Rivista Italiana di Paleontologia e Stratigrafia	volume 101	numero 1	pagine 93-98	Maggio 1995

NOTE BREVI

A THEROPOD (REPTILIA, DINOSAURIA) FOOTPRINT ON A BLOCK OF CRETACEOUS LIMESTONE AT THE PIER OF PORTO CORSINI (RAVENNA, ITALY)

FABIO M. DALLA VECCHIA[+] & SANDRO VENTURINI[*]

Key-words: Footprint, Theropoda, Dinosauria, Upper Hauterivian, Periadriatic carbonate platforms, Cansiglio Plateau, Northern Italy.

Riassunto. Viene descritta una impronta tridattila, riferibile a un dinosauro teropode, rinvenuta su un blocco di calcare hauteriviano utilizzato per la costruzione del molo di Porto Corsini (Ravenna). È stata identificata la probabile zona di provenienza: le cave aperte nel fianco meridionale dell'Altipiano del Cansiglio (Pordenone). Si tratta della prima segnalazione di impronte di dinosauro nel Cretaceo italiano e il primo ritrovamento di impronte hauteriviane nelle piattaforme carbonatiche periadriatiche.

Abstract. A tridactyl footprint referable to a theropod dinosaur, found on a limestone block of Late Hauterivian age, is described here. The block was used to build the pier of Porto Corsini (Ravenna, Italy); the site of provenance is located on the southern flank of the Cansiglio Plateau (Pordenone, Northeastern Italy) where there are several quarries. This is the first record of a dinosaur footprint in the Cretaceous of Italy and the first indication of Hauterivian dinosaur tracks in the Periadriatic carbonate platforms.

Introduction.

The footprint described here was found by one of us (S. Venturini) during the summer of 1994 along the coast of the Adriatic Sea near the town of Porto Corsini (Ravenna, Emilia-Romagna Region). It was preserved on the surface of one of the limestone blocks which were used to build the piers protecting the entry of the port of Ravenna. The block was transported to Porto Corsini from a quarry when the pier was built.

Further blocks of similar lithology and age have been located at the two piers. They preserve structures which may be due to dinosaur activity. These structures are not described here due to their poor state of preservation.

Age, environment of sedimentation and the problem of the source quarry.

Some blocks forming the piers were investigated with success from the biostratigraphic point of view. The printed block contains the benthic foraminifer *Orbitolinopsis capuensis* (De Castro) which has a range limited to the Upper Hauterivian. This foraminifer was also found in four other blocks presenting depressions which may be related to dinosaur activities.

Most of the limestone blocks show similar lithofacies, with bed thickness exceeding a metre, the presence of occasional stylolites and rare requienids; the bed surfaces present mud cracks, bioturbation due to burrowing organisms and pedogenetic breccias (sometimes with black pebbles). The colour ranges from whitish through light brown to pale pink. Generally, the facies corresponds to the peritidal successions of the inner part of the Periadriatic carbonate platforms. The blocks sometimes present desiccation structures (mud cracks, birdseyes) and mostly comprise muddy facies, often with ostracods. In contrast, the level with the footprint is a fossiliferous wackestone (with foraminifers and ostracods), with no traces of subaerial exposure. Therefore the print was probably impressed on intertidal muds which were later covered and sealed by a transgressive subtidal layer (see the following description of the specimen), representing a moderately more open but low energy environment.

The identification of the source quarry of the blocks has been particularly complex. The work on the piers was done by the CMC (Cooperativa Muratori Cementisti) of Ravenna between 1960 and 1966. This firm, however, does not have documentation on the purchase and transport of the material. Transportation by boat from the coast of the former Yugoslavia was rejected by Mr. F. Polani who was foreman during the building of the piers. Mr. F. Polani and Mr. A. Giometti informed us that the transport was done exclusively by lorries coming from northern Italy. Our research was therefore directed to the closer inner carbonate platform outcrops of Early Cretaceous age

+ Museo Paleontologico Cittadino, Via Valentinis 134, I-34074 Monfalcone (Gorizia) and Dipartimento di Geologia, Paleontologia e Geofisica, Università degli Studi, Via Giotto 1, I-35137 Padova.

* Via Dradi 31, I-48100 Ravenna.

(Cellina Limestone Formation): the Cansiglio Plateau (Southern Alps, North-eastern Italy). Only a quarry among those working along the southern border of the Cansiglio Plateau - the "Cava di Sarone" of Sarone (Pordenone) - supplied the CMC of Ravenna for the building of the piers. The Director of the quarry, dr. G. Buttol, kindly provided information concerning other suppliers of the CMC at the time of pier construction. Only two of these quarries produced limestone blocks of Early Cretaceous age: the quarry of Cittanova in Istria (Croatia) and the quarry of Aviano (Pordenone). The first works Albian limestones (see Tišljar et al., 1983, fig. 1). Three kilometers from the quarry, dinosaur tracks were found on limestones dated to the lower part of Late Albian (Dalla Vecchia et al., 1993). Outcrops of Hauterivian limestones occur in a relatively small area on the Istrian peninsula (see Tišljar et al., 1983, fig. 1) where only small quarries for local use are open (for example, at Barbariga, north of Pola/Pula). The quarry of Aviano was opened a few kilometers east of the Sarone quarry at the base of the Cansiglio Plateau and is now closed.

The lithofacies present at Sarone quarry are very similar to those in the blocks of Porto Corsini (similar colours, bed thickness exceeding a meter, occasional stylolites, predominance of muddy facies with ostracods, presence of pedogenetic breccias sometimes with black pebbles). The lithofacies at Aviano quarry are a little different with respect to those of the blocks; we have not found pedogenetic breccias, the stratification is thinner and the colour in general seems to be light gray or whitish.

We sampled the two quarries in order to establish which stratigraphic interval they worked. Only the stratigraphically lower section of the part of Sarone quarry which supplied the material for the CMC was sampled since the upper section is now no longer accessible. The uppermost sampled level contains *Orbitolinopsis capuensis*; therefore there is also strict biostratigraphic correspondence between the blocks of the piers of the port of Ravenna and the levels of the Sarone quarry. Some samples collected at Aviano quarry contain rare specimens of *Salpingoporella* cf. *muehlbergii* (Lorenz) which indicates a probable Barremian age.

Italian carbonate platform rocks of Early Cretaceous age also outcrop in the Central Apennines, in the Southern Apennines, in the Gargano Promontory and in the Murge. In particular, analogous Hauterivian limestones outcrop in the Southern Maiella (Morrone di Pacentro Formation), near Frosinone (Mts. Simbruini and Mts. Ernici, Western Marsica), in the Western Matese Mts., in the Gargano Promontory (S. Giovanni Rotondo Limestones) and in the Murge (Bari Limestone). The provenance of our sample from the quarries extant at these localities can be excluded because 1) they are not among the suppliers of the CMC, 2) they are a long way from Porto Corsini (the closest is at least 350 km far away) and the transport of such an amount of material would have been uneconomic.

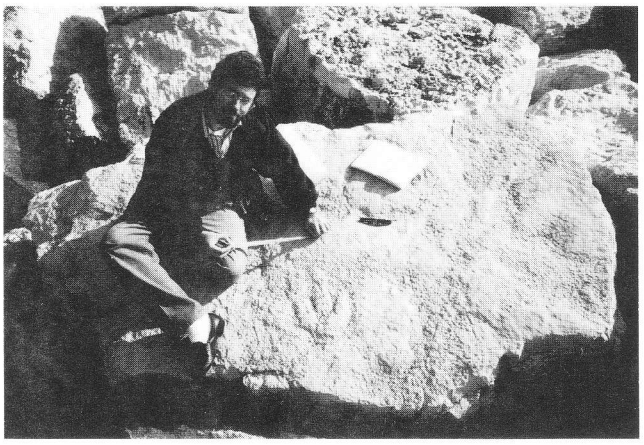

Fig. 1 - Panoramic view of the block with the footprint, taken at 11 a.m. during early autumn, with light coming from the right side of the photograph.

The southern flank of the Cansiglio Plateau is thus the only place of provenance reasonably possible for the Hauterivian blocks of Porto Corsini; on current information, Sarone quarry seems to be the most likely source for them.

Description.

The track is preserved on the exposed surface of a block about 2.5 m x 1.5 m (Fig. 1). It is a convex hyporelief which is not in a very good state of preservation and is evident only with low angle illumination (Fig. 2A). It is tridactyl mesaxonic; none of the distal ends of the digital marks are well defined. The most probable outline is given in Fig. 2B and the following description is based on that interpretation. The median digit is straight and more slender and elongated than the outer digits. The ratio of maximum width to length is 0.25. At the tip there seems to be the track of a small claw, bent to the right (the left in Fig. 2) but its relief is very faint and it is visible only with very low angle lighting; a similar print of the claw is common in large tridactyl dinosaur tracks (see for example, Haubold, 1971, fig. 43-44, 47; Leonardi, 1984, fig. 9; Pittman, 1989, fig. 15.8). The relief is damaged by stylolitic dissolution just before the tip of the median digit print. There are the faint indications of three pads in the proximal, better preserved part of the print; the proximal termination of the phalangeal portion of the digit is quite well marked.

The right digit impression (which is on the left in Fig. 2) is rather wide with respect to its length; the

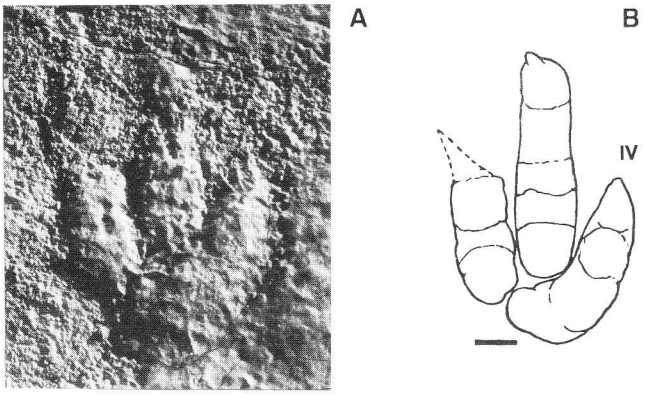

Fig. 2 - A) Photograph of the footprint, taken at 11 a.m. during early autumn, with light coming from the upper right corner of the photograph; B) drawing of the footprint; dotted lines contour doubtful structures. Scale bar: 5 cm.

digit therefore was stocky. Distally the digit print seems to end with a faint pointed mark which is bent outwardly and is modified by stylolitic dissolution. There are two large pads; the proximal termination of the phalangeal portion of the digit is well marked. The left digit is similar to the right one but its distal end does not show a pointed and bent mark; the proximal end of the phalangeal portion is not well marked and it is not possible to recognize the border with the "heel" (sensu Leonardi, 1987). There are only faint traces of pads. The "heel" mark is small. The presence of an indentation between the right digit and the "heel", the merging of the left digit into the "heel", the probable outer bending of the point of the median digit and, perhaps, of the distal end of the right one indicate that the convex hyporelief is the infilling of a left pes print (cf. Haubold, 1971; Pittman, 1989; Thulborn, 1989b). The outer digit on the left in Fig. 2 is therefore digit II (medial), while that on the right is digit IV (lateral).

The length of the footprint is 36 cm. The length of the phalangeal portion of digits II and III is 22.5 cm and 28 cm respectively. The distance between the tip of the digit IV and the posterior termination of the "heel" is 22 cm. The projection of the mark of the digit III beyond that of digits II and IV accounts for 26% and 43% respectively of the whole pes length. The angle between digits II and III is 8° whereas the angle between digits III and IV is 20°; the angle between digits II and IV is therefore 28°. The footprint is decidedly longer than it is broad (ratio width/length = 0.67). Assuming that the described footprint is part of a trackway, the pace length should be equal or higher than 100 cm, since there is no evidence of the right foot on the block surface; in this case, the ratio of stride length/footprint length should be equal or greater than 5.5/1. This conclusion is not valid, of course, if our specimen is an isolated footprint.

Discussion.

Only two groups of dinosaurs are potential candidates as trackmakers for a tridactyl footprint of such age and size: Theropods and Iguanodontids (including related ornithopods; Norman & Weishampel, 1990). In the trackways left by the latter the pes print is sometimes associated with manus prints because they could walk quadrupedally (Leonardi, 1984; Lockley, 1987, 1991; Moratalla et al., 1992; Norman, 1980). The free segment of iguanodontid digit prints is usually rather short with respect to the length of the whole footprint, digit III is not much longer than the outer ones and the footprint is as long as it is wide or even wider than it is long (Haubold, 1971; Leonardi, 1984; Lockley, 1991; Moratalla et al., 1992; Thulborn, 1989b). This is confirmed by comparison with foot osteology (Norman, 1980; Norman & Weishampel, 1990). The tip of the digits was hoof-like therefore claw marks cannot be present; iguanodontid footprints often present instead a bluntly rounded end and, sometimes, the digit (particularly digit III) prints are broadened towards their tip (Leonardi G., pers. comm.; Leonardi, 1984; Lockley, 1991; Pittman, 1989; Thulborn, 1989b). The prints of digits II and IV have similar lengths in iguanodontids (Haubold, 1971; Leonardi, 1984; Moratalla et al., 1992; Thulborn, 1989b) and the prints of the tip of digit II and III are not bent medially (Moratalla et al., 1992; Thulborn, 1989b). Generally speaking, total divarication of digits II-IV is higher in large ornithopods than in large theropods (Thulborn, 1989b). The ratios stride length/footprint length often falls between 3/1 and 6/1 (Thulborn, 1989b).

By contrast, the lack of the manus print in the trackways, the long free segment of digit prints, digit III often decidedly longer than the others and more slender, digit II being shorter than digit IV and clearly separated from the "heel" while digit IV continues posteriorly without interruption into the "heel", the presence of an indentation between digit II and the "heel" print along the posteromedial margin, the frequent medial bending of the tip of digits II and III, the presence of claw marks, "heel" impression relatively small and V-shaped, slightly elongated and asymmetric are typical characters of theropod dinosaur footprints (Haubold, 1971; Lockley, 1991; Moratalla et al., 1992; Pittman, 1989; Thulborn, 1989b). The ratio of stride length/footprint length in large theropod trackways is usually about 5/1 (Thulborn, 1989b).

The shape of the Italian track described above suggests that it does not belong to an ornithopod dinosaur. Its morphology and size indicate that it belongs to a medium-large theropod ("carnosaurian" in the ichnological meaning, see Leonardi, 1984 and Thulborn, 1989b).

More detailed comparison between the Italian specimen and established ichnotaxa is not given here since the material is not in a good state of preservation, it consists of only a single footprint and the taxonomy of tridactyl footprints is in a state of continual and dramatic revision (see for example, Demathieu, 1990; Olsen & Galton, 1984). In comparison to theropod footprints of similar size, our specimen presents a particularly long digit III and stocky outer digits (compare with Haubold, 1971, fig. 40, 43-45, 47; Pittman, 1989, fig. 15.8; Thulborn, 1989b, fig. 6.3-6.4).

Using allometric equations from Thulborn (1989a) we have a hip height of 181 cm.

Conclusions.

Until a few years ago the dinosaur record in Italy was represented only by a single tridactyl footprint from the Upper Triassic of Tuscany (see Tongiorgi, 1980). From the end of the last decade discoveries have become more and more frequent. At present we know dinosaur tracks from the Upper Triassic of Tuscany, Veneto (Mietto, 1988, 1991), Friuli (Mietto, pers. comm.), Alto Adige (Leonardi & Avanzini, 1994), the Lower Jurassic of Trentino (Leonardi & Lanzinger, 1992), Veneto (Mietto & Roghi, 1994) and Marche (P. Arduini, pers. comm.). Bone remains were discovered in the Lower Cretaceous of Campania (Leonardi & Teruzzi, 1994; Leonardi & Avanzini, 1994) and, perhaps, in the Upper Cretaceous of the province of Trieste (Brazzatti & Calligaris, 1994).

We report here the first record of a dinosaur track in the Cretaceous of Italy.

Dinosaur tracks are common in the Cretaceous limestones of the nearby Istria (Croatia) (Dalla Vecchia et al., 1993). During the Early Cretaceous the zone corresponding to the present Cansiglio Plateau belonged to the Friuli Platform, which was connected with the Dinaric Platform extending into Istria (Sartorio, 1991; Zappaterra, 1990). The track reported here demonstrates that dinosaurs could reach and live at the northernmost point of the Periadriatic Carbonate Platforms as it was previously hypothesized (Boscarolli et al., 1993; Dalla Vecchia et al., 1993; Dalla Vecchia, 1994). In addition, the stratigraphic distribution of vertebrate ichnological associations of the periadriatic Cretaceous is increased since previously tracks were known only from Upper Barremian, Lower Albian, Upper Albian and Middle-Upper Cenomanian of Istria (Dalla Vecchia et al., 1993). In this region, however, a fossiliferous bed with sauropod bones was recently found in the deposits of a fossil lake set out on the *Orbitolinopsis capuensis* limestones (Boscarolli et al., 1993; Dalla Vecchia et al., 1993; Dalla Vecchia, 1994).

The bones from Istria and the footprint from the Cansiglio Plateau suggest that during Late Hauterivian dinosaurs colonized the Periadriatic platforms. Therefore the presence of many other dinosaur evidences is to be expected in several different outcrops of intertidal limestone.

This working hypothesis should be verified looking for dinosaur tracks systematically in correspondence of the *O. capuensis* limestones in the inner platform units of Dalmazia, Istria, Southern Alps, Central and Southern Apennines, Gargano Promontory and Murge.

Acknowledgements.

We thank Miss L. Posocco for her help in researching the quarry of provenance, Dr. G. Buttol director of the quarry "Cava di Sarone" for his help and informations, the CMC of Ravenna, Mr. F. Polani, Mr. A. Giometti, Dr. A. Rambaldi for the useful information. Thanks to Prof. G. Leonardi, Prof. P. Mietto and Prof. U. Nicosia for the critical review of the manuscript and the suggestions; to Dr. C. Duffin for correcting the English text. This work is sponsored by M.U.R.S.T. (40% G. Tunis).

REFERENCES

Boscarolli D., Laprocina M., Tentor M., Tunis G. & Venturini S. (1993) - Prima segnalazione di resti di dinosauro nei calcari hauteriviani di piattaforma dell' Istria meridionale (Croazia). *Natura nascosta*, v. 1 (7), pp. 1-20, Monfalcone.

Brazzatti T. & Calligaris R. (1994) - Primi ritrovamenti di dinosauri nei calcari del Senoniano inferiore nei pressi del Villaggio del Pescatore (Trieste). Field Guide-Book delle Giornate Paleobenthos, Trieste, 6-8 Giugno 1994, Stop 4, p. 10, Trieste.

Dalla Vecchia F.M. (1994) - I dinosauri dell' Istria. In Ligabue G. (Ed.) - Il tempo dei dinosauri. *Le Scienze Quaderni*, v. 76, pp. 82-86, Milano.

Dalla Vecchia F.M., Tarlao A. & Tunis G. (1993) - Theropod (Reptilia, Dinosauria) footprints in the Albian (Lower Cretaceous) of the Quieto/Mirna river mouth (NW Istria, Croatia) and dinosaur population of the Istrian region during the Cretaceous. *Mem. Sc. Geol.*, v. 45, pp. 139-148, Padova.

Demathieu R. G. (1990) - Problems in discrimination of tridactyl dinosaur footprints, exemplified by the Hettangian trackways, the Causses, France. *Ichnos*, v. 1, pp. 97-110, New York.

Haubold H. (1971) - Handbuch der Palaeoherpetologie. T.18. Ichnia Amphibiorum et Reptiliorum fossilium. V. of 124 pp., G. Fischer Verlag, Stuttgart.

Leonardi G. (1984) - Le impronte fossili di Dinosauri. In Aa.Vv. - Sulle orme dei dinosauri, pp. 165-186, Erizzo, Venezia.

Leonardi G. (1987) - Discussion of the terms and method. In Leonardi G. - Glossary and manual of tetrapod footprint paleoichnology. Departamento Nacional de Produçao mineral, Republica Federativa do Brasil, pp. 43-51, Brasilia.

Leonardi G. & Avanzini M. (1994) - Dinosauri in Italia. In Ligabue G. (Ed.) - Il tempo dei dinosauri. *Le Scienze Quaderni*, v. 76, pp. 69-81, Milano.

Leonardi G. & Lanzinger M. (1992) - Dinosauri nel Trentino: venticinque piste fossili nel Liassico di Rovereto (Trento, Italia). *Paleocronache*, v. 1 (1992), pp. 13-24, Milano.

Leonardi G. & Teruzzi G. (1994) - Prima segnalazione di uno scheletro fossile di dinosauro (Theropoda, Coelurosauria) in Italia (Cretacico di Pietraroia, Benevento). *Paleocronache*, v. 1 (1993), pp. 7-14, Milano.

Lockley M.G. (1987) - Dinosaur footprints from the Dakota Group of Western Colorado. *Mountain Geologist*, v. 24, pp. 107-122, Denver.

Lockley M.G. (1991) - Tracking dinosaurs. V. of 238 pp., Cambridge Univ. Press, New York.

Mietto P. (1988) - Piste di dinosauri nella Dolomia Principale (Triassico superiore) del M. Pelmetto (Cadore). *Mem. Soc. Geol. Ital.*, v. 30 (1985), pp. 307-310, Roma.

Mietto P. (1991) - Impronte di dinosauri nel Triassico superiore delle Dolomiti. In Muscio G. (Ed.) - Dinosaurs - Il mondo dei dinosauri, pp. 83-87, Trento.

Mietto P. & Roghi G. (1994) - Nuova segnalazione di impronte di dinosauri nel Giurassico inferiore del Sudalpino: le piste di Valle di Revolto (Alti Lessini Veronesi). *Paleocronache*, v. 2 (1993), pp. 39-43, Milano.

Moratalla J.J., Sanz J.L., Jmenez S. & Lockley M.G. (1992) - A quadrupedal ornithopod trackway from the Lower Cretaceous of La Rioja (Spain): inferences on gait and hand structure. *Journ. Vert. Paleont.*, v. 12, n. 2, pp. 150-157, Lawrence.

Norman D.B. (1980) - On the ornithischian dinosaur *Iguanodon bernissartensis* from the Lower Cretaceous of Bernissart (Belgium). *Mém. Inst. R. Sc. Nat. Belgique*, v. 178, pp. 1-130, Bruxelles/Brussell.

Norman D.B. & Weishampel D.B. (1990) - Iguanodontidae and related ornithopods. In Weishampel D.B., Dodson P. & Osmólska H. - The Dinosauria, pp. 510-533, Univ. California Press, Berkeley/Los Angeles/Oxford.

Olsen P.E. & Galton P.M. (1984) - A review of the reptile and amphibian assemblages from the Stormberg. *Palaeont. Africana* (Haughton Memorial Volume), v. 25, pp. 87-110.

Pittman J.G. (1989) - Stratigraphy, lithology, depositional environment, and track type of dinosaur track-bearing beds of the Gulf coastal plain. In Gillette D.D. & Lockley M.G. (Eds.) - Dinosaur tracks and traces, pp. 135-153, New York.

Sartorio D. (1991) - Risedimentazione di *Orbitolina (M.) texana* e discontinuità stratigrafiche nell'Aptiano sup. e Albiano inf.-medio di piattaforma del Sudalpino orientale. *Atti Tic. Sc. Terra*, v. 35 (note brevi 1992), pp. 117-125, Pavia.

Thulborn R.A. (1989a) - The gaits of dinosaurs. In Gillette D.D. & Lockley M.G. (Eds.) - Dinosaur tracks and traces, pp. 39-50, New York.

Thulborn R. A. (1989b) - Dinosaur tracks. V. of 424 pp., Chapman & Hall, Andover.

Tišljar J., Velic I., Radovcic J. & Crnkovic B. (1983) - Upper Jurassic and Cretaceous peritidal, lagoonal, shallow marine and perireefal carbonate sediments of Istria. In Babic L.J. & Jelaska V. (Eds.) - Contributions to Sedimentology of some Carbonate and clastic units of the coastal Dinarides. Excursion Guide-Book, 4th IAS Regional Meeting, Split 1983, pp. 13-35, Split.

Tongiorgi M. (1980) - Orme di tetrapodi dei Monti Pisani. In Aa.Vv. - I vertebrati fossili italiani - catalogo della mostra, pp. 77-84, Verona.

Zappaterra E. (1990) - Carbonate Paleogeographic Sequences of the Periadriatic region. *Boll. Soc. Geol. It.*, v. 109, pp. 5-20, Roma.

Received November 11, 1994; accepted March 5, 1995