

Las Cerradicas tracksite (Berriasian, Galve, Spain): Growing evidence for quadrupedal ornithopods

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Dinosaur footprints occur in shallow marine sedimentary units of the Berriasian Villar del Arzobispo Formation in the Aliaga basin, NE Spain. Las Cerradicas is a small outcrop (25 m²), near Galve, with four dinosaur trackways. Three tridactyl trackways indicate bipedal animals, and have parallel orientation. A fourth ornithopod trackway indicates a quadrupedal animal and is the smallest among any reported in the literature (L = 23 cm, W = 23 cm of pes tracks). It has manus prints that are oval-shaped impressions. These and other recent discoveries shed much light on the abundance of quadrupedal ornithopods during the early Cretaceous.

Keywords: Footprints, dinosaurs, Ornithopoda, early Cretaceous, Spain

INTRODUCTION

Quadrupedal ornithopod trackways are relatively scarce and have only been reported from a few Cretaceous sites, (Casamiquela et al., 1968; Norman, 1980; Currie, 1983; Leonardi, 1984; Lockley, 1987; Pittman, 1989; Currie et al., 1991; Moratalla et al., 1992; 1994; Bengochea et al., 1993). At Galve, near Teruel, four interesting trackways were discovered in 1992. One of them, Trackway Four, is one of the oldest known from the Cretaceous, and one of the smallest (or the smallest) track ever attributed to a quadrupedal ornithopod. The Galve region is justifiably famous for its

archosaur fauna (Buscalioni and Sanz, 1987) and for the mammal assemblages (Canudo and Cuenca-Bescós, 1996). The aim of this paper is to describe this new dinosaur tracksite and make interpretations of the possible trackmakers.

Discoveries of dinosaur footprints have become relatively common in the Lower Cretaceous of the northwestern Iberian Range (Casanovas et al., 1989, 1993; Moratalla et al., 1988, 1992, 1994; Bengochea et al., 1993; Pérez-Lorente et al., 1995) in La Rioja and neighboring areas (Fig. 1). They are typically found in continental sedimentary units known in the regional literature as the Wealden facies. In the southeast of the Iberian Range, in the Aliaga basin, dinosaur footprints are known in the Castellar Formation, at Los Corrales del Pelejón tracksite, near Galve (Casanovas et al., 1983-84, Cuenca et al., 1993). The new tracksite is located in the Galve area (NE Spain, Fig. 1) and, in contrast to most of the dinosaur tracksites described in the continental units (Wealden facies) of the Iberian Range, the tracks are located in the upper part of the shallow marine sedimentary units of the Villar del Arzobispo Formation. Figure 2 shows a schematic section of the sedimentary units located in the core of the Galve syncline, including both the thickness and main lithologies

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FIGURE 1 Map of Spain showing the regions with Lower Cretaceous tracksites cited in the text.

of the Late Jurassic to Early Cretaceous units. These units were deposited during a marine regression which occurred in Late Jurassic-earliest Cretaceous times and have traditionally been known as Purbeck facies.

In the Galve area, the upper boundary of the Tithonian-Berriasian Sequence is represented by a low angle angular unconformity. The unconformity is also marked by an important lithological and sedimentological change where continental red clays at the bottom of the Castellar Formation, sharply overlie transitional marine sediments of the Villar del Arzobispo Formation. It should be noted that the dinosaur tracksite Los Corrales del Pelejón, previously reported in Casanovas *et al.* (1983-1984, Fig. 2), is located at the lower part of the Castellar Formation, and hence above the Berriasian unconformity.

The younger strata recorded in the Villar del Arzobispo Formation correspond to the Early-Middle Berriasian, as dated by both the associations of charophytes found in the contemporary lacustrine and palustrine sediments (Martín i Closas 1990) and benthonic foraminifera from the shallow marine sediments located on top of the Villar del Arzobispo Formation in the Galve section (Díaz *et al.*, 1984).

Las Cerradicas tracksite (Fig. 3) is located near to what should have been the Early-Middle Berriasian shoreline. Along the Tithonian-Berriasian Sequence, the gradual transition from a shallow marine carbonate platform (Higueruelas Formation) to shallow subtidal, intertidal and continental environments (Villar del Arzobispo Formation) is generally well documented. The Villar del Arzobispo Formation consists of an alternation of carbonate and siliciclastic beds, generally arranged in shallowing-upward cycles (Díaz-Molina *et al.*, 1984). Carbonates consist of different facies ranging from oolitic and bioclastic grainstones to burrowed mudstones, which were deposited in a partly enclosed shallow bay. The sandy facies are related to a deltaic complex found in this bay. Cross-bedded sandstones correspond to fluvial-dominated delta plain deposits, showing local traces of subaerial exposure and scarce evidence for tide reworking. The studied trackways are preserved in one of these sandy beds.

As revealed in thin section, this bed is a sandy limestone. Crystalline calcite forms the matrix for the abundant fine-grained angular quartz. The thin section shows minor elements such as muscovite, garnet, dark minerals, calcareous fragments and agglutinated foraminifera. Sedimentary structures include penecontemporaneous ripple marks, vertical U-shaped burrows, probably belonging to *Arenicolites* or *Diplocraterion*, and vertical burrows (*Skolithos*).

TRACKWAY DESCRIPTIONS

The nomenclature, parameters and ratios used for describing the trackways follow Haubold (1971), Casanovas *et al.* (1989) and Thulborn (1990)—see Tables 1-7. The Las Cerradicas outcrop includes 4 trackways (40 footprints), both of bipedal (trackways 1-3) and quadrupedal dinosaurs (trackway 4). We have numbered the tracks according to the direction of movement (Fig. 4A).

Description: The theropoda trackways 1-3 represent those of bipeds (Figs. 4, 6; Tables 2, 3, 4).

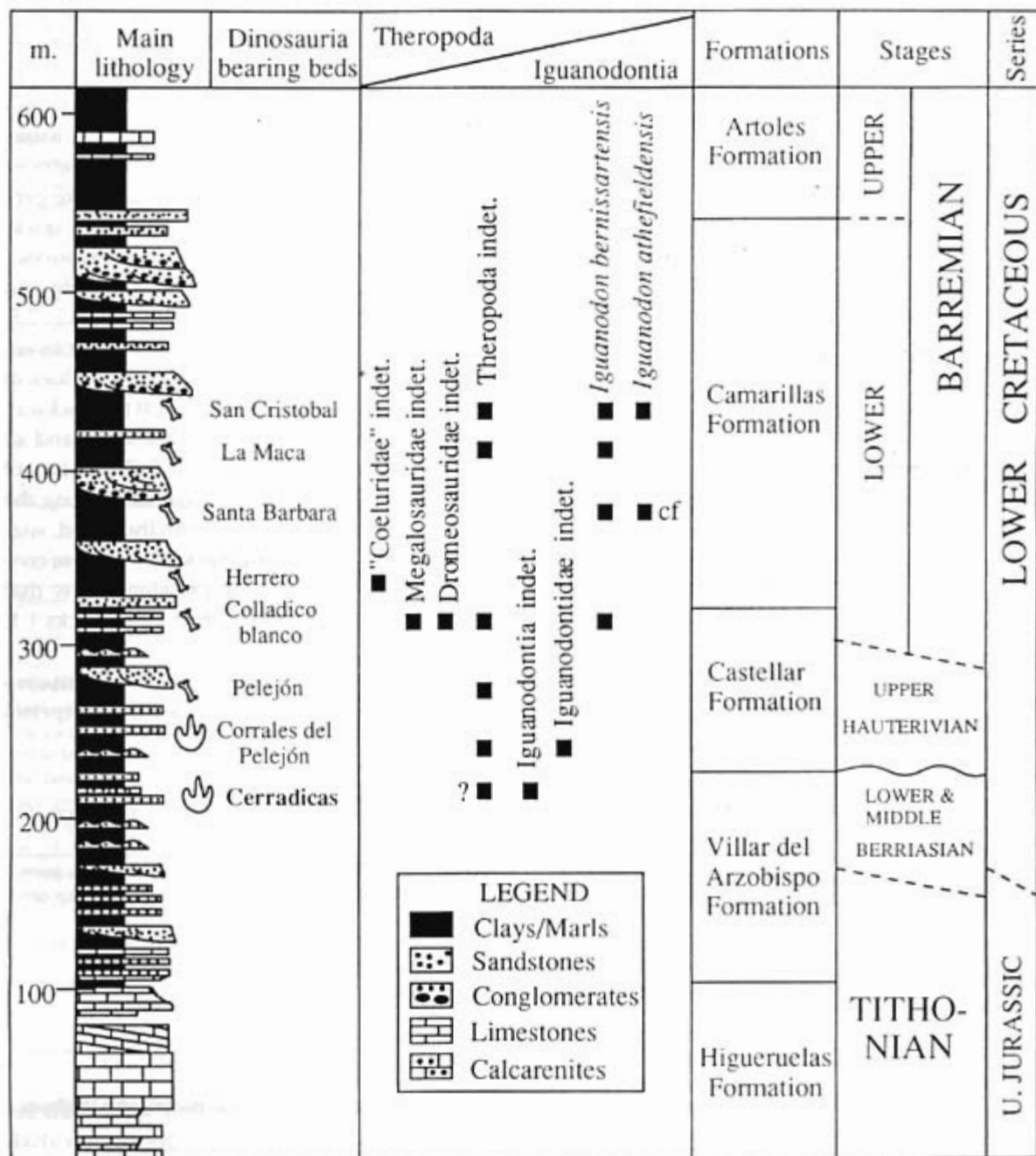


FIGURE 2 Schematic section of sedimentary units located in the core of the Galve syncline, including the thickness and main lithology of the sedimentary units spanning from Late Jurassic to Early Cretaceous. Data from Estes and Sanchez, 1982; Buscalioni and Sanz, 1987; Lapparent, 1960; Cuenca-Bescós et al., 1994; Casanovas et al., 1983-1984.

However, in front of track 1.6 there is an oval impression that could be a manus print. Trackway 1 consist of 8 or 9 footprints. Trackway 2 consists of

10 footprints and trackway 3 of 7 footprints. The main features are: 1) the pes is longer than broader ($0.2 > L-W_{0.16}$). 2) The pace angulation is large

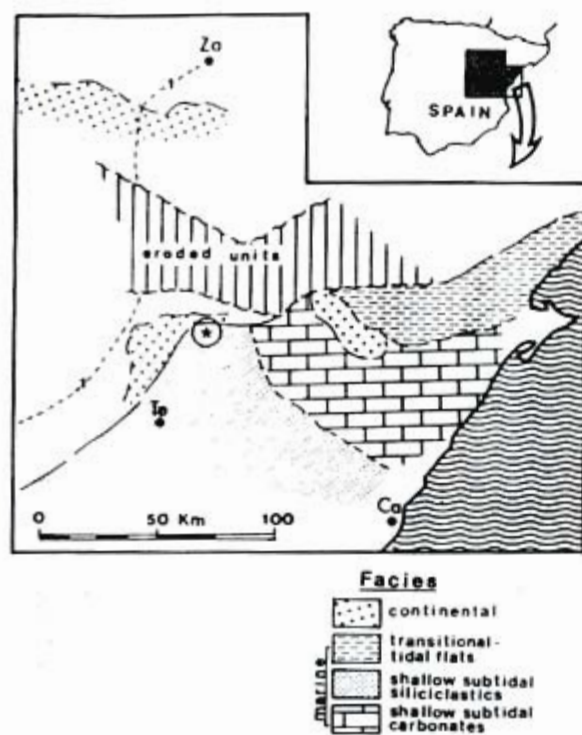


FIGURE 3 Facies distribution map of the Aliaga basin at the onset of the Berriasian. Dashed line indicates the Early Tithonian shoreline. The encircled star points the location of Las Cerradicas.

164 > pa > 161). 3) The variation of trackway deviation is $0.2 > Td/W > 0.15$. 4) The footprints are tridactyl with the central digit III longer than digits II and IV (see Tables 2–5) and digits are acuminate at their distal extremities. 5) digit II forms an angle with digits III and IV, those being almost parallel; thus, interdigital angles II–III (α) are generally less than those of III–IV (β). 6) the trackways are narrow ($21 > tw > 16$). 7) the heel surface (when well preserved) is relatively narrow and projects posteriorly (tracks 1.1, 1.6, 1.7, 2.3, 2.5, 3.3). Other interesting features are: The tracks are relatively small ($31 > L > 19$). The mean values of speed (v) are $v_1 = 3.06$ and $v_2 = 3.00$ for trackway 1; $v_1 = 3.10$ and $v_2 = 2.90$ for trackway 2 and $v_1 = 3.00$ and $v_2 = 3.00$ for trackway 3. The values of stride length (Sl) are relatively constant along the trackways. This fact, together with the speed, suggests that the speeds of the trackmakers were constant as well. The digital impressions show that digit II is somewhat thicker than IV in tracks 1.1, 1.6, 1.7, 2.1, 2.3, 2.4, 2.5, 3.1, 3.3, 3.7.

Trackway 4 includes impressions of the manus and pes (Figs. 4, 5, 7; Table 6). The hind footprints

TABLE 1 Parameters and abbreviations used in the trackway study of Las Cerradicas. After Haubold (1971), Casanovas *et al.* (1989, 1993) and Thulborn (1990), modified

Print length (L):	measured along the axis of digit III, from the tip of this digit to the rearmost limit of the print.
Print width (W):	measured at a right angle to footprint length from the tip of the innermost digit to the tip of the outermost one.
Orientation (O):	angle between the midline of the footprint and the midline of the trackway. If footprint point inwards, to the midline of the trackway, it is negative rotation or inward divarication (Leonardi, 1979).
Footprint midline (LIII):	axis of digit III.
Axis of trackway (mlt):	line between the midpoint of each stride length in the trackway.
Trackway deviation (Td):	distance between pes/manus midpoint and the trackway midline.
Midpoint (mp):	best fit of the centrum of the track-hell if it were a circle.
Trackway width (Tw):	distance between the outer edges of the footprints. It is called external trackway by Thulborn (1990).
Stride length (Sl):	distance between corresponding points in two successive footprints of a single foot.
Hip height (h):	calculated after Thulborn (1990).
Pace length (pl):	distance between landmarks in two successive footprints.
Pace angle (pa):	angle between two pace length lines.
Digit length (LII, LIII, LIV):	length of digits II, III and IV respectively.
Interdigital angles (α , β , δ):	between digits II–III, III–IV and II–IV (total divarication) respectively.
Speed (v1):	speed estimate after Demathieu (1986) method.
Speed (v2):	speed estimate after Alexander (1976) and Thulborn (1990) methods.

TABLE II Measurements (cm) of the trackway 1 from Las Cerradicas (Berriasien, Galve, Spain)

Parameters\Track	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Length pes (L)	22	—	22	19	—	(31)	25	—	—
Width pes (W)	20	—	20	—	—	20	—	—	—
Orientation (O)	-6	—	-5	7	-6	-6	-19	-11	—
Trackway dev. Td)	—	—	—	2.5	3	4	—	7	—
Trackway width (Tw)	—	—	—	24	23	26	—	—	—
Stride length (Sl)	—	112	—	115	115	117	122	115	—
Hip height (H)	104	—	104	88	—	153	120	—	—
Pace length (Pl)	—	—	—	55	60	57	61	54	52
Pace angle (Pa)	—	—	—	170	166	162	161	—	—
Length II	8	10	—	6	—	—	9	—	—
Length III	11	—	15	—	10	14	11	—	—
Length IV	—	—	—	10	6	8	8	—	—
α	24	—	27	25	—	29	—	—	—
β	13	—	—	—	24	23	14	—	—
δ	37	—	—	—	—	51	—	—	—
Sl/h	—	0.9	—	1.0	1.0	1.0	1.1	1.0	—
v1	—	2.9	—	3.0	3.0	3.1	3.4	3.0	—
v2	—	—	—	3.0	3.0	—	—	3.0	—

TABLE III Measurements (cm) of the trackway 2 from Las Cerradicas (Berriasien, Galve, Spain)

Parameters\Track	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10
Length pes (L)	—	—	22	19	25	—	—	19	—	21
Width pes (W)	19	—	16	17	17	—	—	17	19	—
Orientation (O)	—	—	-8	-7	-12	—	—	—	-13	—
Trackway dev. Td)	—	4	3	4	5	—	—	—	6	—
Trackway width (Tw)	—	—	—	21	—	—	—	—	—	—
Stride length (Sl)	—	107	101	106	107	—	107	—	116	—
Hip height (H)	—	—	104	88	120	—	—	88	—	98
Pace length (Pl)	60	49	54	52	57	—	—	—	55	64
Pace angle (Pa)	—	163	164	160	158	—	—	—	155	—
Length II	13	—	—	10	13	—	—	10	10	11
Length III	11	—	14	13	—	—	—	11	—	11
Length IV	11	—	11	13	10	—	—	—	—	—
α	8	—	29	10	26	—	—	49	—	45
β	21	—	24	25	54	—	—	42	—	—
δ	28	—	52	45	80	—	—	89	96	—
Sl/h	—	1.1	1.0	1.1	1.1	—	1.1	—	1.2	—
v1	—	3.0	2.8	3.0	3.0	—	—	3.0	3.0	—
v2	—	3.1	2.9	3.1	3.1	—	3.1	—	3.6	—

are tridactyl with three digits approximately similarly developed. These tracks are relatively small ($26 > L > 20$). The manus prints are in front of the corresponding footprint on each side. The hind footprints are larger than the fore ones. The pes prints have the following features: 1) the pes is as large as broad ($L-W/W = 0$). The average L/W ratio of the hind footprints is 1.01. 2) and the pace

angle is relatively small ($pa = 118^\circ$). 3). The variation of trackway deviation is conspicuous ($Td/W = 0.4$). 4). The toes have blunter tips. 5) The trackway width is broad. 6) The average interdigital angles are $\alpha = 27$ and $\beta = 29$. The manus prints are oval- to round-shaped impressions. They are much smaller than the pes tracks. The main axis of the ovalus has an irregular direction. The para-

TABLE IV Measurements (cm) of the trackway 3 from Las Cerradicas (Berriasien, Galve, Spain)

Parameters\Track	3.1	3.2	3.3	3.4	3.5	3.6	3.7
Length pes (L)	25	—	26	25	—	—	25
Width pes (W)	20	—	20	21	21	—	21
Orientation (O)	—	—	0	214	216	—	—
Trackway desv. Td)	—	0	4	7.5	5	6	—
Trackway width (Tw)	—	—	—	31	—	—	—
Stride length (Sl)	—	125	116	122	120	120	—
Hip height (H)	120	—	125	120	—	—	120
Pace length (Pl)	—	68	55	60	63	60	62
Pace angle (Pa)	—	180	161	152	155	156	—
Length II	13	—	15	14	11	—	16
Length III	15	—	11	16	—	—	11
Length IV	17	—	11	11	—	—	—
a	9	—	28	20	—	—	21
β	25	—	12	30	—	—	—
δ	34	—	40	50	72	—	—
Sl/h	—	1.0	0.9	1.0	0.9	0.9	—
v1	—	3.2	2.9	3.1	3.0	3.0	—
v2	—	3.2	2.9	3.1	3.0	3.0	—

TABLE V Measurements (cm) of the trackway 4 from Las Cerradicas (Berriasien, Galve, Spain)

Parameters\Track	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
Length pes (L)	22	22	26	—	25	22	—	—	20
Width pes (W)	24	21	21	—	21	24	—	—	27
Orientation (O)	-12	-16	-11	-17	-14	-16	—	—	—
Trackway desv. Td)	—	10	9	10	10	5	—	—	—
Trackway width (Tw)	—	35	37	37	37	37	—	—	—
Stride length (Sl)	—	117	125	121	116	130	—	106	—
Hip height (H)	129	129	164	88	—	153	120	—	—
Pace length (Pl)	—	57	65	65	62	62	61	—	—
Pace angle (Pa)	—	146	147	144	142	142	161	—	—
Length II	6	10	—	—	10	10	—	12	—
Length III	10	12	—	—	12	11	—	12	—
Length IV	—	—	—	—	7	6	—	10	—
a	31	27	24	—	20	20	—	—	40
β	32	—	14	0	30	18	—	—	51
δ	63	—	38	—	50	38	—	—	91
Sl/h	—	0.8	0.8	0.8	0.8	0.9	—	0.7	—
v1	—	2.7	2.9	2.8	2.7	3.2	—	2.4	—
v2	—	2.4	2.5	2.5	2.4	3.1	—	1.0	—

meters of trackway width (tw) and pace angles (pa) are similar for pes and manus. The left manus prints (tracks 4.1, 4.3 and 4.9) are closer to the midline than the right manus prints. The midline of the pes tracks are oriented toward the midline of the trackway (negative rotation or inward divarication *sensu* Leonardi (1987)). The orientation (O) is variable in each track, with a mean value of

-16. The manus impressions do not show any constant pattern of rotation.

DISCUSSION

Trackways 1-3 are probably theropod tracks considering their features, Figure 6 being an example.

TABLE VI Mean values (cm) of trackways 1-4 from Las Cerradicas (Berriasien, Galve, Spain)

Trackway	1	2	3	4
Length pes (L)	24	21	25	23
Width pes (W)	20	18	21	23
Orientation (O)	-6	-10	-10	-16
Trackway desv. Td)	3	4	4	9
Trackway width (Tw)	24	21	31	36
Stride length (Sl)	116	107	120	120
Hip height (H)	119	100	121	143
Pace length (Pl)	58	56	61	65
Pace angle (Pa)	165	160	161	148
Length II	8	11	14	10
Length III	18	12	13	12
Length IV	8	11	13	7
a	26	30	20	24
β	19	33	22	24
δ	44	65	49	56
v1	3.1	3.1	3	2.3
v2	3	3	3	2.8

TABLE VII Main ratios of trackways 1-4 from Las Cerradicas (Berriasien, Galve, Spain)

Trackway	1	2	3	4
L-a/W	0.2	0.16	0.19	0
Length III/L	0.5	0.57	0.52	0.50
Td/W	0.15	0.22	0.21	0.4
Sl/L	5	5	4.8	5

They extend in the same direction and show a straight direction of movement. The tracks of three individuals can be followed across the rock. There are few tracks but they have a parallel orientation. The trackmakers were walking in the same direction and seem to have been walking at about the same low speed, about 3 km/h (formulae taken after Alexander, 1976 and Demathieu, 1986—see Table 6). They all had similar-shaped and similar-length feet and probably belonged to the same species. Were these dinosaurs moving around in a group? All the prints seem to have been fresh when silted over and therefore were probably made at about the same time. There is no indication of any older prints being more weathered by physical processes or bioturbated than later prints. There are similar examples in the Lower Cretaceous of La Rioja (Casanovas et al., 1993).

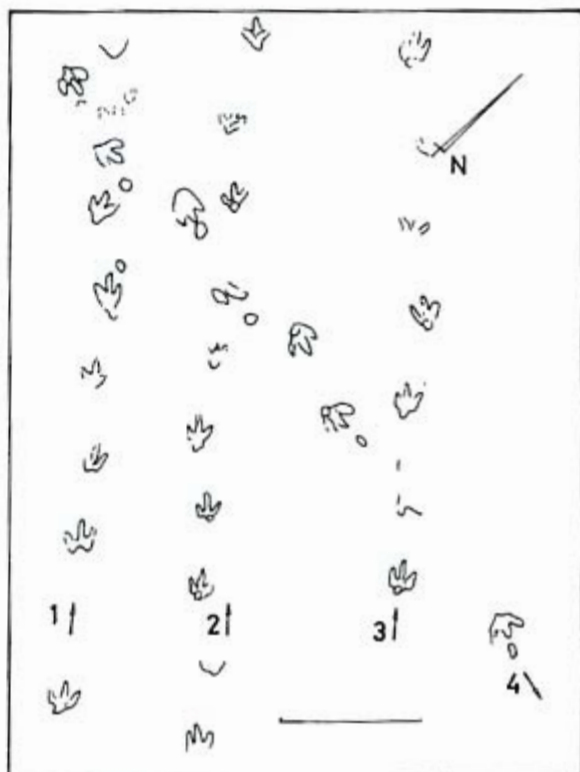


FIGURE 4A. Map of the Las Cerradicas tracksite (Galve, Teruel, Aliaga basin, Berriasien, Spain) showing the bipedal tridactyl trackways (1-3) and the quadrupedal ornithopod trackway (4). Track 1 from trackway 1 is 1.1, track 2 from trackway 1 is 1.2 and so on. 1.1, 1.3, ...; 2.1, 2.3, ... and 3.1, 3.3, ... are left pes prints and 1.2, 1.4, ...; 2.2, 2.4, ...; 3.2, 3.4, ... are right pes prints. Scale bar is 1 m. 4B. Photograph of Las Cerradicas tracksite taken from the Galve road.



FIGURE 5 Detailed map of trackway 4 of Las Cerradicas track-site (Galve, Teruel, Aliaga basin, Berriasian, Spain). Scale bar is 1 m.

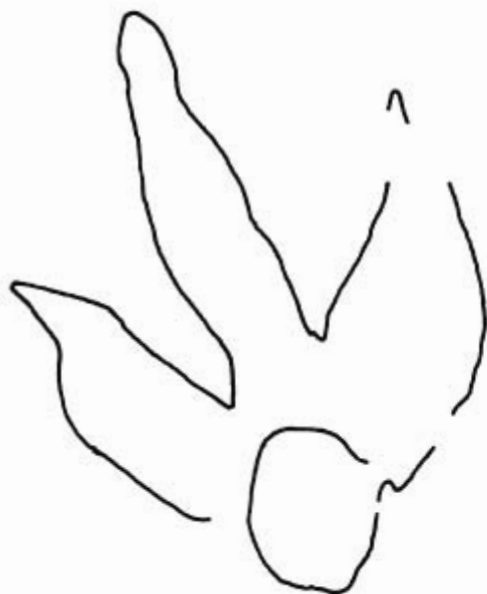


FIGURE 6 Type footprint of the tridactyl trackways 1–3 (Ichnite 2.3). Scale bar is 5 cm.

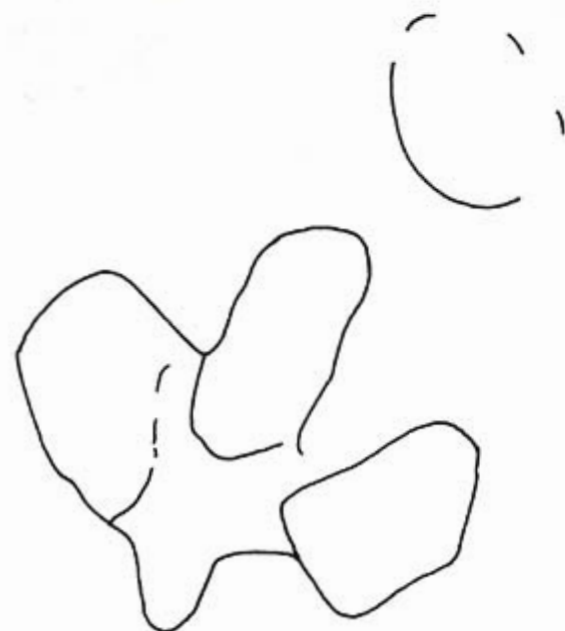


FIGURE 7 Ichnite 4.1. An ornithopod manus-pes print. Scale bar is 5 cm.

Allocation of Trackways 1, 2, 3 within the Theropods

Among the small to medium size Theropoda of similar age, Late Jurassic to Early Cretaceous, the trackmakers of trackways 1–3 could fit with Ornithomimosauria, Ceratosauria, and small or young Megalosauridae.

According to Barsbold and Osmólska (1990), the Ornithomimosauria were tridactyl; the pedal unguals are pointed at their tips; the third digit is the longest and robust but generally the three digits are long; the phalanges of the fourth digit are shortened and digit II has more robust phalanges than digit IV. These skeletal features can be observed in tracks as acuminate digit-ends, long digits, and digit II being somewhat thicker than IV (i.e., left footprint 2.3 and left footprint 3.1). Ornithomimosaurians have been found in Late Cretaceous sediments elsewhere, but in Europe, the first ornithomimosaur was reported in Las Hoyas (Province of Cuenca, Spain, Pérez-Moreno *et al.*, 1994). Dated as Early Cretaceous, ornithomimosaurians like *Pelecanimimus polyodon* from Las Hoyas (Pérez-Moreno *et al.*, 1994), could represent the trackmaker of Las Cerradicas trackways 1–3.

According to Rowe and Gautier (1990), Ceratosaurians have digits shorter than those of ornithomimosaurians; some Ceratosaurians are diagnosed by the fusion of the proximal end of metatarsals II and III, digit II being slightly divergent from digits III and IV (see fig. 5.10.D in Rowe and Gautier (1990). This morphology could be expressed in the tracks as a greater divergence of digit IV, with digits III and II approximately parallel, as in trackways 1, 2, 3 where the interdigital angle β (between digits III–IV) is generally bigger than interdigital angle α (between digits II–III—see Tables 1, 2, 3, 4). If trackmakers 1–3, were travelling together, they could be part of a herd and that fact seems to be consistent with the discovery of several Ceratosauria in “mass burials”, in a variety of depositional environments, which suggests that, as Welles (1984, in Rowe and Gautier 1990) pointed out, some Ceratosaurians were gregarious.

The adult carnosaurs of Late Jurassic-Early Cretaceous age, known in Europe, North Africa and Asia, should be larger than those which made trackways 1-3 from Las Cerradicas. There is the possibility of them having been made by juvenile carnosaurs, but known hindlimbs of adult Carnosaurs are tridactyl to tetradactyl, with very robust phalanxes, and digits quite similar in length although digit III is the longest (Molnar et al., 1990).

Other theropods are too different (Oviraptorosauria, Troodontidae, Dromaeosauridae, "Coelurosaurs") to be compared with those which made trackways 1-3 from Las Cerradicas. Theropoda such as Oviraptorosauria and Troodontidae have curved pedal unguals that would be marked in the tracks, and they are only known in the Late Cretaceous (see Weishampel et al., 1990). Dromaeosauridae, though being Early-Late Cretaceous in age, have a very peculiar second digit with a strongly curved pedal ungual (Ostrom, 1969). "Coelurosaurs" are small theropods of Late Jurassic-Late Cretaceous age; they have very long digits, especially III and IV (Norman, 1990); they have a pace angle among 160-170° but sometimes the trackway is so narrow that pace angulation measures 180° with digits splayed out in roughly symmetrical pattern (Thulborn, 1990). Thus, it seems most probable that the trackmaker of trackways 1, 2, 3 could be either an ornithomimosaurian or ceratosaur, though a young megalosaur cannot be ruled out.

The Ornithopoda origin conjecture: At least six factors suggest that trackways 1-3 may be of ornithopod origin. 1) One track (1.7) appears to have an associated manus (Fig. 4A). 2) Some tracks have a central heel pad in some cases and do not have the typical theropodan asymmetry that includes a postero-median indentation at the proximal end of the impression of digit two. 3) The steps are all consistently short. 4) The digit impressions lack pads, but have an elongated teardrop shape as seen in many ornithopod tracks. 5) The parallel orientation is more consistent with an ornithopod interpretation than theropod origin, though the number of trackways is not sufficient

to make a definitive conclusion. 6) There is now evidence from North America that tracks of this general morphotype appear in the stratigraphic record in the Late Jurassic, and an ornithopod origin is proposed for the tracks (Lockley, written communication).

Allocation of Trackway 4 within the Ornithopods

In Trackway 4 the pes prints have typical features of ornithopods (Casanovas et al., 1989; Moratalla et al., 1992). The most important characteristics of Trackway 4 are the size ($L = 23$, $h = 1.43$), the quadrupedal progression of the trackmaker and the oval impressions of the manus prints. Trackway 4 shows a straight direction of movement. It seems to have been made after trackways 1-3, because track 4.2 overprints track 1.8, track 4.4 overprints track 2.7 and track 4.7 overprints 3.2.

The comparison between quadrupedal ornithopod trackways (Casamiquela and Fasola, 1968; Norman, 1980; Currie, 1983; Leonardi, 1984; Lockley, 1987; Pittman, 1989; Currie et al., 1991; Moratalla et al., 1992; Bengoechea et al., 1993—see Table 8 and Fig. 8) shows that Trackway 4 from Las Cerradicas with a mean value of $L = 23$ cm and $W = 23$ cm is smaller than any of the quadrupedal ornithopod tracks known in the literature. The only exception is *Camptosaurichnus* (length of pes prints 25 cm and length of the manus prints 11 cm) from the Hauterivian of Chile (Diaz and Gasparini, 1976 in Weishampel, 1990). The recently discovered quadrupedal ornithopod trackways from Regumiel de la Sierra, Burgos, Spain (Bengoechea et al., 1993) were made by ornithopods with large foot dimensions ($L = 63$ and 45).

The length of the footprints in Trackway 4 indicates a small ornithopod of the type that often have pentadactyl hands with manus prints which show star-shaped or fan-shaped prints. Among small Ornithopoda from the Late Jurassic-Early Cretaceous, with pes length that could fit with the size of the trackmakers (among 20-25 cm), are *Camptosaurus dispar* and *Iguanodon atherfieldensis*

TABLE VIII Literature of known quadrupedal ornithopod trackways: 1. Casamiquela *et al.*, 1968; 2. Norman, 1980; 3. Currie, 1983; 4. Leonardi, 1984; 5. Lockley, 1987; Pittman, 1989; 7. Currie *et al.*, 1991; 8. Moratalla *et al.*, 1992; 9. Bengoechea *et al.*, 1993; 10. Moratalla *et al.*, 1994

YEAR	ORNITHOPODS TRACKS	GEOGRAPHICAL LOCATION	AGE
1. 1968	<i>Camptosaurichnus</i> (iguanodont)	Chile	Hauterivian
2. 1980	ornithopod (iguanodont)	England	Valanginian-Barremian
3. 1983	<i>Amblydactylus</i> (hadrosaur)	Canada	Aptian-Albian
4. 1984	<i>Caririchnum</i> (iguanodont)	Brazil	Early Cretaceous
5. 1987	<i>Caririchnum</i> (iguanodont)	U.S.A.	Aptian-Albian
6. 1989	ornithopod	U.S.A.	Aptian-Albian
7. 1991	<i>Caririchnum</i> (iguanodont)	U.S.A.	Albian-Cenomanian
7. 1991	ornithopod (hadrosaur)	Canada	Campanian-Maastrichtian
8. 1992	ornithopod (iguanodont)	Spain	Hauterivian
9. 1993	<i>Caririchnum</i> (iguanodont)	Spain	Hauterivian-Aptian
10. 1994	<i>Caririchnum</i> (iguanodont)	Spain	Hauterivian-Aptian
9. 1993	ornithopod (iguanodont)	Spain	Hauterivian-Aptian

(Table 9). *Camptosaurus* ranges from the Kimmeridgian up to the Barremian and *Iguanodon* from the Berriasian up to the Albian (Norman and Weishampel, 1990). The Barremian localities of Galve (Fig. 2), have yielded Iguanodontidae indet., *Iguanodon bernissartensis* and *I. cf. atherfieldensis* (Sanz *et al.*, 1987). According to Norman and Weishampel (1990), the carpus of *Iguanodon*, with its coossification and ligament connections, suggest weight bearing in conjunction with quadrupedality, as also suggested by the study of Moratalla *et al.*, (1992). The manus of *Iguanodon bernissartensis* and *I. atherfieldensis* shows that adaptation for weight support was less well developed in the latter species according to Norman (1980). Although *I. atherfieldensis* shows some characteristics associated with quadrupedality, it was not a bipedal as were the anatomically similar hadrosaurs, since its forelimb was well adapted for locomotion (Norman, 1980). For this reason we include Trackway 4 in the type of iguanodonts, which have oval manus impressions (Thulborn,

1990), possibly a new ichnite (Leonardi, personal communication).

In Figure 8, ornithopod ichnites described by other authors have been drawn to the same scale. Unfortunately, Casamiquela *et al.* (1968) do not provide any drawings, only oblique photographs from which it is impossible to obtain data for comparison. The footprints of these authors are probably larger than those from Las Cerradicas because magnitudes of 24–25 cm are given for the length of the foot. They do not indicate whether they are mean values or correspond to only one of the ichnites of each trackway.

With respect to the age of the trackways it is observed that Las Cerradicas contains the oldest quadrupedal ornithopod tracksite, with the exception of the one which Leonardi (1984) cites, whose age is early Cretaceous. The indefinite nature of this age validates the assertion of the oldest age of Las Cerradicas footprints.

There is no indication that the size or the relative manus-pes orientation of the footprints are re-

TABLE IX. Data of the Hip height and Length pes obtained from the skeletal reconstructions. The reconstruction of *Camptosaurus prestwichii* is a non-adult individual.

Species	H	L	Reference
<i>Camptosaurus dispar</i>	119	21.4	Norman & Weishampel, 1990, (fig.25.20)
<i>Camptosaurus prestwichii</i>	119	16.7	Galton & Powell, 1980 (fig.3)
<i>Iguanodon bernissartensis</i>	252.4	47.6	Norman & Weishampel, 1990 (fig.25.21)
<i>Iguanodon atherfieldensis</i>	137	24.66	Norman & Weishampel, 1990 (fig.25.22)

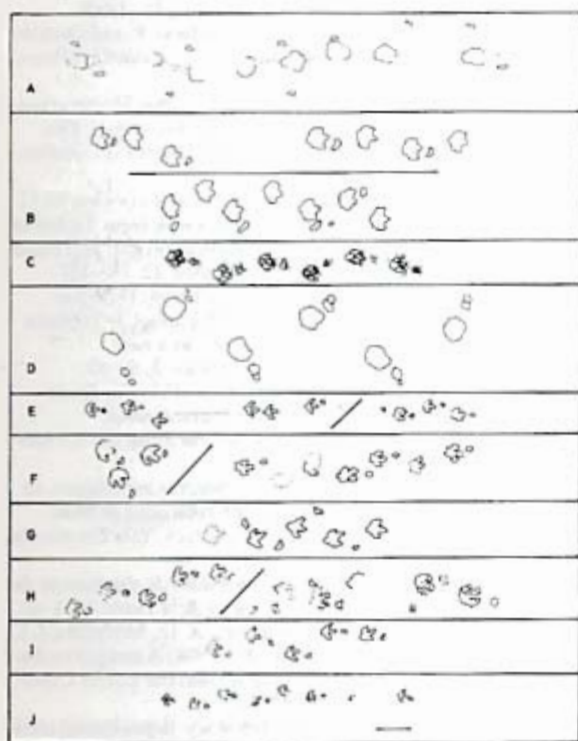


FIGURE 8 Tracks of quadrupedal ornithopods. A. Norman, 1980, part of Plate V; B. Currie, 1983, part of trackway A, I from Fig. 2; C. Leonardi, 1984, part of Fig. 8; D. Pittman, 1989, Fig. 15.6C; E. Lockley, 1987, Figs. 5A and 5C; F. Currie et al., 1991, part of Figs. 4 and 5; G. Moratalla et al., 1992, Fig. 3A; H. Bengoechea et al., 1993, Figs. 14 and 15. I. Moratalla et al., 1994, Fig. 6; J. Las Cerradicas trackway 4. Scale bar 1 m.

lated to the age, although Trackway 4 is the oldest and smallest of those described up until now. This finding allows extension of the fossil record of quadrupedal ornithopod footprints to the Berriasian-Cenomanian interval.

CONCLUSIONS

The Las Cerradicas tracksite consists of 4 trackways (40 footprints) located at the top of the Villar del Arzobispo Formation, Berriasian in age, near Galve (Teruel, Spain). Trackways 1-3 are tridactyl produced by a debatable trackmaker (ornithopod or theropod). Among the small Theropoda, the makers of these trackways have been either Ornithomimosauria, Ceratosauria or young mega-

losauridae. Trackway 4 is a typical ornithopod track, probably from an iguanodont of a small size.

Thus the evidence suggests this is not only an ornithopod tracksite, but one of the oldest known from the Cretaceous, and with some of the smallest (or the smallest) tracks ever attributed to a quadrupedal ornithopod. The site appears to record some of the first Cretaceous ornithopod trackmakers that herald the appearance of many more larger quadrupedal ornithopods (probably iguanodontids and their relatives).

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