Theropod Palaeopathology inferred from a Late Jurassic trackway, Asturias (N. Spain)

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ABSTRACT – Although references to traumas and illness in dinosaur bones are very frequent, there are few reports about pathologies of these reptiles through studies of isolated footprints and trackways, and the majority of these refer to limping dinosaurs. The example presented here refers to a short theropod trackway of four consecutive footprints, preserved as convex epireliefs. Anomalous arrangement of the fourth digit in the right pedal prints suggests a pathology, although we can not determine if it is malformation or trauma due to fracture. The similarity in the pace length and angle suggests that if it is a fracture, this was produced a long time before as there is no evidence of limping in the reptile gait.

Key words: *palaeopathology, ichnology, Theropoda, Upper Jurassic, Asturias, Spain*

INTRODUCTION AND GEOLOGICAL SETTING

Asturian Late Jurassic is well known for the numerous finds and good preservation of vertebrate footprints, most of them are of dinosaurs (Sauropods, Ornithopods, Theropods and Thyreophoran). Others footprints from the same outcrops are attributed to lizards, pterosaurs, turtles and crocodiles (Lires, 2000; Piñuela, 2000; García-Ramos *et al*., 2002; 2004; Avanzini *et al*., 2005; Avanzini *et al*., *in press*).

The sedimentary sequence of the Late Jurassic of Asturias crops out along the coast between Gijón and Ribadesella (fig. 1). This sequence has a total thickness of more than 600 meters and consists of the following units: La Ñora, Vega, Tereñes and Lastres Formations (García-Ramos et al., 2002; 2004). The trackway described is preserved in the last of them, close to Argüero (Villaviciosa).

The Lastres Formation, deltaic in origin, is characterised by an alternation of grey sandstones and marls (García-Ramos *et al*., 2002; 2004). Remarkable examples of depositional sequences are shown in the deltaic model, including prodelta, crevasse splay and levee, interdistributary bay and the typical delta abandonment facies. Sedimentation was repeatedly interrupted by small transgressive events recorded by laterally extensive shell beds formed mainly by abundant bivalves and some gastropods. Isolated ammonoids allow

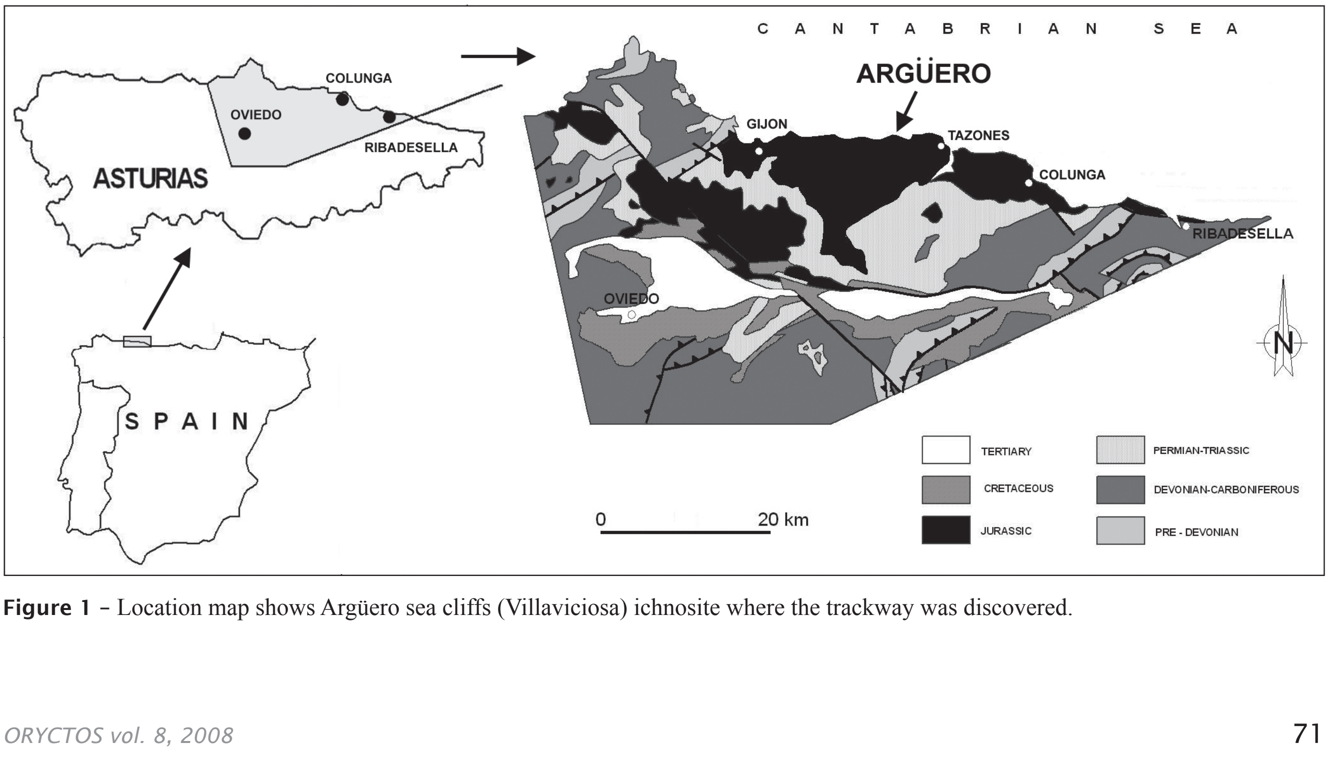

Figure 1 – Location map shows Argüero sea cliffs (Villaviciosa) ichnosite where the trackway was discovered.

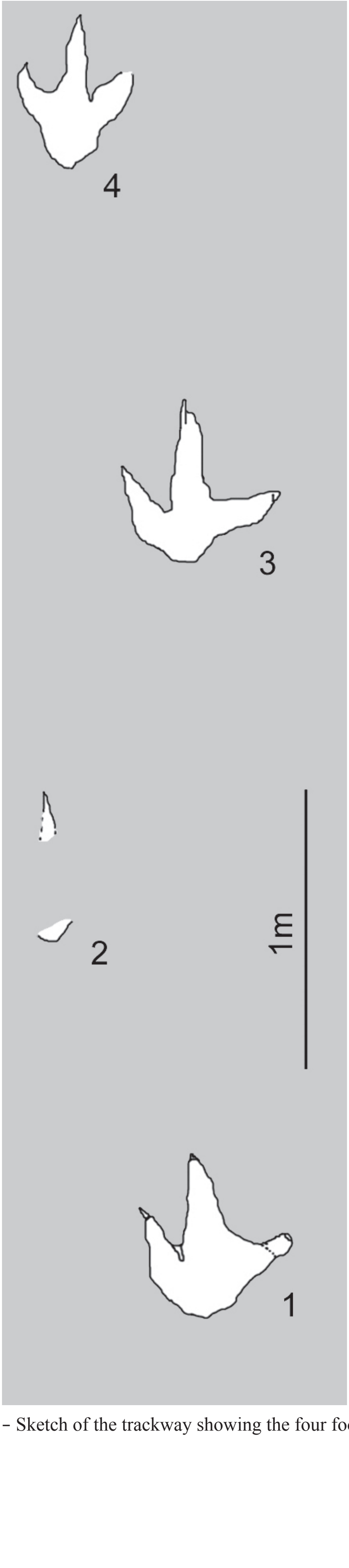

Figure 2 – Sketch of the trackway showing the four footprints.

dating this formation as Lower and Upper Kimmeridgian (Dubar & Mouterde, 1957; Olóriz et al., 1988).

TRACKWAY DESCRIPTION

The dinosaur that left the trackway reported here walked on a sand bar that accumulated during the crevassing of a principal distributary channel which belonged to a fluvial dominated deltaic complex.

The dinosaur trackway (figs. 2 and 3) is formed by four consecutive tridactyl footprints, preserved as convex epireliefs and partially infilled by a yellow-brown sandstone. The footprints show the typical morphology of theropod pedal prints, with three slender, elongated digits and well preserved claw impressions at the tip.

The best preserved footprint (4) is 58 cm in length and 43cm in width, while the first and third footprints measure 58cm in length and 58cm in width (tab. 1). This last parameter is higher due to the peculiar disposition of the fourth digit in the first and third footprints, corresponding to right hind foot. The interdigital angle between digits III and IV of these latter footprints is very high for theropod dinosaurs, in this example close to 80º. The homologous interdigital angle in the footprint (4) is 37º. In footprint 3, digit IV appears better preserved than those of footprint 2. In this case, the digit proximal region seems regular in its morphology, and the angulations between digit III and IV seems normal at their base. The distal portion of digits (about 2/3) is instead rotated outward about 80° respect to the footprint axis and about 25° respect to their proximal portion.

The trackway length is 475 cm, the mean pace length is 149 cm, the mean stride length 282 cm, and the mean pace angulation 142º. There are no substantial changes in pace or stride length (tab. 2).

The poor preservation of the footprints does not permit taxonomic determination. Comparison with other large theropod prints in the Asturian track assemblages show that these tracks could be referred to *Megalosauripus* (Lessertisseur, 1955, Lockley et al., 2000; Thulborn, 2001) or to *Hispanosauropus*, (Mensink & Mertmann, 1984), both used to describe large Late Jurassic theropod tracks from the Iberian Peninsula (Lockley et al., *in press*).

The length of the footprints indicates a large individual (L>25 cm) (Thulborn, 1990: p. 251) with a height at the hip that can be estimated at close to 284 cm and with a slow gait (5 km/h).

DISCUSSION

References to traumas and illness in dinosaur bones are relatively frequent (Tanke & Rothschild, 1997; 2002; Rothschild & Tanke, 2005). Stress fractures in pedal phalanxes, caused by strenuous repetitive activity, have been reported for several dinosaur skeletons. They are also well represented across the spectrum of theropod size, and their frequency in tyrannosaurids and allosaurids was significantly

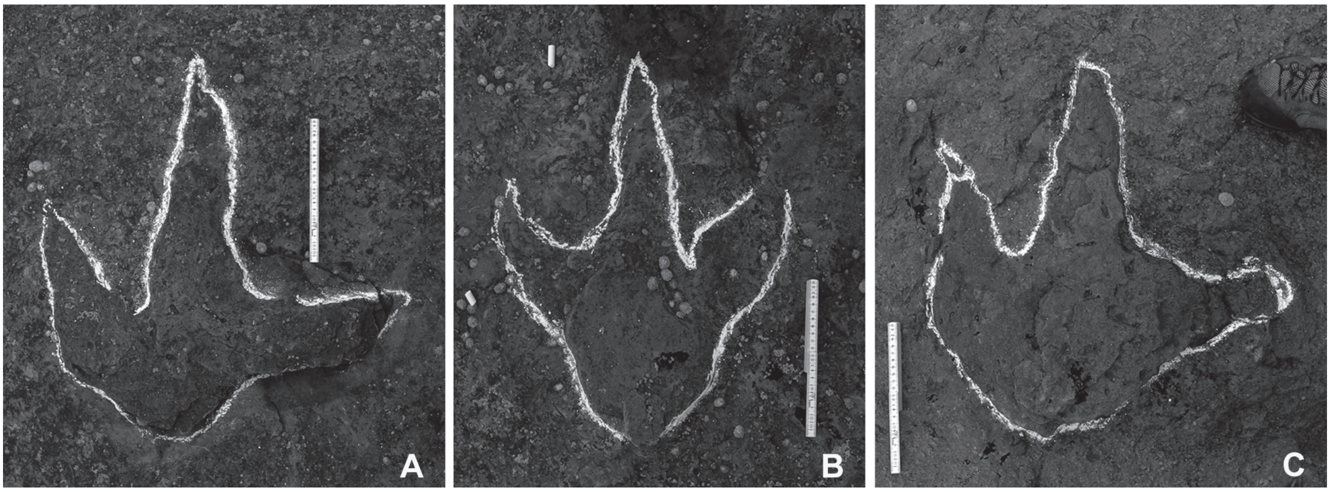

Figure 3 – Comparison between right (A, C) and left footprints (B) of the trackway. In the right pes, the interdigital angle between III and IV is close to 80º. Scale bar: 20 cm.

greater than that noted in other theropods (Rothschild et al., 2001). Pedal traumatic fractures and/or exostoses are reported in some middle to large-sized theropods. Laws (1997) described an infection in the left metatarsal III of *Allosaurus* MOR 693 (Museum of the Rockies, Bozeman, Montana) recently reinterpreted as an exostosis; the same pathology was found in *Gorgosaurus* pedal phalanx TMP 91.36.500 (Royal Tyrrel Museum, Drumheller, Alberta) (Rothschild & Tanke, 2005: p. 355).

No congenital pathology has been reported on appendicular skeletons of dinosaurs.

Reports about the pathologies of these reptiles through studies of both isolated footprints and trackways are little known, and the majority of them refer to limping dinosaurs (Dantas et al., 1994; Lockley et al., 1994; Tanke & Rothschild, 2002).

Many of the trackways described refer to large carnivorous dinosaurs that show missing or curled digits (Lockley, 1991, fig. 6.5; Tanke & Rothschild, 1997: p. 528). Footprint and trackway evidence of limping theropods (Dantas et al., 1994; Ishigaki, 1986) suggests injury or arthritis. Examples include mainly middle-sized theropods footprints such as *Anchisauripus* and *Eubrontes* (Tanke & Rothschild, 2005). Foot pathologies in large bipedal dinosaurs have been related to more active life-styles or natural fragility of the narrow, protruding digits (Tanke & Rothschild, 1997: p. 528). Abel (1935) reported a good example of a theropod trackway (*Eubrontes*) with a malformed or injured foot from the Connecticut Valley. In this trackway, the left footprints appear as normal tridactyl pedal prints while the right ones lack the inner (II) toe. Thulborn (1990: p. 123) suggested that this dinosaur's right foot was afflicted by a congenital defect or had sustained an injury at some earlier stage of its life due to the apparent regularity of the trackway and the absence of a limping gait. Amputation or sloughing off of individual toes could be expected if the injured areas became serious infected, as with extant lizards (Tanke & Rothschild, 1997: p. 528). Another example of anomalous footprints is represented by *Sauroidichnites abnormis*, a theropod footprint with an abnormally positioned toe (Ishigaki, 1986, fig. 2) possible due to injury. Footprints in this trackway clearly reveal that the right foot was abnormal, with the two outer digits (III and IV) held very closely together. Thus, as suggested by Lockley et al. 1994, the abnormality is probably indicative of a foot injury.

The trackway reported here shows an important variation in the width and interdigital angles of the footprints that we inferred as consequence of a pathology. Interdigital angle II-IV is higher in the first and third track (right hind foot) due to peculiar outward rotated IV digit. The interdigital angle between digits III and IV of these latter footprints is very high for theropod dinosaurs, in this case close to 80º, while the homologous interdigital angle in the fourth footprint (left pes) is about 40º (fig. 3). In the two right footprints (1 and 3), digit IV is well developed and has normal dimensions with respect to II and III. The outward rotation of digit IV begins only at around 1/3 of the distance from the digit base. This suggests that a fracture or malformation was located in correspondence to the articulation between the first and second phalanx and that there were no affections at the metatarsal-phalangeal articulation. An anomaly in this part of the digit would not have greatly conditioned the foot kinematics. In the trackway reported here, the pace length does not change in a substantial manner; thus, we discarded limping. This suggests that the malformation was produced a long time before the owner made the trackway, as there is no evidence of limping in the slow gait.

CONCLUSIONS

The shape of the footprints in the described trackway is typically theropod-like, with well-developed digits

Pace		Stride		Pace angulation		Length		Width		digit II-III divarication		digit III-IV divarication	
	P		P		P		P		P		P		P
1-2	147	1-3	277	1-3	141°	1	58	1	58	1	10°	1	75°
2-3	150	2-4	284	2-4	143°	2	58	2	-	2	-	2	-
3-4	150					3	58	3	58	3	24°	3	80°
						4	58	4	43	4	33°	4	37°

Table 1 – Measures of footprints. Pace, stride, length and width in cm. Interdigital divarication angles in degrees.

and claw marks. Digit IV in the right footprint shows a high divarication angle, close to 80°, and an anomalous curvature in correspondence to the I-II phalangeal articulation.

Anomalous arrangement of the fourth digit in the right footprint is interpreted here as indicative of a pathology, although we cannot determine if it is a malformation or a fracture. The similarity in the pace length suggests that if it is a fracture, this was produced a long time before the owner made the trackway, as long as there is no evidence of limping in the reptile gait.

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