

Dinosaur footprints in the Upper Turonian-Coniacian limestone in the Krnica Bay (NE Istria, Croatia)

Stopinje dinozavrov v zgornjeturonijsko-coniacijskem apnencu v zalivu Krnica (NE Istra, Hrvaška)

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Abstract

Three isolated footprints and one trackway that can be attributed to bipedal dinosaur, from a limestone bed in vicinity of Požara promontory, Krnica Bay, are described. According to the stratigraphic position the footprints are late Turonian to Coniacian in age. This is the first record of dinosaur remains in the Turonian-Coniacian and the youngest footprint site on the Adriatic-Dinaric Carbonate Platform described thus far.

Povzetek

V tem prispevku so opisane izolirane stopinje in sled hoje, ki jo pripisujemo bipednemu dinozavru. Stopinje so v zgornjeturonijsko-coniacijskem apnencu blizu rta Požara v zalivu Krnica (SE Istra). To je zaenkrat edina najdba dinozavrov v turoniju in coniaciju celotne Jadransko-Dinarske karbonatne platforme in hkrati najmlajše opisano najdišče stopinj na tem območju.

INTRODUCTION

European dinosaurs of the early part of the Late Cretaceous are relatively poorly known (Buffetaut, 1997). There is almost no record of Turonian and Coniacian dinosaurs in Europe (Buffetaut, 1997; Weishampel et al., 1990). The research carried out in Istria during the past decades revealed many sites with dinosaur evidence in Lower and Upper Cretaceous platform carbonates. Footprints have been reported from

the Berriasian to the Cenomanian (Table 1). Most of the sites are located on the west and southwest part of Istria.

In spring 2001 three isolated footprints and a trackway attributed to dinosaurs were found on a limestone bed near the Požara promontory (rt Požara) in the Krnica Bay (Krnika luka) (Fig. 1);* The trackway is an assemblage of three successive footprints for which the direction of movement can be determined (Fig. 2; Plate 1, Fig. 2; Plate 2, Fig. 4). Footprints occur on a subhorizontal li-

* After reviewing the site in the May 2003 we found number of isolated footprints 50 meters away from the described site, along the beach in northwestern direction. These newly discovered footprints are much smaller, but of the same morphology as P3, P4 and P5 described above.

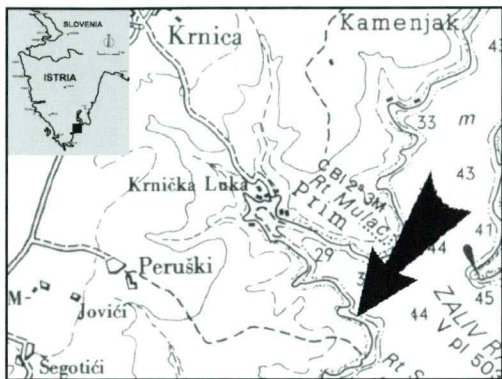


Fig. 1: Position of the Krnica footprint-bearing site.

Slika 1: Položaj najdišča Krnica z odtisi stopinj dinozavrov.

mestone bed under the rudist limestone (Plate 1, Fig. 3). The footprint-bearing surface crops out as a flat, about 12 meters long plate with maximum width of 10.5 meters (Plate 1, Fig. 1). Footprints are located on SSE part of the plate. According to Moro (1997) the footprint-bearing limestone is Late Turonian-Coniacian in age. The purpose of this paper is to give a description of the youngest footprint-bearing site that has been recorded in the Adriatic-Dinaric region thus far.

DESCRIPTION OF THE FOOTPRINTS

There are six footprints (P1 – P6) present at the site, which are not very well preserved and morphologically distinct. This could be due to erosion and probably low consistency of substrate during the time of imprinting. Measurements (length, width, depth of the footprint, length of digits, length of furrows inside the footprints, interdigital angle, stride length, straddle and orientation of footprints and trackway) and descriptions (shape, expulsion rims...) were taken in the field (Fig. 2).

The footprint P1 (Plate 2, Fig. 1) is the best-preserved footprint in the site. It is horseshoe-shaped with barely projecting "digits" in the wider anterior portion. The length of the footprint is 16 cm and the width is 14 cm. Maximum depth measure 3 cm on the right anterior part of the print, although generally the print is deepest in

the middle part; posteriorly it becomes shallower and ends with a heel-like impression on the left side. Impressions of "digits" have a narrow triangular form with sharply pointed terminations. Morphologically well-distinguished expulsion rims on the left and right side of the footprint show that the footprint was imprinted in water-logged substrate. We assume that furrows in the anterior part of the print are impressions of distal part of digits, since in wet sediments digits leave furrow-like imprints (Gatesy et al., 1999).

The footprint P2 (Plate 2, Fig. 2) has a different morphology and a different direction than P1. The shape of the footprint resembles tridactyl mesaxonid footprint. There are similarities between the footprint P2 found at Krnica site and footprint described by Dalla Vecchia et al. (1993, p.141) from Mirna river mouth, which is now stored in Speleovivarium of Trieste, although in the case of P2 only the impression of the second digit is clearly visible. In the middle of the anterior part of P2 there are two furrows, seven and six cm long, which can be interpreted as outlines of the third digit or conjoined imprints of third and fourth digit. Interdigital angle between second and third digit is about 40°. The length

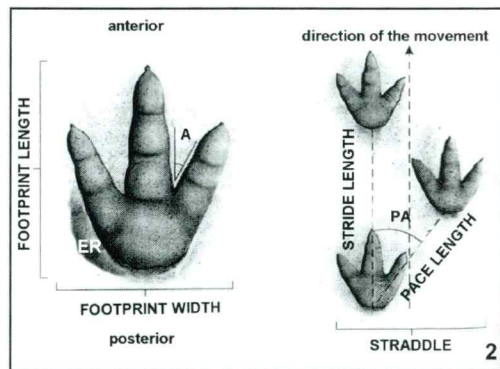


Fig. 2: Measurable parameters that can be derived from dinosaur track (A-interdigital angulation, PA-pace angulation, ER-expulsion rim) according to different sources.

Slika 2: Parametri, ki jih lahko merimo na stopinjah (A-medprstni kot, PA-koračni kot, ER-iztisnjen rob, footprint length-dolžina stopinje, footprint width-širina stopinje, stride length-dolžina koraka, straddle-širina razkoraka, pace length-dolžina med zaporedno levo in desno stopinjo v koraku) povzeto po različnih virih.

| | Age | Locality |
|------------------|---------------------------|---|
| Late Cretaceous | Maastrichtan | Kozina - Slovenia + |
| | Campanian | Devin (Duino) - Italia + |
| | Santonian | Polotok Marlera, Mali Levan - Medulin*? |
| | Coniacian | Rt Požara - Krnica |
| | Turonian | |
| Early Cretaceous | Cenomanian | ?Unije Fenoliga Premantura Lovrečica, Karigador |
| | Albian | Solaris I,II, Punta del Dente -Červar Rt Plješivac - V. Brijun Puntizela - Fažana Camp Lanterna - Mirna river mouth Punta Verudela, Zlate stijene - Pula ** Rt Ploče - Veli Brijun |
| | Aptian | |
| | Barremian | Rt Pogledalo - Veli Brijun Punta Barbana - Veli Brijun Vanga |
| | Barremian, Hauterivian | Barbariga Zaliv Kolone - Bale + Zaliv Cisterna - Rt Gustinja |
| | Valanginian | |
| | Berriasian | ?Kamnolom Fantazija - Rovinj |

Table 1: List of the Cretaceous sites of dinosaur footprints and skeletal remains on Adriatic-Dinaric Carbonate Platform according to different sources (Debeljak et al., 1999; Dalla Vecchia, 2000; Dalla Vecchia & Tarlao, 1995; Dalla Vecchia et al., 1993, 2000; Forlani, 1995; Gogala, 1975; Gogala & Pavlovec, 1978; Mezga & Bajraktarevič, 1999)

* Reported personally by Božidar Godec who found the supposed footprints in the 1970s; the site has not been found later; no description or pictures provided (after Gogala & Pavlovec, 1978; Forlani, 1995).

** Footprints have been destroyed during constructional works (after Gogala & Pavlovec, 1978; Forlani, 1995).

? Uncertain locality

+ Skeletal remainings

Tabela 1: Seznam krednih najdišč stopinj in kostnih ostankov dinosavrov na območju Jadransko-Dinarske karbonatne platforme (Debeljak et al., 1999; Dalla Vecchia, 2000; Dalla Vecchia & Tarlao, 1995; Dalla Vecchia et al., 1993, 2000; Forlani, 1995; Gogala, 1975; Gogala & Pavlovec, 1978; Mezga & Bajraktarevič, 1999)

* O verjetnih stopinjah dinosavrov na območju Medulina je Božidar Godec poročal v 70 letih prejšnjega stoletja Matiji Gogali in Rajku Pavlovcu. Stopinje kasneje niso bile najdene, niti ni bilo podano slikovno gradivo (Gogala & Pavlovec, 1978; Forlani, 1995).

** Stopinje so bile uničene med izgradnjo hotela (Gogala & Pavlovec, 1978; Forlani, 1995).

? nezanesljiva lokacija

+ kostni ostanki

of the footprint is 17 cm. The width is impossible to measure accurately, since the right portion of the footprint is fusing into the surrounding matrix and therefore it is difficult to determine the outline of the print. The estimated width is 17 to 21 cm. The expulsion rim is visible in the left posterior portion, where the print is deepest (3.5 cm).

The footprint P6 (Plate 2, Fig.3) is a rounded depression having about 17 cm in diameter. It is poorly preserved and no digit impressions or furrows indicating digits are visible. Two batches of displaced sediment are visible close to the posterior margin. Obviously, the substrate was saturated with water during the imprinting since the print is relatively deep (the maximum depth is 5.5 cm).

Footprints P3, P4 and P5 (Plate 2, Fig.4) are consecutive footprints of probably left, right and left foot. They are of similar morphology, size and direction although P3 is slightly more rounded than P4 and P5. The orientation of the trackway P3-P5 is about 300°. The stride length (distance from the middle point of the left footprint P3 to the middle point of the left footprint P5) is 280 cm. The straddle (distance between the outside of footprints on the left and right sides of the trackway) is narrow and thus indicates that animal walked in an upright posture. There are narrow and elongated furrows inside the footprints. In the case of P4 and P5 these furrows are parallel to the long axis, whereas in the case of P3 furrows spread radially from the anterior part to the center.

The footprint P3 (Plate 2, Fig. 5) is 19 cm long and up to 18 cm wide. Posterior margin

is broken off. Displacement rim is visible on the left side of the footprint. Original whitish infilling is still preserved; indicating that P3 and other footprints are true tracks and not undertracks (Lockley, 1991).

The length of the footprint P4 is 18 cm and its width is 16 cm. Parallel furrows are visible inside it. The medial portion is the deepest part of the print. Expulsion rims are not visible. Parallel furrows of the left footprint P5 (Plate 2, Fig. 7), which is 20 cm long and 17 cm wide, are proceeding from anterior portion of the print into the surrounding matrix. The left portion of the print is gradually deepening from the margin toward the deepest portion of the print, while the right flank is steeper. The maximum depth of the footprint is 6 cm. The posterior part of the print is surrounded with 3 cm wide expulsion rim. The rim is visible on the right margin of the print as well.

INTERPRETATION OF THE FOOTPRINTS

The state of preservation of the footprints at the Krnica Bay site is poor because the substrate was waterlogged during the formation of the tracks, which is indicated by clearly visible expulsion rims, depth of the prints and furrow-like impressions of the digits. Footprints are also deteriorated due to the recent carstification of the surface by meteoric water and sea erosion. Considering all the observed data, a small to medium-sized theropod or ornithopod dinosaur left the footprints P1 – P6 at Krnica Bay site. However, the exact taxonomic position of the footprints cannot be accurately determi-

PLATE 1 – TABLA 1

Fig. 1: View from the footprint-bearing surface (FBS) towards north, to the Požara promontory.

Slika 1: Pogled s plošče, na kateri se nahajajo stopinje dinozavrov (FBS), proti severu, proti rtu Požara.

Fig. 2: Krnica Bay site with six dinosaur footprints located on SSW part of the footprint-bearing surface.

Slika 2: Najdišče Krnica s šestimi stopinjami dinozavrov, ki so locirane na južnem, jugozahodnem delu plošče.

Fig. 3: Rudist limestone overlaying the footprint-bearing surface.

Slika 3: Apnenec z rudisti, ki leži nad plastjo s stopinjami.



ned because of the poor preservation of the prints, their scarcity and an inadequate record of Turonian and Coniacian dinosaurs. Because of the narrow straddle we presume that the track (P3 – P5) was made by a bipedal dinosaur. Footprint P2 could belong to a small bipedal ornithopod (high angle of divergence between the second and third digit, absence of claw impressions, footprint almost as wide as long) or to a small theropod (medial bending of the distal part of the second digit) (see Dalla Vecchia et al., 1993, p. 141; Dalla Vecchia & Tarlaoui, 2000, p. 233). Different orientation of furrows in footprints P3 and P4, P5 could be interpreted as a result of a different motion of withdrawal of the foot. The approximate height of the hip and the gait speed of the trackmaker (P3–P5) were estimated. Speed was calculated by the equation of Alexander (1976): $V = 0.25g \times 0.5SL^{1.67} \times h^{-1.17}$ (V-velocity, SL-stride length, h-height of the hip). For this calculation the morphometric ratio ($h = 4.6$ FL) for small bipedal dinosaur was used, for which length of the footprint (FL) is less than 25 cm (Thulborn, 1989). The calculation implies that the dinosaur hip was

about 0.87 m high and that dinosaur was walking with approximate speed of 12.5 km/h.

CONCLUSIONS

Footprints from Krnica site were made by small to medium-sized bipedal dinosaur. This site indicates the existence of the temporally emerged part of the Adriatic–Dinaric Carbonate Platform during Late Turonian and Coniacian and the existence of dinosaurs on it. Together with dinosaur localities from Slovenia and Italy this site proves that during Late Cretaceous dinosaurs were still living on Adriatic–Dinaric Carbonate Platform. It also proves more or less continuous existence of dinosaurs through entire Cretaceous Period.

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PLATE 2 – TABLA 2:

Fig. 1: Footprint P1. Furrows in the anterior part, expulsion rims on the left and right side and heel-like mark are visible.

Slika 1: Stopinja P1. Na sliki so vidne brazde v sprednjem delu stopinje, iztisnjena roba na levi in desni strani ter petast odtis, ki se nahaja levo posteriorno.

Fig. 2: Footprint P2.

Slika 2: Stopinja P2.

Fig. 3: Footprint P6.

Slika 3: Stopinja P6.

Fig. 4: Trackway of three successive footprints. The arrow is showing the direction of walking.

Slika 4: Sled hoje, ki jo sestavljajo tri zaporedne stopinje. Puščica kaže smer hoje.

Fig. 5: Footprint P3. Original whitish infilling is still visible.

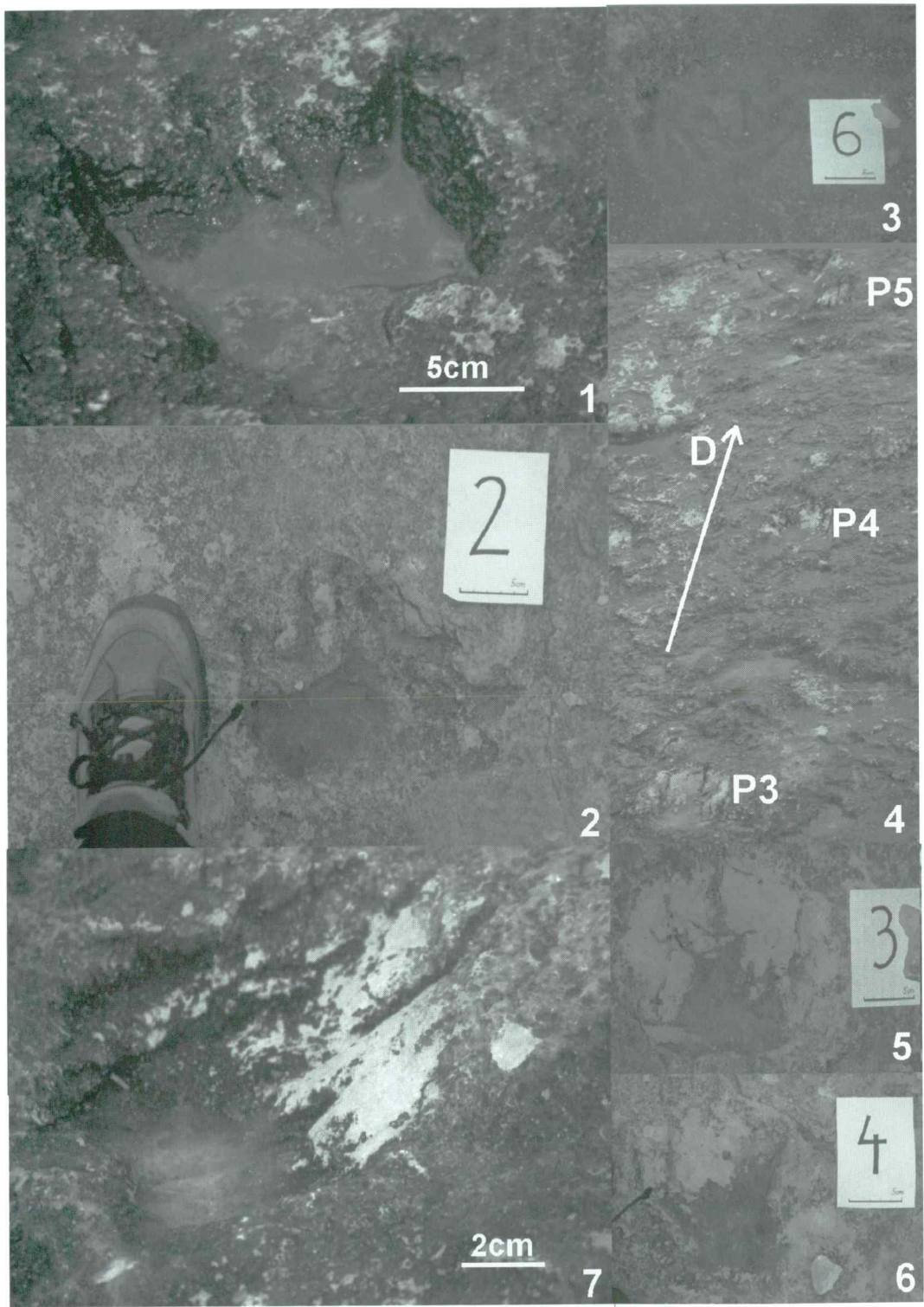
Slika 5: Stopinja P3. Prvotna zapolnitev stopinje je še vedno vidna.

Fig. 6: Footprint P4. No expulsion rim is visible.

Slika 6: Stopinja P4. Iztisnjen rob ni viden.

Fig. 7: Concave profile of left footprint P5 (view from the right margin toward left margin of the footprint). Furrows preceding the footprint margin are visible.

Slika 7: Konkaven profil stopinje P5 (pogled z desnega proti levemu robu stopinje). Brazde, ki se nadaljujejo v okolico stopinje so dobro vidne.



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