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Jurassic tetrapod tracks from Italy: a training ground for generations of researchers

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ABSTRACT - This article reports the state of the art of research on the Jurassic tetrapod footprints from Italy. Most dinosaur ichnosites are located in the Southern Alps (Northeastern Italy, Veneto, Trentino Alto-Adige) with the exception of Mattinata (Southern Italy, Gargano Promontory, Apulia) and the Burano River ichnosite (Central Italy, Central Apennines), where a marine tetrapod reptile trackway was found. The Southern Alpine sites occur in four distinct stratigraphic levels of the Lower Jurassic Calcari Grigi Group whereas the Mattinata site is provisionally assigned to the Upper Jurassic Sannicandro Formation (Kimmeridgian-Tithonian).

In this review, we provide geographical and geological setting, age, ichnotaxonomy and the possible identity of trackmakers for each site. Additionally, we report on the history of discovery, the state of the art in ichnological knowledge and the evolution of methodological approaches and techniques adopted through time.

Keywords: dinosaur tracks; Early Jurassic; Calcari Grigi Group; Sannicandro Formation.

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1. INTRODUCTION

In a chapter on Italian Mesozoic reptiles, written 36 years ago for the book 'Sulle orme dei dinosauri' (Bonaparte et al., 1984), one of the authors of the present study (GL) stated that a special chapter on Italian dinosaurs *"cannot exist, because these reptiles had 'snubbed' Italy, or rather the whole of seas and islands that constituted the present Italian peninsula in the Mesozoic"* (Leonardi, 1984a, p. 197). This statement reflects the state of knowledge about palaeontology, geology and Mesozoic palaeogeography of the peri-Mediterranean area at the beginning of the 1980's. Only a few years later the situation changed completely.

Actually, the chapter cited above included a picture of the Triassic dinosaur tracks of Mt. Pelmetto (Dolomites, northern Italy), not yet published at that time, that to the regret of the author (GL) was accompanied by a completely wrong caption, added by the publishing house. The trackways of the giant boulder from Mt. Pelmetto were then soon studied (Mietto, 1988, 1990) and together with the discovery of many dinosaur trackways on the large landslide surface of the Lavini di Marco (Rovereto, Trento, northern Italy), only a few years after the publication of Leonardi (1984a, 1984b) the whole perspective on the Italian Mesozoic changed. At Lavini di Marco, Lanzinger and Leonardi (1991) and Leonardi and Lanzinger (1992) identified several track-bearing horizons in the Calcari Grigi Group, (Hettangian; Monte Zugna Formation). This discovery triggered great media interest and gave rise to a series of discoveries in various outcrops and different stratigraphic levels within the Calcari Grigi Group, both in the Trentino and the Veneto regions (Figs. 1, 2). The perspective widened, in both geographical and stratigraphical terms, when Late Jurassic dinosaur footprints from Apulia (southern Italy) were reported (Conti et al., 2005). In addition to the rich dinosaur-dominated tracksites from these marginal marine environments, unusual tracks referred to swimming marine reptiles have been reported from

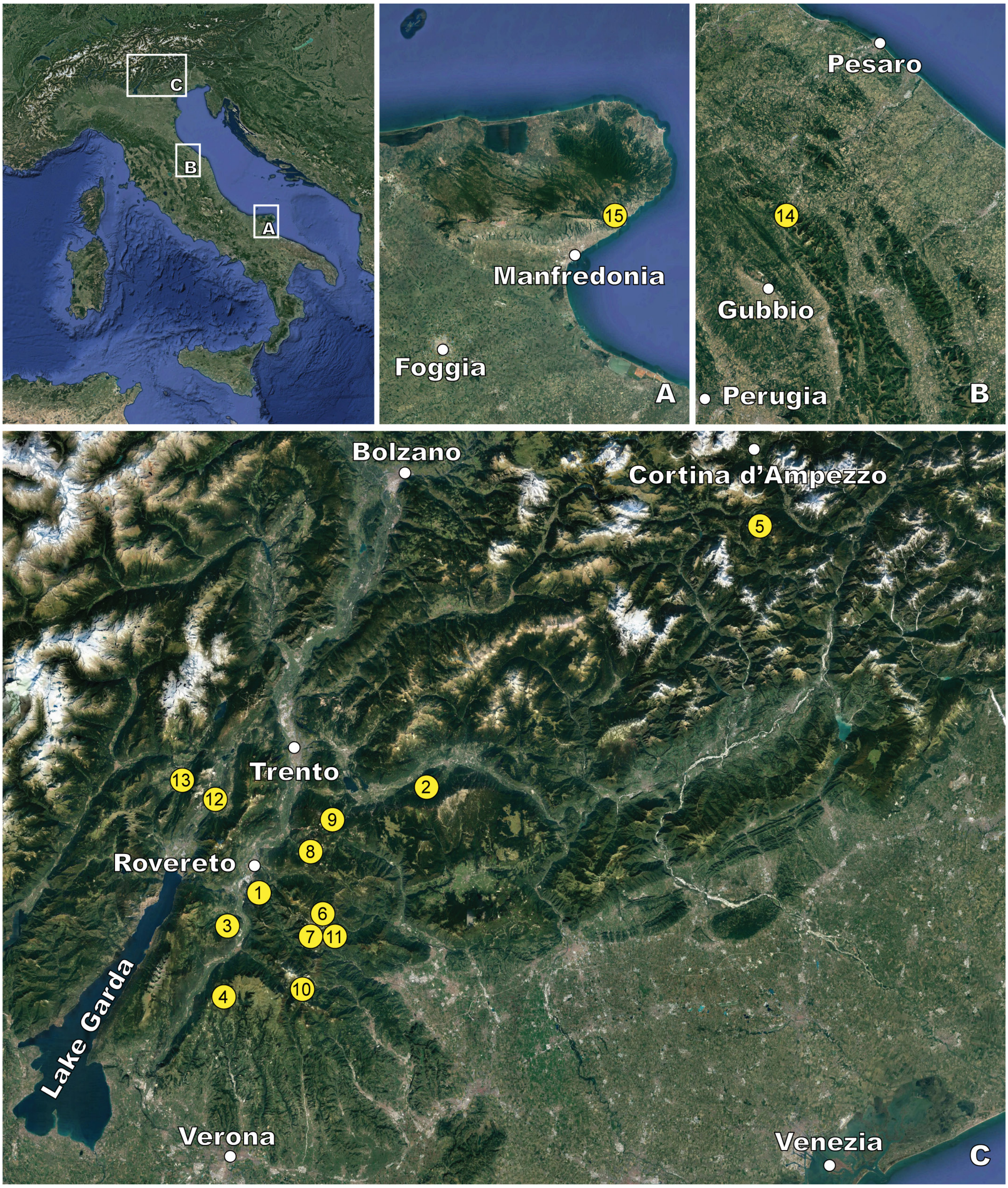

Fig. 1 - Synthetic maps with the location of the Early and Late Jurassic Italian tetrapod tracksites: A) Gargano Promontory. B) Umbria-Marche. C) north-eastern sector of the Southern Alps. Tracksites list: 1) Lavini di Marco; 2) Pizzo di Levico; 3) Chizzola; 4) Sega di Ala; 5) Monte Pelmo; 6) Malga Buse Bisorte; 7) Cima Palon; 8) Monte Finonchio; 9) Becco di Filadonna; 10) Bella Lasta; 11) Stol dei Campiluzzi; 12) Marocche di Dro; 13) Coste dell'Anglone; 14) Burano River; 15) Mattinata.

the Pliensbachian of central Italy (Marche Region; Manni et al., 2000).

Dinosaurs constitute the most conspicuous group of tetrapod trackmakers in the Jurassic of Italy. The Italian Jurassic dinosaur tracksites can be divided into two groups: the diverse dinosaur ichnoassemblages from the Lower Jurassic Calcari Grigi Group of the Trento plateau (North-Eastern Italy) and the scattered dinosaur footprints from the Apulian platform, which are ex situ (?Late Jurassic or Early Cretaceous).

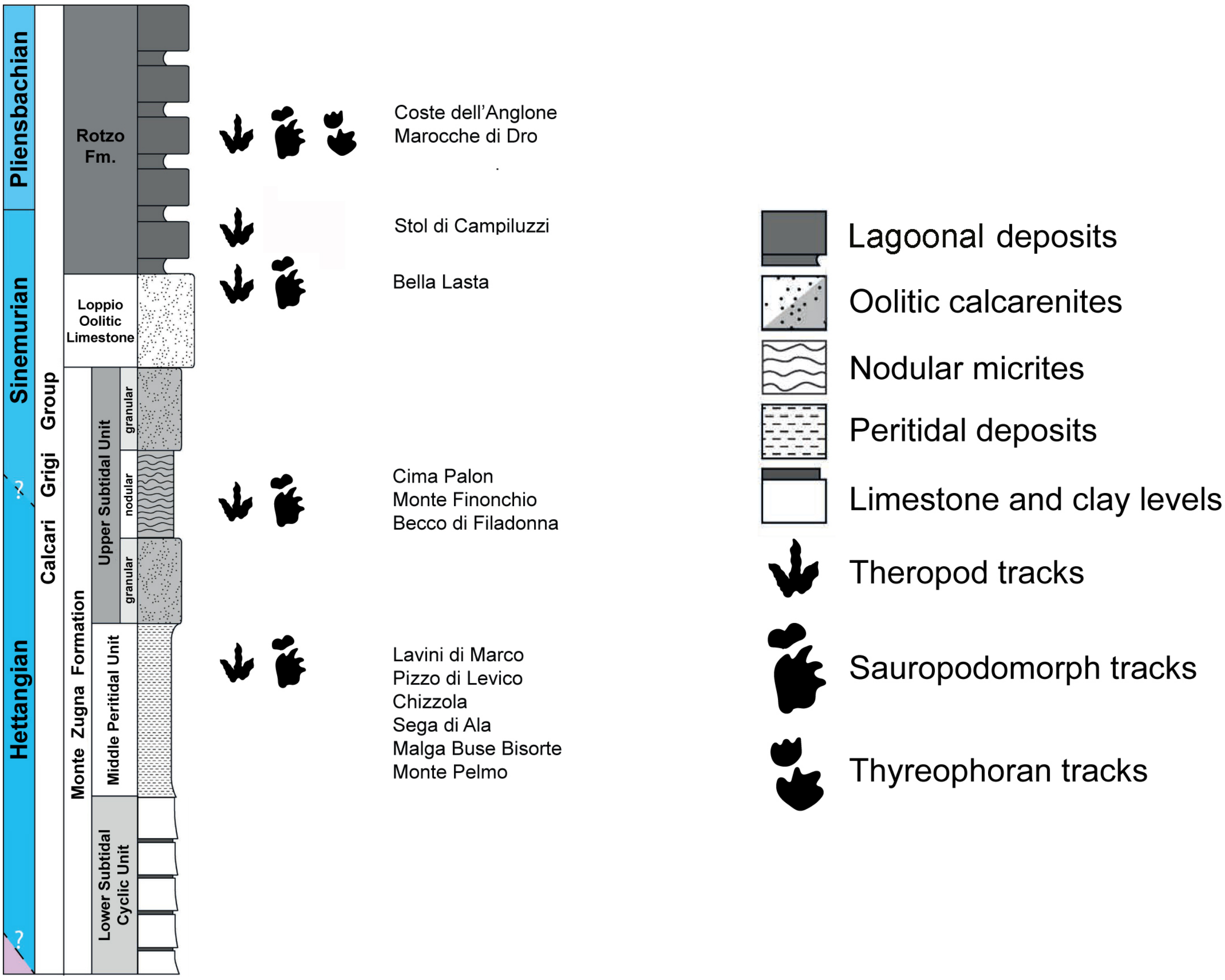

Fig. 2 - Lithostratigraphy of the Calcari Grigi Group with the stratigraphic position of the track levels. Redrawn after Avanzini et al. (2006).

The Calcari Grigi Group was deposited on the Trento carbonate platform (Fig. 3a), whose deposits crop out from Verona to Bolzano (NE Italy). This area, characterized by epicontinental deposits during the Triassic, was affected by the rifting phase of the Southern Alps since the Early Jurassic, linked to the opening of the central North Atlantic. Throughout the Early Jurassic, sedimentation was dominated by shallow-water carbonates that are represented by peritidal, subtidal and oolitic facies belts. The Trento carbonate platform was bounded by the Belluno pelagic basin to the east and the Lombardy pelagic basin to the west (Fig. 3A; Bosellini and Broglio Loriga, 1971; Winterer and Bosellini, 1981; Bertotti et al., 1993; Castellarin et al., 2005; Avanzini et al., 2006; Masetti et al., 2012).

The Apulian carbonate platform (Fig. 3B) is a large palaeogeographical unit which, during the Mesozoic, was part of the southern margin of the Tethys Ocean. It is considered one of the shallow-water domains within the Periadriatic sector ('Periadriatic carbonate platforms' *sensu* Zappaterra, 1990, 1994), quite similar in facies architecture, size and shape to the modern Bahama Banks (Bernoulli, 1972; D'Argenio, 1976).

During Middle-Late Jurassic and Cretaceous times, the Apulian carbonate platform has been interpreted as a small and isolated area, separated from other Periadriatic carbonate shelves (e.g. the Adriatic-Dinaric and Apenninic carbonate platforms) by pelagic basins (e.g. Lagonegro-Molise, Umbria-Marche-Sabina, Belluno, Imerese-Sicanian, and East-Gargano basins) and far from the continental margins of Eurasia and Gondwana (Zappaterra, 1990).

2. EARLY JURASSIC TETRAPOD FOOTPRINTS FROM ITALY

2.1. LAVINI DI MARCO ICHNOSITE, ROVERETO (TRENTINO-ALTO ADIGE, NORTHERN ITALY), HETTANGIAN

Lanzinger and Leonardi (1991) and Leonardi and Lanzinger (1992) were the first to record the occurrence of several dinosaur tracks in the area of Lavini di Marco, located near Rovereto, some 25 kilometres SSW of Trento, on the western slope of Mt. Zugna (Trentino-Alto Adige) (Fig. 4). The tracksite is one of the most important European dinosaur track localities, and has been the

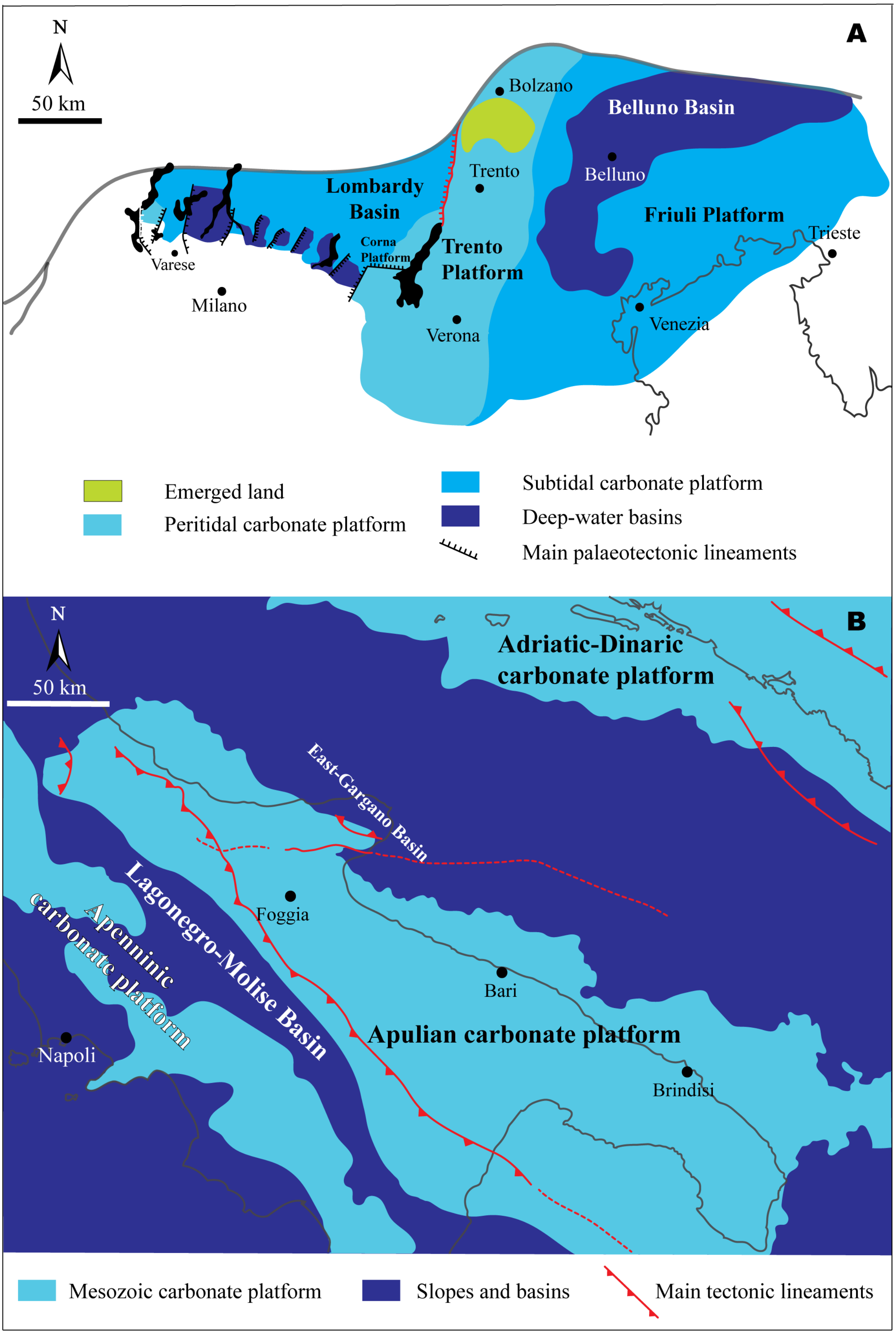

Fig. 3 - A) Palaeogeographic restoration of the central-eastern Southern Alps during the Early Jurassic. B) the Apulia carbonate platform and the adjacent Mesozoic palaeogeographic domains. Redrawn after Petti et al. (2011b) and Morsilli et al. (2017).

subject of several studies since its initial discovery in 1989 by the amateur naturalist Luciano Chemini (Lanzinger and Leonardi, 1991; Leonardi and Lanzinger, 1992; Avanzini and Leonardi, 1993, 1995, 1999; Leonardi and Avanzini, 1994; Avanzini et al., 1995, 1997, 2000 a,b,c, 2001a, 2003, 2006; Leonardi, 1996, 1997, 2000, 2008; Avanzini and Finotti, 1998; Leonardi and Mietto, 2000; Lockley and Meyer, 2000; Avanzini, 2002; Nicosia et al., 2005; Piubelli et al., 2005; Piubelli, 2006). The area is located on a wide monoclinal surface, produced by several landslide events of prehistorical and historical age between 21.200±100 and 800±200 years B.P. (Martin et al., 2014) that covers about 300,000 m^2 (Leonardi and Mietto, 2000; Piubelli et al., 2005).

The first systematic study of such a large and important ichnosite required several preliminary surveys and two major field campaigns (June 1992 and June 1993) directed by Giuseppe Leonardi and Paolo Mietto. Financial and logistical support came from the Museo Tridentino di Scienze Naturali di Trento (now MUSE, Science Museum of Trento), through its director Gino Tomasi and the then curator of the Geology and Palaeontology section Michele Lanzinger, presently director of MUSE. Additional support came from the Museo Civico di Rovereto, through its director Franco Finotti, who was a constant presence during the field campaigns and promoted the conservation, enhancement and musealisation of the Dinosaur Tracks Park of Rovereto (Arzarello et al., 2000). During these two campaigns the first 200 individual dinosaur tracks were numbered, photographed, classified, and some of them were moulded. Trackways were marked with metal plates, each carrying the code and number of footprints, to provide a metric scale and to show the midline axis. Many other footprints were discovered and numbered later, currently reaching about 800 individual tracks in this locality (Avanzini et al., 2003, 2005, 2006; Piubelli et al., 2004, 2005; Piubelli, 2006; Antonelli, 2018; Sacco, 2018).

This site was the training ground for many Italian students and researchers to develop methods and techniques in modern ichnology. The first study of this tracksite led to the publication of a large collective volume, coordinated by the two above-mentioned museums and with the support of the National Research Council (CNR) and the Autonomous Province of Trento (Leonardi and Mietto, 2000).

The Lavini di Marco tracksite consists of alternating stromatolite and dolomite levels, light grey peloidal mudstones, dark grey bioclastic wackestones and reddish mudstones (Avanzini et al., 1997).

Seven track-bearing layers have been identified within a 7 meters thick section: they belong to the 'Middle Peritidal Unit' of the Monte Zugna Formation. Rare microfossils (e.g. the dasycladalean *Palaeodasycladus mediterraneus*) indicate a Hettangian age (Avanzini et al., 2006; Avanzini and Petti, 2008).

Several ichnological surveys led to the identification of hundreds of tracks, preserved as concave epirelief (*sensu* Leonardi, 1987) and assigned to both bipedal and quadrupedal dinosaurs (Figs. 5, 6; Leonardi and Mietto,

Fig. 4 - Field campaign at the Lavini di Marco tracksite in 1991; from left to right Michele Lanzinger, Franco Finotti, and Paolo Mietto.

2000).

Leonardi and Mietto (2000) described six functionally tridactyl morphotypes (Pl. 1, figs. a-f), attributed to small to medium-sized theropods, with footprint lengths rarely exceeding 20 cm. Depending on features such as size and divarication angle of the footprints, shape and relative proportions of the digits, presence/absence of a partial metatarsal impression (described as a wedge-shaped wide "heel", often accounting for about half the area of the whole track) and hallux mark (reported from a single footprint only), the morphotypes were compared with the widespread Early Jurassic ichnotaxa *Grallator* and *Eubrontes*, the Triassic ichnogenus *Coelurosaurichnus* (junior synonym of Grallator according to Leonardi and Lockley, 1995) and the Cretaceous ichnogenera *Columbosauripus* and *Bueckeburgichnus*. The authors however explicitly stated that this comparison is meant to highlight morphological similarities and that they were not formally referring their morphotypes to any of these ichnotaxa.

Piubelli (2006) reassessed the morphotype subdivision and grouped all tridactyl tracks into four morphotypes only (named LA1, LA2, LA3, LA4), based on morphological and morphometrical analyses (Pl. 1, figs. g-j). A type specimen was designated for each morphotype. LA1 is defined as a small-sized track, longer than wide, with low values of the total divarication and a highly extended digit III. LA2 is a medium to large-sized footprint, characterized by digits widening distally, high total divarication and triangular shape of the heel. LA3 is a small to large-sized tridactyl impression (FL between 10 cm and 27 cm), characterized by FL/FW ratio ranging between 1.2 and 1.5, narrow digit III, low mesaxony, total divarication about 55°. Tracks belonging to LA4 are large-sized (FL>22 cm; FW>15 cm), longer than wide (1.3<FL/FW<1.5), characterized by stubby and highly divaricated digits and marked extension of digit III (te/FW≥0.5).

The ichnotaxonomical analysis provided by Piubelli et al. (2005) and Piubelli (2006) led to the identification of a theropod ichnoassemblage composed by the ichnogenera *Grallator* and *Kayentapus* (type specimen ROLM 418; Pl. 1, fig. j). *Kayentapus* isp., an ichnogenus usually associated to a dilophosaur-like trackmaker and known from the Early Jurassic of North America (Welles, 1971) and Northern Europe (Gierliński, 1991; Gierliński and Alhberg, 1994), represents the main ichnotaxon of the Lavini di Marco ichnoassemblage (Piubelli et al., 2005;

Fig. 6 - The largest theropod footprints found at the Lavini di Marco ichnosite (ROLM 219). From left to right: Ilario Sirigu, Marco Avanzini, and Giuseppe Leonardi.

Fig. 5 - Aerial view of trackway ROLM 1 at the Colatoio Chemini taken in 1991.

Piubelli, 2006). The global distribution of this ichnotaxon led the authors to the conclusion that a wide connection, probably represented by the Southern Alps sector, between Laurasia and Gondwana existed during the Early Jurassic (Piubelli et al., 2005).

Avanzini et al. (2001a) reported the occurrence of a couple of tridactyl tracks representing the right and left foot of the same small individual, set side-by-side and sub-parallel with metatarsal impressions. This led them to the suggestion that they might represent a resting posture. The tracks were originally assigned to the ichnogenus *Anomoepus* and attributed to a small ornithischian. According to Avanzini et al. (2001a), these *Anomoepus* specimens show affinities with the forms documented from South Africa (Ellenberger, 1972; Olsen and Galton, 1984; Haubold, 1986), and differ from the specimens from Poland (Gierliński, 1991; Gierliński and Pieńkowski, 1999), thus suggesting a Gondwanan origin for the Lavini di Marco ichnoassemblage.

Recent investigations by FMP, MA and ES (Antonelli, 2018) have shown that the supposed 'metatarsal impressions' described by Avanzini et al. (2001a) are actually due to the overlap of distinct tridactyl footprints. The hypothesis of *Anomoepus* with metatarsal impressions is likely to be rejected.

Since the first studies, 15 trackways produced by herbivorous dinosaurs were identified. Leonardi and Mietto (2000) described two morphotypes, initially referred to sauropod and possible ornithopod trackmakers, respectively.

Undisputable sauropods (Fig. 7) are represented by about 15 short trackway segments, the longest being 7 meters long and constituted by 10 *manus-pes* couples. All trackways in this morphogroup are quadrupedal and narrow-gauge, with the *manus-pes* axis slightly outward oriented (32°) with respect to the trackway midline. The *pes* prints are pear-shaped and up to 52 cm long, often with evident raised rims, and sometimes four small digital impressions are identifiable. The *manus* prints are kidney-shaped, smaller than the associated pedal impressions and externally located with respect to the hindlimb tracks. In four trackways, the *manus* prints are not well-impressed or covered by the overlapping pedal track. Leonardi and Mietto (2000) compared the Lavini di Marco sauropod tracks to the ichnogenera *Parabrontopodus* and *Breviparopus* (Pl. 2, figs. d and f), attributing them to trackmakers belonging to the Eusauropoda group, such as the Vulcanodontidae or the Cetiosauridae.

Five trackways were assigned by Leonardi and Mietto (2000) to a bipedal or semi-bipedal trackmaker (Fig. 8; Pl. 2, fig. e), possibly an ornithopod (but see below for more recent discussion on this topic). The longest trackway in this morphogroup is fourteen meters long and composed of 24 tracks. It is characterized by alternating long and short oblique pace and sub-elliptical or pear-shaped tracks, in which three rounded large digits (II-III-IV) and, rarely, a short and small spur-shaped digit (I) are recognizable. The remaining four trackways referred to this morphogroup are roughly similar, but partly differ in the stubbier shape of the ectaxonic *pes*, characterized by a triangular and elongated heel impression, given by the long impression of digit IV (Leonardi and Mietto, 2000).

After carefully reviewing these trackways and isolated footprints in the field, there is consensus among the authors of this study that they must be attributed to sauropods, which was given as a second alternative hypothesis by Leonardi and Mietto (2000, p. 209).

Avanzini et al. (2003) described the new ichnotaxon *Lavinipes cheminii* from the Lavini di Marco tracksite, referred to a quadrupedal dinosaur (Pl. 2, figs. a-c). The holotype trackway is narrow-gauge, with a tetradactyl *pes* longer than wide (FL=43 cm; FW=31 cm) and a pentadactyl, U-shaped *manus*, wider than long (FL=19 cm; FW=25 cm). Beside the holotype, Avanzini et al. (2003) refer a second trackway to this new ichnotaxon. This quadrupedal form shares some affinities with the ichnotaxa *Otozoum* and *Pseudotetrasauropus*, generally referred to sauropodomorph dinosaurs, but it clearly differs for other characters such as gait (quadruped), digit morphology and numbers.

As a result, the ichnotaxonomical analysis justifies the establishment of the new ichnotaxon *Lavinipes*

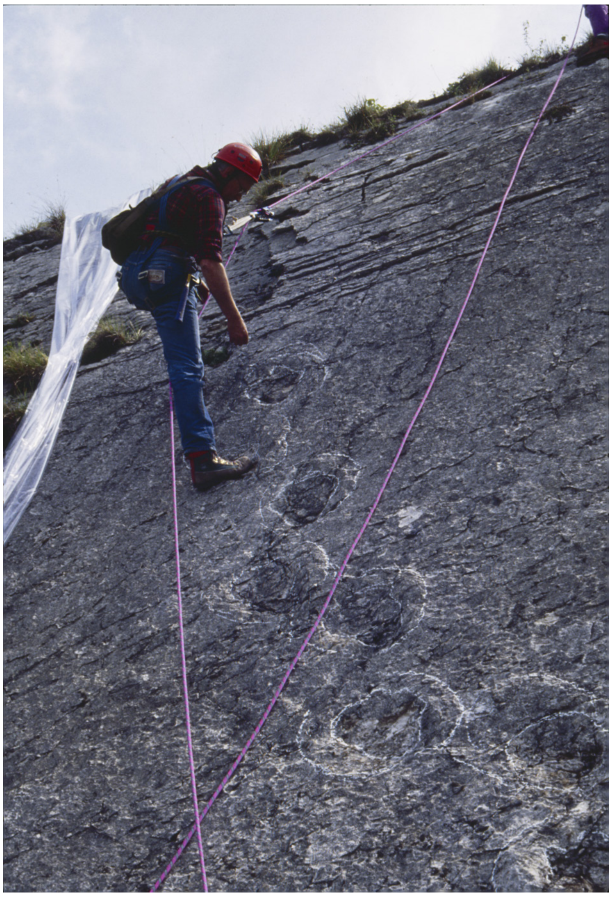

Fig. 7 - Giuseppe Leonardi on the rope analysing one of the quadrupedal trackways (ROLM 26) of the Lavini di Marco tracksite during the field campaign of 1992.

Fig. 8 - The bipedal trackway ROLM 9 at the Colatoio Chemini taken in 2019 (Giuseppe Leonardi for scale).

cheminii Avanzini, Leonardi and Mietto, 2003. Avanzini et al. (2003) attributed *Lavinipes cheminii* to a primitive sauropod trackmaker, related to the basal Eusauropoda group.

In summer 2010 new ichnological surveys were performed by a team composed by researchers from the Geology Section of the Museo Tridentino di Scienze Naturali (now the MUSE, Science Museum of Trento) and the Geological Survey of the Autonomous Province of Trento. During this period the various track-bearing surfaces were carefully analysed and each footprint was georeferenced (Fig. 9).

In 2018, an ichnological review of the Lavini di Marco tracksite was carried out by FMP, MB, MA and ES, within a joint project between MUSE, Sapienza University of Rome and the Autonomous Province of Trento. The results were preliminarily published in two master's degree theses (Antonelli, 2018; Sacco, 2018). The analysis started with a new ichnological survey that led to the identification of more than 700 tridactyl footprints and several quadrupedal trackways. The field work was carried out with combining close-range and aerial photogrammetry to study the tracksite both at the meso-and macroscale. Different types of Unmanned Aerial Vehicles (UAVs; i.e. drones) were used to produce the first detailed map of the large and complex dinosaur track-bearing surface. Close-range photogrammetry models provided extremely detailed information, permitting careful analysis of morphological characters and more reliable ichnotaxonomical assignments and ichnosystematic attributions. Morphological and morphometrical analyses led to assign the tridactyl tracks to the ichnogenera *Anchisauripus, Grallator, Eubrontes*, and *Kayentapus* (Antonelli, 2018). The ichnotaxonomical review of quadrupedal trackways led to an emended diagnosis of *Lavinipes cheminii* and to assign several other isolated tracks and trackways to *L. cheminii* (Sacco, 2018). *Panguraptor*-like and *Sinosaurus*-like theropods have been identified as most likely trackmakers for the tridactyl footprints (Antonelli, 2018), whereas the sauropodomorph *Gongxianosaurus* has been identified as the most likely trackmaker of *Lavinipes cheminii* (Sacco, 2018). The ichnoassemblage reveals a clear Laurasian affinity allowing to hypothesize that during the Early Jurassic the Trento carbonate platform was probably connected to Laurasia through the northern and western sectors of the Southern Alps. These issues will be dealt with in a forthcoming publication.

It should be noted that also a synapsid track assigned to the ichnogenus *Brasilichnium* Leonardi, 1981, has been discovered at the Lavini di Marco ichnosite (Piubelli et al., 2004).

From 2001, the Lavini di Marco ichnosite has been under the supervision of the Civic Museum of Rovereto

Fig. 9 - Georeferencing footprints at the Colatoio Chemini in summer 2010.

and the Museo Tridentino di Scienze Naturali (now MUSE), with the creation of educational trails, walkways and illustrative panels.

2.2. PIZZO DI LEVICO ICHNOSITE, CALDONAZZO LAKE (TRENTINO-ALTO ADIGE, NORTHERN ITALY), HETTANGIAN

Avanzini and Tomasoni (2002) described an isolated tridactyl dinosaur track from the carbonate deposits of Pizzo di Levico. The ichnite was discovered by the authors during the geological survey of the Cima Vezzena area for the CARG Project (Geological CARtography). The locality is about 6 kilometres south-east of the Caldonazzo Lake (Valsugana, Trentino-Alto Adige).

The outcrop belongs to the 'Middle Peritidal Unit' (*sensu* Avanzini et al., 2006) of the Monte Zugna Formation (Hettangian). The track (Fig. 10) is preserved at the top of a reddish oolitic grainstone with intraclasts and black pebbles, but it is most likely an underprint of a tridactyl track left in the overlying stromatolitic horizon (Avanzini and Tomasoni, 2002). The specimen, referred to a medium-sized theropod, shows two clear phalangeal pads on digits II and IV, with digit III better preserved and not exceeding the length of the other digits. It was originally assigned to the ichnogenus *Eubrontes* (Avanzini and Tomasoni, 2002); later, Avanzini and Petti (2008) referred it to the ichnogenus *Kayentapus*.

2.3. CHIZZOLA ICHNOSITE, ALA (TRENTINO-ALTO ADIGE, NORTHERN ITALY), HETTANGIAN

Leonardi and Mietto (2000) described three dinosaur tracks along the provincial road SP 22 leading from Mori to Ala (TN), 3 km south of the Lavini di Marco tracksite. These tracks are no longer visible, having been destroyed during road work.

The track layer forms part of the 'Middle Peritidal Unit' (Fig. 2) of the Monte Zugna Formation and it is therefore Hettangian in age (Leonardi and Mietto, 2000; Avanzini and Petti, 2008). The tracks are preserved as convex hyporelief (*sensu* Leonardi, 1987) on the lower surface of a light-grey stromatolitic interval, dolomitized at the top (Avanzini et al., 1997; Leonardi and Mietto, 2000). The best-preserved track was a left tridactyl footprint, 33 cm long (Pl. 3, fig. a); it showed stubby digits, in which several phalangeal pads were recognizable, with sharp claw marks (Leonardi and Mietto, 2000). Although originally attributed to the ichnogenus *Eubrontes* (Leonardi and Mietto, 2000), the morphology of this track shows close affinities with *Kayentapus* isp. (Avanzini and Petti, 2008). This large footprint was referred to a large ceratosaur-like trackmaker (Leonardi and Mietto, 2000). The remaining two tracks were poorly preserved: the first was originally referred to an herbivorous dinosaur, while the second was attributed to a small-sized theropod (Leonardi and Mietto, 2000).

2.4. SEGA DI ALA ICHNOSITE, LESSINI MOUNTAINS (TRENTINO-ALTO ADIGE, NORTHERN ITALY), HETTANGIAN

Avanzini (2001) described an isolated dinosaur track from a section along the Ala-Passo Fittanze road, south-east of Ala (Lessini Mountains, Trentino-Alto Adige).

The track layer is Hettangian in age, belonging to the 'Middle Peritidal Unit' (Fig. 2) of the Monte Zugna Formation. The footprint is preserved in a natural vertical section (Avanzini, 2001). Three depressions are clearly visible, suggesting the occurrence of a tridactyl track. The central depression, interpreted as that of digit III, is the deepest (i.e. 3 cm in depth), while the lateral depressions, interpreted as digits II and IV, reach 2 cm in depth. The track was referred to a medium-sized theropod (Avanzini and Petti, 2008).

2.5. MONTE PELMO ICHNOSITE, DOLOMITES (VENETO, NORTHERN ITALY), HETTANGIAN

Mietto et al. (2012) first recorded the occurrence of possible dinosaur tracks from Monte Pelmo (Dolomiti di Zoldo, Belluno, Veneto), 3037 m above sea level. Belvedere et al. (2017) described the tracksite, located in the lower part of the Calcari Grigi succession, which is characterized by shallowing upward peritidal cycles (Fig. 11). The track-bearing level lies within the 'Middle Peritidal Unit' (Fig. 2) of the Monte Zugna Formation, indicating a Hettangian age (Belvedere et al., 2017).

Twenty tracks have been recognized, forming three or four trackways: they are very poorly preserved but can be

Fig. 10 - The medium-sized theropod footprint from the Pizzo di Levico ichnosite.

attributed to three different morphotypes.

The first one is represented by a shallow tridactyl footprint (PELM. A1), referred to a theropod trackmaker and morphologically similar to *Kayentapus* isp., although the lack of anatomical details prevents a reliable ichnotaxonomical assignment (Belvedere et al., 2017).

The second morphotype is represented by five or six irregular tracks arranged in a bipedal trackway (PELM. B), in which anatomical details are not preserved. Only PELM. B5 displays a slender tridactyl morphology: the elongated digit III and the narrow interdigital angles show some morphological affinity with the ichnogenus *Grallator* (Belvedere et al., 2017).

The third morphotype is represented by six large tracks (PELM. D), longer than wide, in which only one (PELM. D1) shows a smaller impression, interpreted as the forelimb track of a quadrupedal trackmaker with a marked heteropody. The poor preservation of the tracks prevents a reliable ichnotaxonomical assignment, although they share some affinity with *Parabrontopodus* isp., usually referred to a sauropodomorph trackmaker (Belvedere et al., 2017).

The ichnosite of Monte Pelmo is illustrated in the Vittorino Cazzetta Museum in Selva di Cadore (Belluno) together with a 3D reproduction of theropod footprint derived from a photogrammetric model.

2.6. MALGA BUSE BISORTE AND CIMA PALON ICHNOSITE, MONTE PASUBIO (TRENTINO-ALTO ADIGE, NORTHERN ITALY), LATE HETTANGIAN - EARLY SINEMURIAN

Avanzini (2001) recorded the discovery of two track-bearing outcrops from the Monte Pasubio area, about 10 kilometres south-east of Rovereto (Trentino-Alto Adige). The first track horizon is situated near Malga Buse Bisorte, 1885 m above sea level.

The dinosaur tracks occur at the top of the lower stromatolitic layers of the 'Middle Peritidal Unit' (Fig. 2) of the Monte Zugna Formation, so their age can be referred to the Hettangian (Avanzini and Petti, 2008).

The second track-bearing surface is located west of Cima Palon (Dente Italiano), 2187 m above sea level. It crops out within a stratigraphic interval characterized by nodular brown and dark grey, bioturbated mudstones to wackestones, and marked by the occurrence of two different stromatolitic layers (Fig. 12). The deposits belong to the 'Upper Subtidal Unit' (*sensu* Avanzini et al., 2006) of the Monte Zugna Formation, suggesting a Hettangian to Sinemurian age (Avanzini and Petti, 2008). Tracks from Monte Pasubio are isolated and show a sub-circular morphology, with an average diameter of 30 cm (Avanzini and Petti, 2008). They are surrounded by clear raised rims, whereas the deepest part of the depression occasionally shows collapse structures. The ichnoassemblage of the Monte Pasubio has been attributed to medium-sized sauropodomorph trackmakers, whereas an ichnotaxonomical assignment remains difficult, due to the poor preservation of the anatomical features of the analysed tracks (Avanzini and Petti, 2008).

2.7. MONTE FINONCHIO ICHNOSITE, ROVERETO (TRENTINO-ALTO ADIGE, NORTHERN ITALY), LATE HETTANGIAN - EARLY SINEMURIAN

Avanzini et al. (2008) described five *manus-pes* sets from the western flank of the Monte Finonchio, close to S. Corrado, within the deposits of the 'Upper Subtidal Unit' (Fig. 2) of the Monte Zugna Formation (late Hettangian-early Sinemurian). The stratigraphic interval is characterized by a basal grainy deposit covered by brown and dark grey mudstone-wackestone, within which nodular beds show tractive sedimentary structures (Avanzini et al., 2008).

The dinosaur tracks are preserved as underprints at the top of a mudstone level overlain by a stromatolitic horizon. The track-bearing surface is represented by a steep wall and extremely difficult to access (Fig. 13). For this reason, the ichnological documentation was carried out using a terrestrial laser scanner (TLS), with the aim to obtain a 3D model of the whole surface. The acquisition was performed with a Leica ScanStation 2 laser scanner from a distance of 90 m, setting a mean point to point spacing of 0.005 m (Avanzini et al., 2008). The poorly preserved quadrupedal tracks occur on three superimposed carbonate layers and were interpreted as undertracks, due to their shallow depth (Avanzini et al.,

Fig. 11 - The Mount Pelmo in the Eastern Dolomites; in the foreground, the narrow surface where dinosaur footprints are preserved (Photo by M. Belvedere).

Fig. 12 - Medium-sized sauropodomorph tracks preserved in vertical cross section at Cima Palon (Monte Pasubio, Rovereto; Hettangian-Sinemurian).