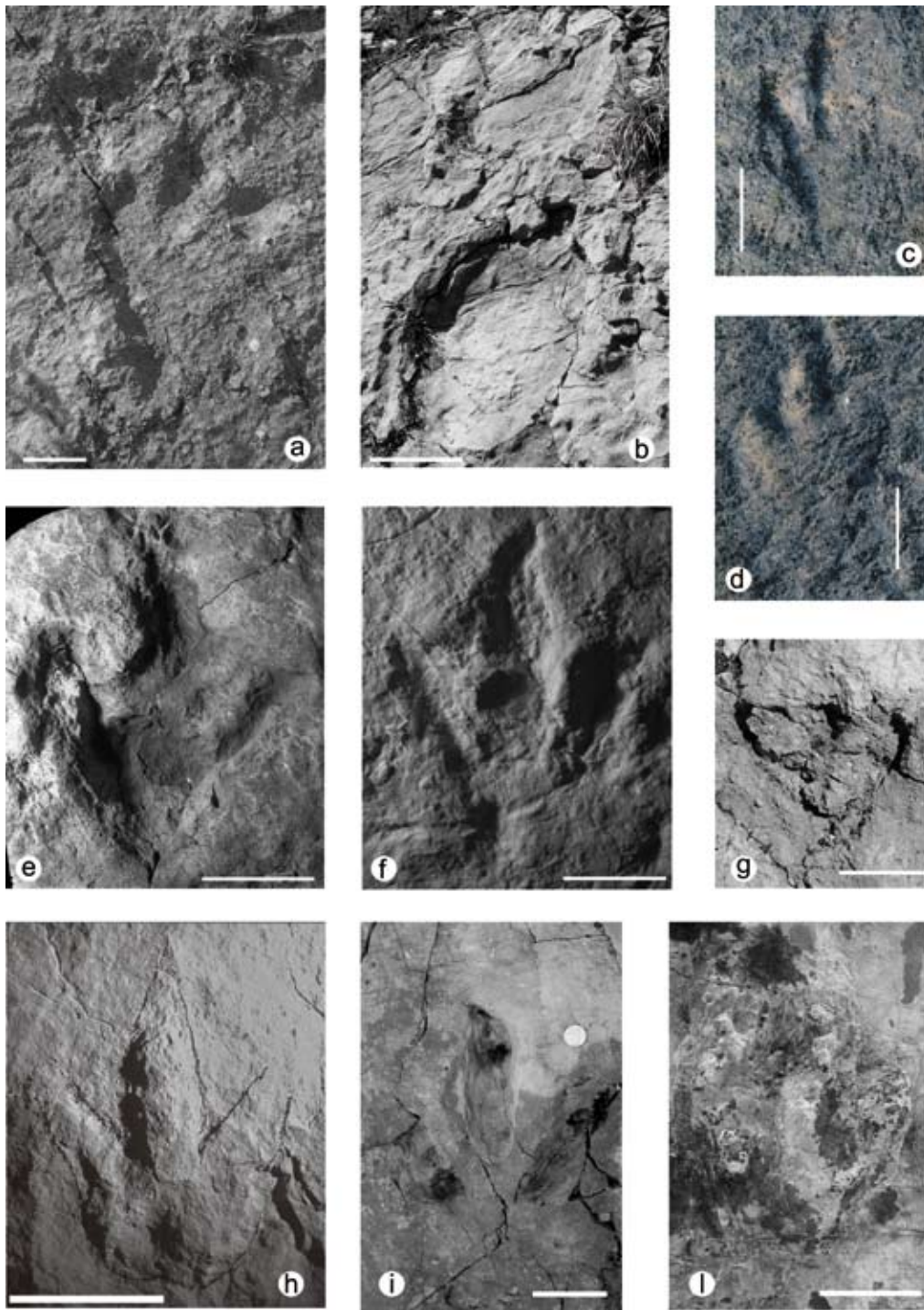
Pl. I - Panoramic view of the main dinosaur tracksites from the Lower Jurassic Calcarei Grigi Group (Southern Alps, Northern Italy). a. Lavini di Marco (Hettangian); b. Marocche di Dro (Sinemurian-Pliensbachian); c. Becco di Filadonna (Hettangian-Sinemurian); d. Pizzo di Levico (Hettangian); e. Bella Lasta (Late Sinemurian); f. Monte Finonchio (late Hettangian-early Sinemurian); g. Coste dell'Anglone (Late Sinemurian-Pliensbachian).

*Pl. I - Vista panoramica dei principali siti con orme dinosauriane del Gruppo dei Calcarei Grigi (Alpi Meridionali). a. Lavini di Marco (Hettangiano); b. Marocche di Dro (Sinemuriano-Pliensbachiano); c. Becco di Filadonna (Hettangiano-Sinemuriano); d. Pizzo di Levico (Hettangiano); e. Bella Lasta (Sinemuriano superiore); f. Monte Finonchio (Hettangiano superiore-Sinemuriano inferiore); g. Coste dell'Anglone (Sinemuriano superiore-Pliensbachiano).*



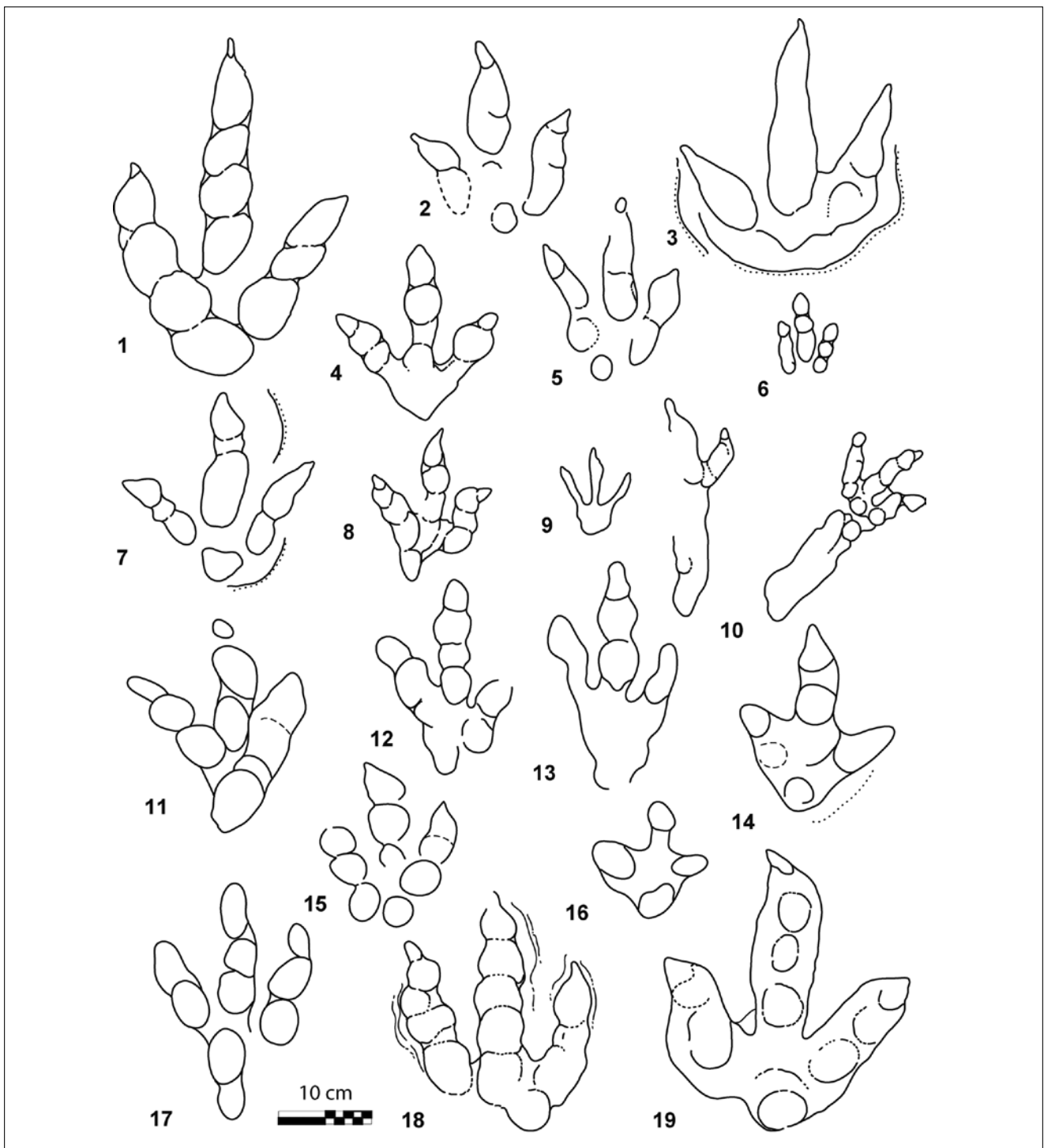
Pl. II - Photos of tracks and trackways from the Lower Jurassic Calcarei Grigi Group. a. ROLM 9 trackway from the Lavini di Marco ichnosite (Hettangian; foot length about 40 cm); b. limestone block displaying MDK 1/1 trackway at Marocche di Dro tracksite (Sinemurian-Pliensbachian; foot length is about 25 cm); c. track attributed to medium sized sauropodomorph visible in natural section at Cima Palon ichnosite (Hettangian-Sinemurian); d. tridactyl theropod trackway from the Coste dell'Anglone ichnosite (late Sinemurian-Pliensbachian; foot length is about 25 cm); e. theropod trackway (*Kayentapus* isp.) at Bella Lasta ichnosite (late Sinemurian) scale bar 10 cm; f. *Parabrontopodus* isp. at the Bella Lasta ichnosite (late Sinemurian).

Pl. II - Foto di orme e piste rinvenute nel Gruppo dei Calcarei Grigi (Giurassico Inferiore). a. Pista ROLM 9, icnosito dei Lavini di Marco (Hettangiano; lunghezza del pes circa 40 cm); b. blocco calcareo su cui è preservata la pista MDK 1/1, icnosito Marocche di Dro (Sinemuriano-Pliensbachiano; lunghezza del pes circa 25 cm); c. orma dinosauriana (visibile in sezione) attribuita ad un sauropodomorfo di medie dimensioni, icnosito Cima Palon (Hettangiano-Sinemuriano); d. pista tridattila attribuibile ad un teropode di medie dimensioni, icnosito Coste dell'Anglone (Sinemuriano superiore-Pliensbachiano; lunghezza del pes circa 25 cm); e. pista di teropode (*Kayentapus* isp.), icnosito Bella Lasta (Sinemuriano superiore; scala 10 cm); f. *Parabrontopodus* isp., icnosito Bella Lasta (Sinemuriano superiore).



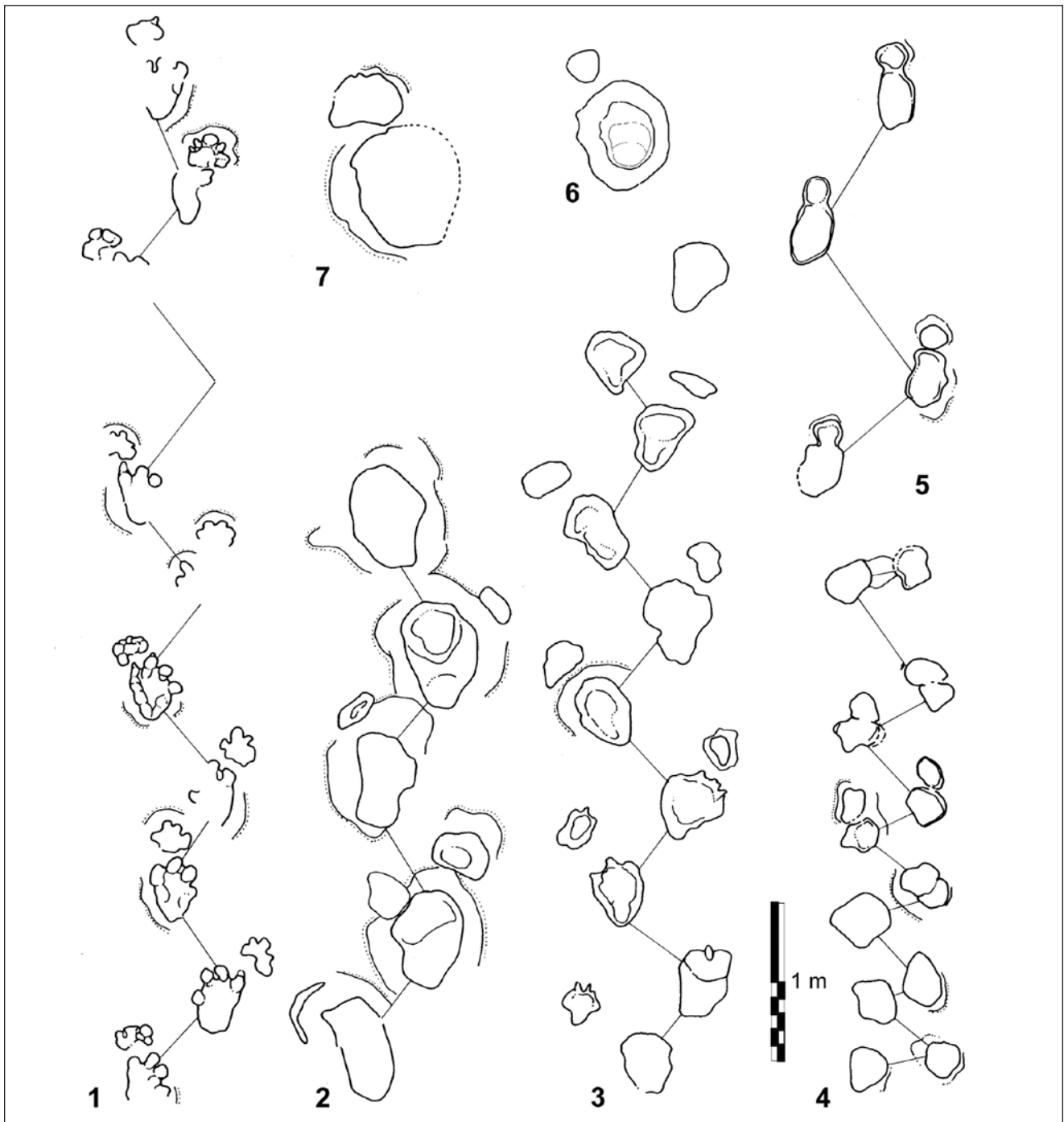
Pl. III - Selected photos of footprints from the Lower Jurassic of Southern Alps. a. *Lavinipes cheminii* manus-pes couple from Lavini di Marco ichnosite (scale bar 10 cm); b. sauropodomorph footprint from Becco di Filadonna ichnosite (scale bar 30 cm); c-d. tridactyl footprints from the Coste dell'Anglone ichnosite (scale bar 10 cm); e. large theropod footprint, Lavini di Marco tracksite (scale bar 10 cm); f. medium-sized theropod footprint, Lavini di Marco (scale bar 5 cm); g. small-sized theropod footprint (*Kayentapus* isp.), Pizzo di Levico (scale bar 10 cm); h. ornithischian track (*Anomoepus* isp.), Lavini di Marco track site; i. theropod track, Bella Lasta track site (scale bar 10 cm); l. medium-sized tridactyl theropod footprint (*Kayentapus* isp.), Chizzola ichnosite (ALCH 1; scale bar 10 cm).

Pl. III - Orme dinosauriane provenienti dal Giurassico Inferiore delle Alpi Meridionali. a. coppia manus-pes di *Lavinipes cheminii*, icnosito Lavini di Marco (scala 10 cm). b. orma attribuita a sauropodomorfo, icnosito Becco di Filadonna (scala 30 cm). c-d. orme tridattile del sito delle Coste dell'Anglone (scala 10 cm); e. orma di teropode di grandi dimensioni, icnosito Lavini di Marco (scala 10 cm); f. orma di teropode di medie dimensioni, Lavini di Marco (scala 5 cm); g. orma di teropode di piccole dimensioni (*Kayentapus* isp.), Pizzo di Levico (scala 10 cm); h. orma attribuita a Ornitischii (*Anomoepus* isp.), Lavini di Marco; i. orma di teropode, Bella Lasta (scala 10 cm); l. orma tridattila di teropode di medie dimensioni (*Kayentapus* isp.), Chizzola (ALCH 1; scala 10 cm).



Pl. IV - Tracings of some tridactyl footprints from the Lower Jurassic Calcarei Grigi Group (Southern Alps, Southern Alps). 1-9. Tridactyl theropod footprints from the Lavini di Marco ichnosite, Hettangian (redrawn from Leonardi & Mietto 2000; Piubelli *et al.* 2005); 10. *Anomoepus* isp., Lavini di Marco, Hettangian (redrawn from Avanzini *et al.* 2001); 11-17. unnamed tridactyl footprints from the Coste dell'Anglone tracksite, Late Sinemurian-Pliensbachian; 18. medium-sized tridactyl theropod footprint (ALCH 1; *Kayentapus* isp.), Chizzola ichnosite, Hettangian (redrawn from Leonardi & Mietto 2000); 19. medium-sized tridactyl theropod footprint (*Kayentapus* isp.), Bella Lasta ichnosite, Late Sinemurian (redrawn from Mietto *et al.* 2000).

Pl. IV - Rilievi grafici di orme tridattile appartenenti al Gruppo dei Calcarei Grigi (Giurassico Inferiore, Alpi Meridionali). 1-9. Orme tridattile attribuite a teropodi dall'ichnosito dei Lavini di Marco, Hettangiano (ridisegnato da Leonardi & Mietto 2000; Piubelli *et al.* 2005); 10. *Anomoepus* isp., Lavini di Marco, Hettangiano (ridisegnato da Avanzini *et al.* 2001); 11-17. orme tridattile provenienti dal sito delle Coste dell'Anglone, Sinemuriano superiore-Pliensbachiano; 18. orma tridattila di un teropode di medie dimensioni (ALCH 1; *Kayentapus* isp.), Chizzola, Hettangiano (ridisegnato da Leonardi & Mietto 2000); 19. orma tridattila di un teropode di medie dimensioni (*Kayentapus* isp.), Bella Lasta, Sinemuriano superiore (ridisegnato da Mietto *et al.* 2000).



Pl. V - Tracings of quadrupedal dinosaur tracks and trackways from the Calcari Grigi Group (Lower Jurassic, Southern Alps). 1. *Lavinipes cheminii* from the "Middle Peritidal Unit" of the Monte Zugna Formation (Hettangian), Lavini di Marco; 2-3. Small *Parabrontopodus* isp. from the "Middle Peritidal Unit" of the Monte Zugna Formation (Hettangian), Lavini di Marco; 4. Unnamed dinosaur trackway (MDK 1/1) attributed to basal ankylosauridae (Sinemurian-Pliensbachian), Marocche di Dro; 5. Unnamed dinosaur trackway (MDK 4/1) likely attributable to prosauropods (Sinemurian-Pliensbachian), Marocche di Dro; 6. *Parabrontopodus* isp. from the "Upper Subtidal Unit" of the Monte Zugna Formation (late Hettangian-early Sinemurian), Monte Finonchio; 7. Large *Parabrontopodus* isp. from the "Upper Subtidal Unit" of the Monte Zugna Formation (Hettangian-early Sinemurian), Bella Lasta.

Pl. V - Rilievi grafici di orme e piste di dinosauri quadrupedi appartenenti al Gruppo dei Calcari Grigi (Giurassico Inferiore, Alpi Meridionali). 1. *Lavinipes cheminii* proveniente dalla "Middle Peritidal Unit" della Formazione di Monte Zugna (Hettangiano), Lavini di Marco; 2-3. *Parabrontopodus* isp. proveniente dalla "Middle Peritidal Unit" della Formazione di Monte Zugna (Hettangiano), Lavini di Marco; 4. pista di dinosauro (MDK 1/1) attribuita ad anchilosauridi basali (Sinemuriano-Pliensbachiano), Marocche di Dro; 5. pista di dinosauro (MDK 4/1) riferibile a prosauropodi (Sinemuriano-Pliensbachiano), Marocche di Dro; 6. *Parabrontopodus* isp. dalla "Upper Subtidal Unit" della Formazione di Monte Zugna (Hettangiano-Sinemuriano inferiore), Monte Finonchio; 7. *Parabrontopodus* isp. dalla "Upper Subtidal Unit" della Formazione di Monte Zugna (Hettangiano-Sinemuriano inferiore), Bella Lasta.

