

Vertebrate ichnology in Italy

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1. INTRODUCTION

All across the world, fossil footprints were undoubtedly noticed many times in antiquity. Their discovery probably gave origin to the many legend of dragons and giants, as well as on many continents of pious fables regarding the passing of saints and demons.

The first reliable mention of a fossil track was in 1800 or 1802, when the young farmer-student Pliny Moodie found a Jurassic dinosaur track in Connecticut.

Excluding the publication of potential but dubious human footprints (Mississippi Valley) by Henry R. Schoolcraft & T.H. Benton (1822), the first scientific work on tetrapod ichnology was that of the Rev. Henry Duncan, 1831, about Permian tracks of Scotland. There is also the historic published letter of F.K.L. Sickler (1834) to J.F. Blumenbach and the publication of J.F. Kaup (1835) on the first findings of *Chirotherium* in Thuringia.

Ichnology became widespread in the following 50 years, especially in Great Britain, Germany and the United States, even if in the beginning the interpretations were rather debatable.

This enthusiasm weakened afterwards and there were few works in the first decades of the 19th century, precisely in the countries where ichnology began.

In contrast, the newborn discipline continued to spread here and there in other countries: Canada, Slovenia, Australia, China, countries of the Maghreb, Portugal, and Georgia. But until the 1950s, they were marginal studies with respect to classical paleontology.

Starting in the 1960s and 1970s, ichnology progressively reaffirmed itself. Discoveries and publications flourished all over the world. Geology and paleontology conferences held more and more ichnology symposiums, and ichnology journals were founded. To sum up, ichnology today is decidedly in expansion and offers a valuable complement to osteological research as well as to other body fossils and to other fields of Earth Sciences such as stratigraphy and palaeogeography.

2. VERTEBRATE ICHNOLOGY IN ITALY

In Italy, Ichnology got a late start, nearly 50 years after the birth of ichnology as a science. The first ichnology work

was by A. Portis (1879) regarding Eocene tracks in Piemonte, even if some ichnology notes on Permian tracks in the Orobic Alps were present in the work of G. Curioni (1870) a few years earlier (Fig. 1). The same were noted by Geinitz (1869) and Gümbel (1880). A few years later Permian tracks were discovered around Bolzano-Bozen, a region that then was part of Austria, by Ernst Kittl (1891). In 1904, Paolo Vinasza de Regny published a paper on the tracks of Montenegro, still an Italian protectorate. In 1915, A. Fucini described the tracks of Monte Pisano (Pi), revisited later by Friederich von Huene (1940a, 1940b, 1941) and many years later still (1980) by Marco Tongiorgi (1980) who demonstrated that they were not Cretaceous, but Upper Triassic (Fig. 2).

In 1926, Othenio Abel for the first time noticed tetrapod tracks from the Middle Triassic of the Alps, and in 1935 J.J. Dozy published an article about Permian tracks of the Orobic Prealps. Carlo I. Migliorini (1947) noted possible Eocene fossil tracks which were later interpreted by da G.C. Parea (1965) as invertebrate traces. A total of nine new Italian ichnology publications or regarding Italian materials appeared in around 70 years.

In the early 1950s, after gaining experience through the study of a slab with a fossil trackway from the Buntsandstein of Thuringia (1940), Piero Leonardi began to dedicate himself, rather successfully, to the study of Upper Permian fossil tracks from the Alto Adige-Südtirol area, and afterward in Trentino, mostly in the Bletterbach gorge. From this, a true Italian tradition and school began in tetrapod ichnology (Leonardi P. 1951a, 1951b; 1952; 1953a, 1953b, 1953c, 1955; 1957; 1960; 1967). Piero Leonardi also noticed Triassic tracks from the Dolomites (Leonardi P. 1952; 1967) and Spain (Leonardi P. 1959).

After a brief interruption, following the lines of Piero Leonardi and with encouragement from Bruno Accordi and Odoardo Girotti, and with the logistical support and hospitality of the family of Sepp Perwanger from Zimmerhof, the team of then students in geological and natural sciences made up of Maria Alessandra Conti, Giuseppe Leonardi, Nino Mariotti and Umberto Nicosia started to study the Bletterbach gorge and its surroundings (Fig. 3). Shortly after, Umberto Nicosia discovered a surprisingly large track, for that period (Leonardi & Nicosia 1973). A series of systematic field works that began in 1973 led to the discovery of a large num-

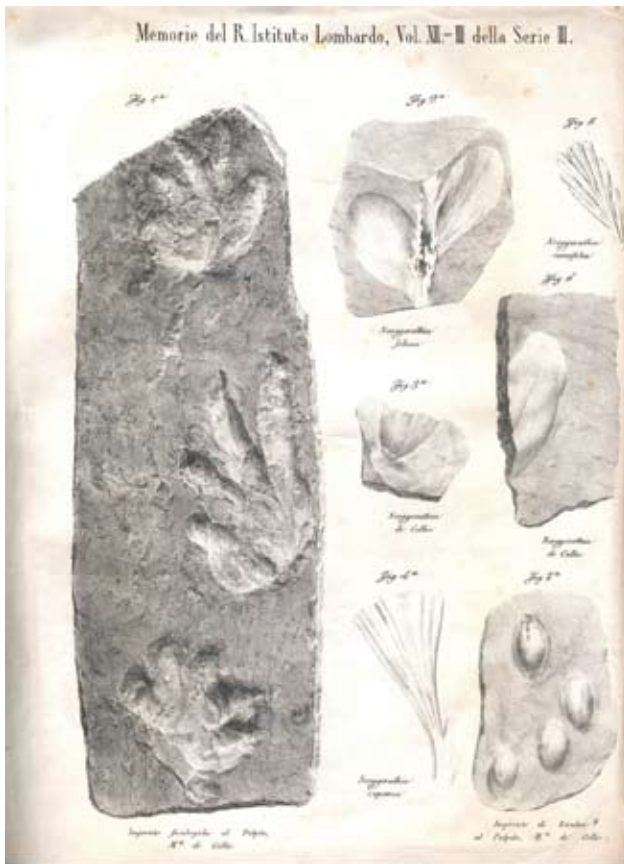


Fig. 1 - Permian tetrapod tracks from the Collio Mounts, Orobic Alps (Lombardy, Northern Italy); from Curioni (1870). Scale bar 5 cm.

Fig. 1 - Orme di tetrapodi permiani provenienti dai Monti del Collio, Alpi Orobiche (Lombardia, Italia settentrionale); tratto da Curioni (1870). Scala 5 cm.

ber of tracks and trackways, to a systematic stratigraphic and paleoenvironmental study, to the revision of their chronological attribution (from the Middle to the Upper Permian), and later to their ichnofaunal and ichnotaxonomic revision (Leonardi G. 1974, 1979; Leonardi P. *et al.* 1975; Conti *et al.* 1975, 1977, 1980). The Bletterbach gorge research continued (Valentini *et al.* 2004, 2007) and the site became a geology park with marked itineraries for visits and local documentation centres (Loppi *et al.* 1998, 2000).

Meanwhile (1974-1989) Giuseppe Leonardi left to work in Brazil as a missionary. Although he continued to collaborate with his colleagues from Rome, he started an intense series of field studies (more than 90) in Brazil and other Latin American countries on vertebrate (especially dinosaurs) and invertebrate ichnology, as well as on geology. This gave rise to a Brazilian ichnology school, as well as a glossary and a manual which contributed to unification of the terminology and methods in the field of tetrapod ichnology at a global level (Leonardi G. 1987). It also led to the first comprehensive treatise of fossil tetrapod tracks (Leonardi, 1994). Further expeditions in later years led Giuseppe Leonardi to the

discoveries of fossil tracks (mostly dinosaur) in Israel, Australia, Bolivia, Paraguay, and other countries.

Rainer Brandner (1973) published a series of Triassic tracks of the Braies Dolomites (Fig. 4) which were found in an area first described by Abel (1926).

Paolo Mietto (1975, 1981, 1986, 1987) carried out ichnological researches in the Upper Permian of the Piccole Dolomiti around Recoaro. Two papers about small amphibian trackways from the Upper Carboniferous of the San Giorgio Basin (Iglesiente area, Sardinia) were published by Roberto Fondi (1979, 1980).

The state of the art of tetrapod ichnology in Italy until 1980 can be found in the volume *I Vertebrati Fossili Italiani* (Italian Fossil Vertebrates), a catalogue of an exhibit at the Museo Civico di Storia Naturale of Verona (AA. VV. 1980).

From the early 1990s to today, many field studies were carried out in the Lower Permian Collio Formation (Northern Italy, Valtrompia, Val Brembana, Valle dell'Inferno) to study amphibian and reptile ichnoassociations, by ichnologists from the University of Rome "La Sapienza" and the University of Pavia (Ceoloni *et al.* 1987, Conti *et al.* 1991, 1997; Santi & Krieger, 1999; Nicosia *et al.* 2000a; Santi, 2001; Santi & Krieger, 2001; Confortini *et al.* 2002; Ronchi & Santi 2003; Santi, 2003, 2004, 2005, 2007)

Italian ichnology seemed once again to be in decline, when in 1991 the discovery of two dinosaur trackways in the Lavini di Marco (Lower Jurassic, Rovereto, TN) by Luciano Chemini brought Giuseppe Leonardi and then many other ichnologists to systematically study what would progressively become a very rich dinosaur tracksite (Fig. 5). Dinosaur tracks and trackways attributed to the Lower Jurassic were also discovered in other zones in Trentino and the Dolomites (Leonardi & Lanzinger 1992; Avanzini & Leonardi 1993; Leonardi & Avanzini 1994; Leonardi G. 1996; Avanzini & Leonardi 1999). A voluminous summary on Italian dinosaurs, particularly concentrated on the Lavini di Marco tracksite, as well as on other tetrapod tracks and trackways, was published in 2000 with contributions from 25 researchers, mostly paleontologists and geologists from various Italian institutions (Leonardi & Mietto, 2000).

The Lavini di Marco field works gave new impulse to ichnology research, particularly on dinosaur tracks, thanks to the participation of many young paleontologists. Afterward, Marco Avanzini published – alone or with other colleagues – a number of papers on fossil trackways from the Anisian-Lower Jurassic deposits of Trentino and the eastern sector of Southern Alps in general (Avanzini *et al.* 2000, 2001b, 2001c, 2001d; Avanzini & Leonardi 2002; Avanzini *et al.* 2003).

Paolo Mietto (1988) studied and made preliminary publications of the tracks and trackways in the Monte Pelmetto area, attributed both to carnivorous and herbivore dinosaurs (Belluno, Veneto) (Fig. 6). These were the first findings in Alps and practically the first in Italy, except for the three small footprints of Monte Pisano attributed to carnivore

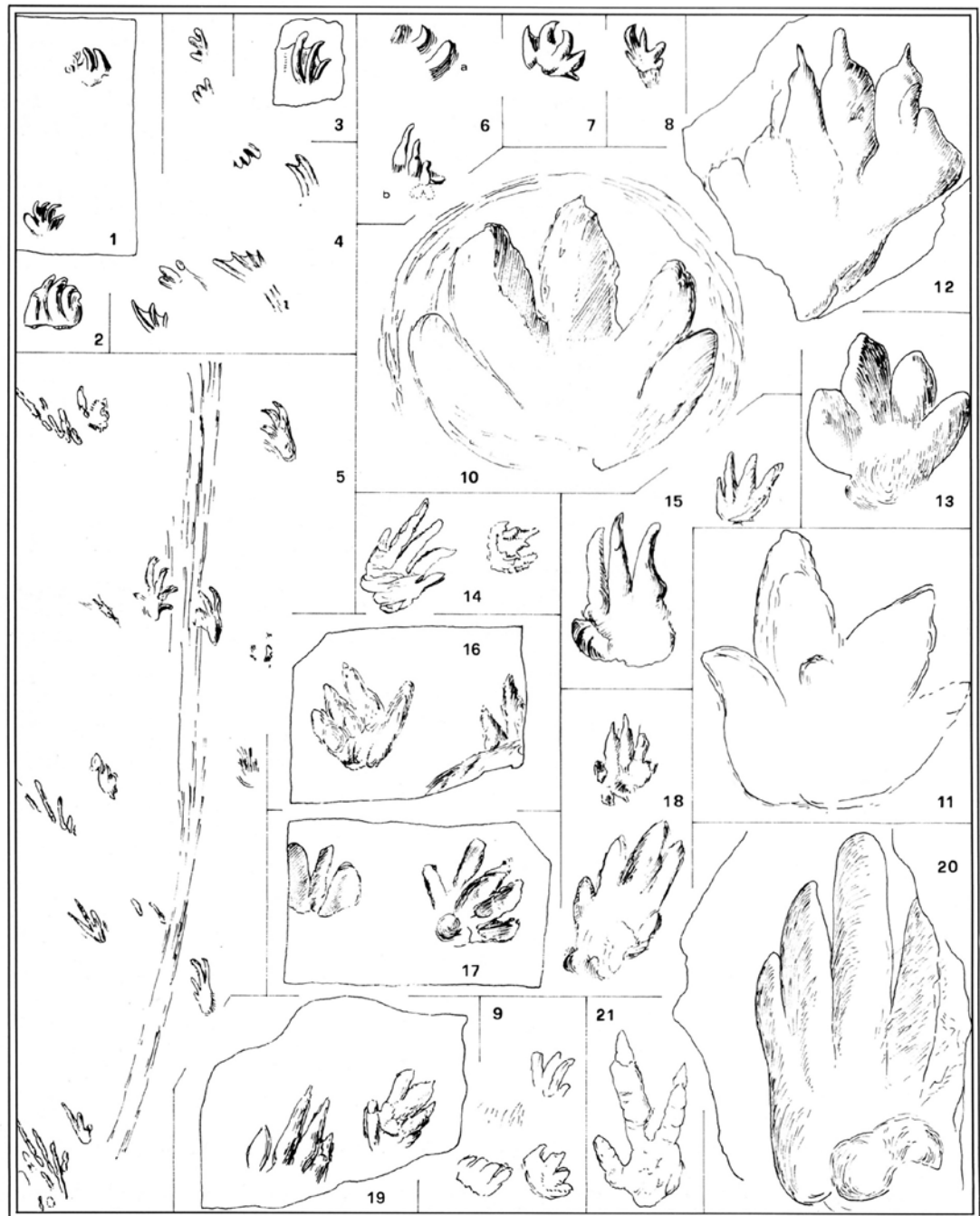


Fig. 2 - Upper Triassic tetrapod tracks from the Pisani Mounts (Tuscany, central Italy). Dimensions are about 2/3 than life size. The plate is from Tongiorgi (1980) and is composed with the original drawings by von Huene (1941).
 Fig. 2 - Orme di tetrapodi del Triassico superiore, provenienti dai Monti Pisani (Toscana, Italia centrale). Le dimensioni sono circa 2/3 della grandezza naturale. La tavola è tratta da Tongiorgi (1980) ed è stata composta con i disegni originali di von Huene (1941).

rous dinosaurs. This unquestionably important find was first mentioned by Vittorino Cazetta.

In 1988, Ilario Sirigu (who regrettably died prematurely), a high school student with a passion for dinosaurs, discovered near Lerici (La Spezia, Liguria) some interesting Carnian tracks which were attributed to small prosauropod dinosaurs and to quadrupedal archsauromorphs (Sirigu & Nicosia 1995; Sirigu & Tongiorgi 1997; Nicosia & Loi 2003; Nicosia *et al.* 2005).

Leonardi & Lockley (1995) proposed – unfortunately without immediate follow up to the brief abstract – reclassifying the first dinosaur tracks found at Monte Pisano as *Gral-*

lator sp., and thus abandoning the ichnogenus *Coelurosaurichnus* and the ichnospecies *Coelurosaurichnus toscanus*, instituted by F. von Huene on the basis of a totally misleading sketch and brief description (1941).

Toward the end of the last century and the start of the present, a whole series of publications reported on various fossil tracks and trackways – mostly dinosaurs but not only – in the east central Alps, especially in many localities of Trentino, Alto Adige and Veneto, as well as in the whole Dolomiti area. It is worth mentioning the Anisian materials (beyond the already cited publications of Abel 1926 and Brandner 1973; Conti *et al.* 2000; Avanzini *et al.* 2001a; Avanzi-



Fig. 3 - Bletterbach gorge, near Redagno (Bolzano, Alto Adige, Northern Italy).

Fig. 3 - La gola del Bletterbach, nei pressi di Redagno (Bolzano, Alto Adige, Italia settentrionale).



Fig. 4 - *Brachychirotherium* aff. *parvum* from the Middle Triassic of Braies Dolomites (Alto Adige, Northern Italy).

Fig. 4 - *Brachychirotherium* aff. *parvum*, Triassico medio delle Dolomiti di Braies (Alto Adige, Italia settentrionale).



ni & Renesto 2002; Avanzini & Lockley 2002), often represented by lacertoid tracks, attributed to the ichnogenus *Rhynchosauroides*, chirotheriid tracks related to quadrupedal archosauromorphs, or yet the tridactyl tracks attributed to interesting dinosaur precursors (Nicosia *et al.* 2005).

Analogously, there are abundant finds and recent publications of ichnological materials from the Upper Carnian and Norian deposits of the Southern Alps. Fabio M. Dalla Vecchia (1996) – beyond his exemplary studies and publication on Slovenian and Croatian dinosaur tracks – studied tracks and trackways, attributed to quadrupedal archosaurs, from the upper Carnian of Dogna (UD). In addition, with Paolo Mietto, he published on a number of dinosaur trackways of the Carnic Prealps (Dalla Vecchia & Mietto 1998).

Fig. 5 - G. Leonardi and M. Avanzini analyzing one of the trackway at the Lavini di Marco.

Fig. 5 - G. Leonardi and M. Avanzini esaminano una delle piste dei Lavini di Marco.

A lot of new dinosaur footprints were then found in the Lower Jurassic carbonate deposits, mainly from the Calcari Grigi Group, of southern Prealps and Alps, in what became known as the Calcari Grigi mega-ichnosite (Leonardi & Miletto 2000; Avanzini *et al.* 2001a, 2001d, 2006, 2007).

Two Cretaceous dinosaur footprints, one attribute to theropods and the other to sauropods, were discovered on a breakwater boulder of Porto Corsini, near Ravenna (Dalla Vecchia & Venturini 1995).

The unexpected discovery by two geologists (Massimo Sarti and Michele Claps) of very numerous dinosaur tracks (about 30.000) in an abandoned quarry around Altamura (Upper Cretaceous, Bari, southern Italy) opened up an ichnological research phase in the Mesozoic carbonate deposits of southern and central Italy. The Altamura tracks, attributed to ornithopods (Fig. 7) and thyreophorans and dated to the lower Santonian were studied in detail by Umberto Nicosia and by other ichnologists from the University of Rome "La Sapienza" (Andreassi *et al.* 1999; Nicosia

et al. 2000b, 2000c; Perugini & Ragusa 2004; Perugini *et al.* 2005; Petti 2006).

Taken together, this is generally beautiful, impressive material to look at, but difficult to study due to the general lack of morphological details. Here, study would require considerable commitment both in personal and financial terms. It also poses the problem of conservation. A permanent laboratory and an in loco research center would be required.



Fig. 6 - View of the Monte Pelmetto boulder (Belluno, Veneto, Northern Italy).

Fig. 6 - Veduta del masso del Monte Pelmetto boulder (Belluno, Veneto, Italia settentrionale).



Fig. 7 - Ornithopod trackway (ACDL 99/2) of the Altamura tracksite (Bari, Apulia, Southern Italy).

Fig. 7 - Pista di ornitopode (ACDL 99/2) del sito di Altamura (Bari, Puglia, Italia meridionale).



Fig. 8 - A. Bosellini close to a theropod trackway of the Borgo Celano tracksite (Gargano Promontory, Puglia Italia meridionale).

Fig. 8 - A. Bosellini accanto ad una pista di teropode dell'ichnosito di Borgo Celano (Promontorio del Gargano, Puglia, Italia meridionale).



Fig. 9 - Sauropod trackway (SCP I-1) discovered at the Sezze tracksite (Latina, Lazio, Central Italy).

Fig. 9 - Pista di sauropode (SCP I-1) rinvenuta nel sito di Sezze (Latina, Lazio, Italia centrale).

In early 2001, in the wake of the Altamura find, two speleologists (A. Wagensommer and V. Savino) found some medium sized theropod tracks on three calcareous blocks of the pier in the port of Mattinata, in the southwestern sector of the Gargano Promontory. The tracks belong to the Upper Jurassic and thus represent the oldest evidence of dinosaurs in the Apulian carbonate Platform (Conti *et al.* 2005).

In June 2000, numerous dinosaur tracks were discovered by a research group from the University of Ferrara (A. Bosellini, P. Gianolla and M. Morsilli) in a quarry a little south of Borgo Celano, in the Gargano Promontory (Fig. 8) (Gianolla *et al.*, 2000a, 2000b, 2001). The quarry, still active, is in a carbonate platform succession belonging to the Lower Cretaceous. The tracks, discovered on three distinct levels of the upper Hauterivian-lower Barremian interval, are mostly tridactyl, and referred to medium sized theropods and ornithischians (Petti *et al.* 2008).

In July 2003, hundreds of dinosaur tracks were discovered on three distinct levels in an abandoned quarry (Cava Petrianni), to the west of Sezze (Monti Lepini, Latina, southern Lazio), about 70 km south of Roma. The material, attributed to the lower Cenomanian, is represented by a trackway attributed to medium sized sauropod (Fig. 9) and by hundreds of tridactyl and tetradactyl footprints related to small and medium sized theropods (Nicosia *et al.* 2007).

Then, in 2004 the ichnologists of the University of Rome began a new field excavation in the Upper Carboniferous deposits of the San Giorgio Basin (Iglesiente area, Sardinia), bringing to light new small tetrapods tracks (Conti *et al.* 2004; Nicosia *et al.* 2004).

In 2006, footprints attributed to various dinosaur groups were identified in the Aptian carbonate deposits of Apulia (Bisceglie, Bari; Sacchi *et al.* 2006) and Lazio (Esperia, Frosinone; Petti *et al.* 2007).

Recent discoveries of dinosaur tracks in Italy questioned the palaeogeographic reconstructions of the western Tethys and opened a new line of research. Thus, the importance and the role of paleoichnology in paleogeographic re-

construction has been underscored by a number of studies that created models which are constrained both by geological and ichnological data (Bosellini 2002; Dalla Vecchia 2002; Piubelli *et al.* 2005; Conti *et al.* 2005; Petti 2006; Nicosia *et al.* 2007).

A synthesis, updated to 2005, of the Italian continental vertebrate record from the Paleozoic and Mesozoic, including tracks, was presented by Umberto Nicosia and many others researchers in a volume of the *Memorie del Museo Civico di Storia Naturale di Verona*, edited by L. Bonfiglio (2005), in which a more complete summary can be found.

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