

The First Dinosaur Trackway from the Valtos Sandstone Formation (Bathonian, Jurassic) of the Isle of Skye, Scotland, UK.

N.D.L. Clark* and J. L. Barco Rodríguez**

*Hunterian Museum, University of Glasgow, GLASGOW G12 8QQ, Scotland, UK.

**Area de Paleontología, Universidad de Zaragoza, C/Pedro Cerbuna s/n, ZARAGOZA 50009, Spain.

Abstract

A trackway from near the base of the Valtos Sandstone Formation (Bathonian, Jurassic) was discovered on a loose block of bioclastic sandstone. Nine distinct track cast, and some less distinct, are preserved in hyporelief on a mud-cracked surface with two sea-worn counterparts of three of the tracks. Of these tracks only four can be associated with confidence into two trackways. The individual track sizes range from about 18cm to over 30cm in length and are characteristic of a Eubrontes/Grallator association.

Resumen

Un rastro de dinosaurio fué descubierto en un bloque rodado, compuesto por areniscas bioclásticas, en la base de la Valtos Sandstone Formation (Batiense, Jurásico). El bloque contiene una superficie, que presenta grietas de desecación, en la que se han preservado en hiporelieve nueve pisadas que se distinguen con claridad y otras posibles huellas. Se conservan también contramoldes, algo erosionados por el mar, de tres de las pisadas. Solamente cuatro de las pisadas pueden ser asociadas con confianza en dos rastros. La longitud de las impresiones oscila entre 18cm y 30cm y son características de la asociación Grallator/Eubrontes.

Key words: Jurassic, Valtos Sandstone Formation, tridactyl tracks, trackway, Eubrontes/Grallator association.

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Introduction

Dinosaur fossils of any kind are rare in Scotland. Since the discovery of the first dinosaur track in 1982 (Andrews and Hudson 1984) at the top of the Lealt Shales Formation, no other tracks have been found until this latest find. The single track of 1982 was found in close proximity to the latest discovery at Rubha nam Brathairean (figure 1) and is thought to be that of an ornithopod (Delair and Sargeant 1985) although it was originally described as theropod track (Andrews and Hudson 1984). The new tracks form two partial trackways and a number of individual tracks. The small narrow toed tridactyl tracks are identified as the ichnogenus *Grallator* and the larger wider-toed with rounded ends are identified as of the ichnogenus *Eubrontes* (Hitchcock 1858, Lull 1953, Colbert 1963, Ostrom 1968).

It was not until 1994 that further dinosaur discoveries were made in Scotland. A possible cetiosaur femur

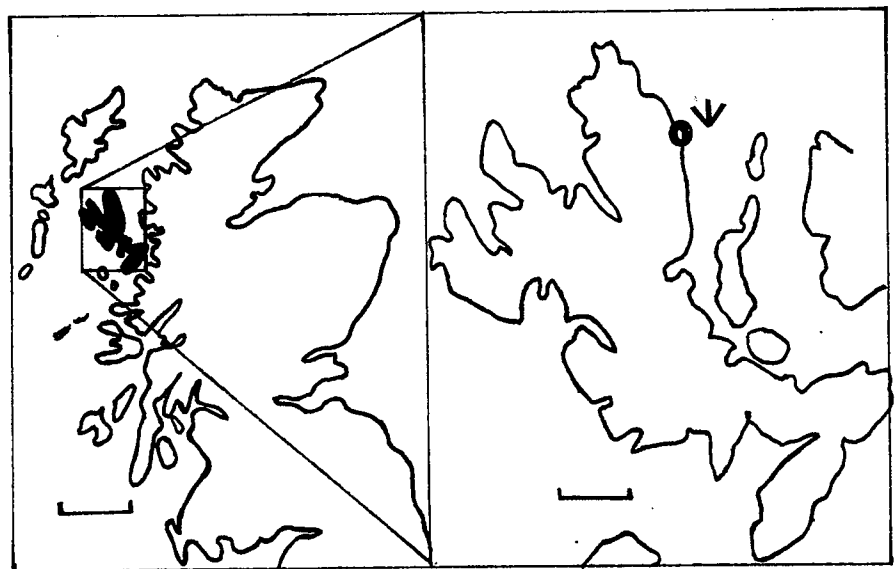


Fig. 1. Locality map for the Valtos Sandstone Formation on the Isle of Skye, Scotland, UK* (locality at Rubha nam Bratairean); scale bar on map of Scotland=50km; scalebar on map of Isle of Skye = 5km.

Fig. 1.- Mapa de situación de la Formación Valtos Sandstone en la isla de Skye, Escocia, Reino Unido (Localidad de Rubha nan Bratairean); Barra de escala en el mapa de Escocia = 50 km. Barra de escala sobre el mapa de la isla de Skye = 5km

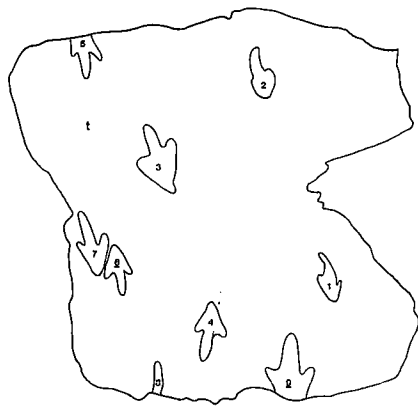


Fig. 2.- Diagram showing the distribution of tracks on the mud-cracked surface of the bioclastic sandstone.

Fig. 2.- Diagrama mostrando la distribución de rastros sobre la superficie con grietas de desecación de la arenisca bioclástica

from the Valtos Sandstone Formation (Bathonian) (Clark *et al.* 1995) and a theropod tibia from the Broadford Beds Formation (Hettagian) (Benton *et al.* 1995) were the first dinosaur bones from Scotland. Since the several more bones including a small coelophysid-like caudal vertebra, a large possible theropod caudal vertebra, a rib and a stegosaur ulna and radius have been found from the Valtos Sandstone Formation. Miller *et al.* (1989) suggested that *Grallator* may be produced by a small coelurosaur similar to *Coelophysis*. The remains of a coelophysid-like dinosaur from the same formation is a fortuitous coincidence. The originator of the *Eubrontes* tracks may be an ornithopod, although Lull (1953) suggested that it may be a carnosaur and Colbert (1963) indicated that they may have been produced by a prosauropod. The Middle Jurassic age of these rocks makes it unlikely that a prosauropod made these tracks and more likely that either a carnosaur or ornithopod was the track-maker. Although there is a lack of *Eubrontes/Grallator* associations from the Middle Jurassic in the literature, there have been some recent discoveries in Yorkshire of similar tracks of that age (Manning *pers. comm.*)

Stratigraphical and sedimentological setting

The trackway (figure 2) was found on a loose block of bioclastic sandstone containing the bivalve *Neomiodon* in abundance. This is a characteristic of the

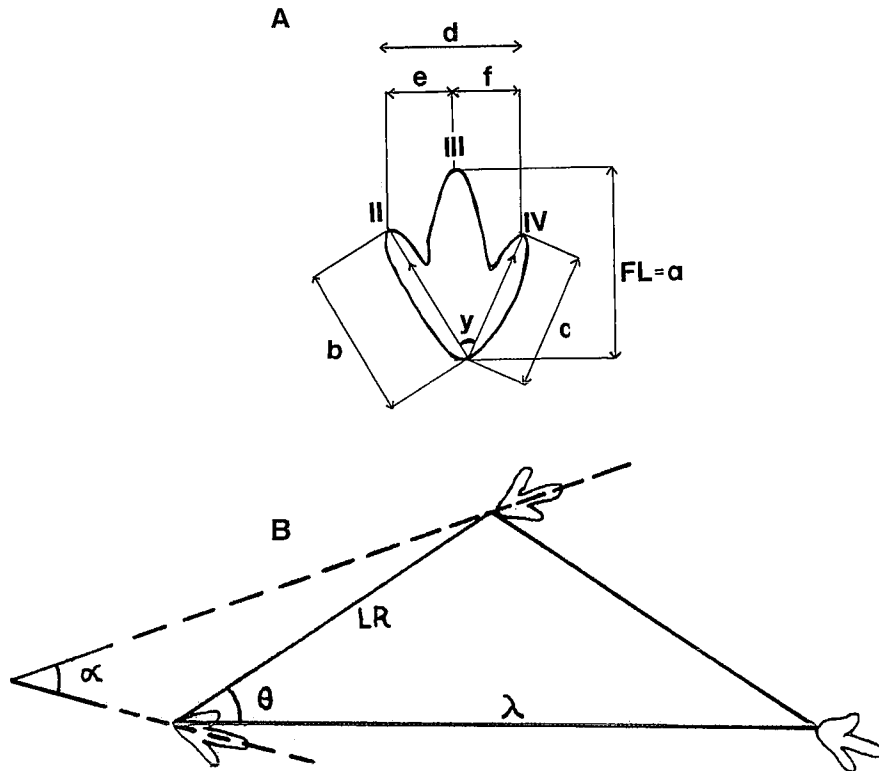


Fig. 3.- Measurements used in tables 1 and 2 for a: individual tracks b: trackways.

Fig. 3.- Medidas empleadas en las tablas 1 y 2 para a: trazas individuales; b: rastros

Valtos Sandstone Formation (Bathonian) which is exposed in the cliffs immediately above where the block was found. The only other horizon exposed in the vicinity is that of the slightly older Lealt Shale Formation (Bathonian) which is represented by muddy limestones and shales containing abundant fish remains. The Valtos Sandstone Formation was deposited in a shallow lagoonal deltaic environment periodically exposed which allowed hypersaline mudflats to develop (Hudson 1964, Hudson and Harris 1979, Bell and Harris 1986, Bradshaw and Cripps in Bradshaw *et al* 1992, J6b, Harris 1992). It was during one of these exposed episodes that the trackway was formed indicated by desiccation cracks on the surface of the block.

Material and Methods

A greater than 15cm thickness of the surface of the block was split along a bedding plane using rock-saws, pneumatic drills, chisels and sledge hammers. This was further broken into manageable blocks and individually numbered for carrying from the shore to the top of the cliff. The block was reassembled to check that all material was collected before transportation to the Hunterian Museum, University of

Glasgow. A silicone rubber mould and fibre-glass resin cast of the surface was produced for photographing. The blocks were accessioned into the collections of the Hunterian Museum, University of Glasgow, specimens GLAHM 101273/1-38, GLAHM 101274, GLAHM 101275. The main block measures 1m58 X 1m20 X 1m30 X 1m26 in plan view and weighs over 800kg. Specimen GLAHM 101274 is the counterpart to tracks 6 and 7 and specimen GLAHM 101275 is the counterpart to track 8.

Description

Nine tracks are clearly visible although there appears to be the faint outlines of other tracks, and partial tracks, including one possible quadruped track. The consistency of the mud may have been a factor on the amount of relief and definition exhibited by the different tracks. It is thought that the tracks were made at, or near to, the level of the mudcracks as there appears to be no disruption of the sediment above the level of the tracks except where the sediment has in-filled the tracks. On the counterparts (GLAHM 101274 and GLAHM 101275) there is some disruption of the sediment below where the impression appears to flatten and

enlarge further from the track surface.

The smaller of the tracks (1 and 2; figure 2) are likely to have been made by the same individual shown by their alignment and orientation. Tracks 1 and 2 represent the right and left pes of a small bipedal animal respectively. The middle toe appears to curve inwards in a similar manner to the Triassic to lower Jurassic tracks from Connecticut of the ichnogenus *Grallator* (Hitchcock 1858, Olsen and Golton 1984). The curvature and the narrowness of the toe suggest that the track-maker was a theropod. The curvature of the middle toe may be a result of the foot twisting as the animal moves forwards rather than a true representation of the foot shape (Manning *pers. comm.*). These are the smallest of the tracks (approximately 21cm in maximum length), and are also the most clearly defined.

Tracks 5 and 6 (figure 2) may also belong to a single animal, but are larger than tracks 1 and 2 upto about 30cm in length. The larger size, straight middle toe and broad curved tip to the toes are similar to the ichnogenus *Eubrontes*, also known from the Triassic to Lower Jurassic tracks of Connecticut (Hitchcock 1858, Olsen and Golton 1984). The rounded ends to the toes suggest that the track-maker was an ornithopod. If the sediment was unstable enough to collapse in smoothing the edges and making the track appears larger, then the *Eubrontes* track-maker may also be a theropod.

The rest of the tracks (3, 4, 7-9; figure 2) are all of the *Eubrontes* type with angles between digits II and IV of 52°-71°. The *Grallator*-like tracks (table 1, figure 3a) have angles of 35°-39° between digits II and IV. It is unlikely that the spread of the toes is a useful diagnostic character for these tracks as so much depends on the sediment and depth of the tracks (Manning *pers. comm.*). Track 9 has a *Eubrontes* morphology with an atypical angle of 39° between digits II and IV and is also incomplete, lacking the posterior border of the track, which may have resulted in the derived angle being slightly less than expected.

Although the tracks may all have been produced by the same track-making species, it was considered best to retain the commonly used ichnospecies terminology for these forms of tracks - *Eubrontes* and *Grallator*. The size and shape of the tracks may depend on the amount of sediment deposited above the track-bearing level at the time the track were made. As there does not appear to be any disturbance of the sediment above

	a	b	c	d	e	f	angle
track 1	21	12.7	12.8	9.1	4.2	4.9	35
track 2	21.5	12.5	13.5	9	5.5	3.3	39
track 3	28.4	18.5	20.9	15.5	7.2	8.3	65
track 4	24.6	16.5	15	13.6	6.2	7.4	71.5
track 5	18.2	10.9	13.8	8.8	3.7	5.1	67
track 6	19	9	11.5	8.8	3.8	5	63
track 7	24	14.5	14.5	11	5	6	52
track 8	-	-	-	-	-	-	-
track 9	30	16	22.5	17.3	7.3	10	39

Table 1. Measurements of the tracks in cm; a, maximum length; b, length of digit II; c, length of digit IV; d, maximum width; e, width between digits II and III; f, width between digits III and IV; angle, angle between digits II and IV.

Tabla 1.- Medidas de las trazas en cm; a, longitud máxima; b: longitud del dígito II; c, longitud del dígito IV; d, anchura máxima; e, anchura entre dígitos II y III; f, anchura entre dígitos III y IV; ángulo, ángulo entre dígitos II y IV.

the level of the tracks, and there is a break in sedimentation at the same level where mud has accumulated during a period resulting from a desiccation of a lagoon, or lagoon edge, then it is likely that the track-makers walked on the sediment at this level and not above. If the tracks were all made at the same level, as proposed here, then the variation in the track size and form may be a true reflection of a difference in track-maker. This will also allow a reasonably reliable measurement of speed of movement for the four tracks that are part of two trackways. The variation in definition and shape of the tracks may be as a result of differences in the consistency of the sediment immediately below the track, which may vary in mud content and water saturation. The trackways are not long enough to state whether the differences between the tracks are diagnostic, but the smaller and narrower toed *Grallator* tracks (1 and 2) are quite different from the larger and broader toed *Eubrontes* track (3-9).

The possible tetrapod track is not well enough defined to allow a positive identification. The single five toed track appears to be part of a trackway which is

poorly defined and disturbed on this surface (figure 2: t).

Results

The two trackways were measured to assess the velocity of the track-makers using the equations to measure the hip height of theropods and ornithopods proposed by Thurlborn and Wade (1984) and Thurlborn (1989) and the speed of travel proposed by Alexander (1976). As there were only two tracks for each trackway, the stride length also had to be calculated geometrically using the direction toe III is pointing and the distance and angle between the tracks to project the probable position of the next track assuming constant velocity and direction (figure 3b).

The calculated stride length for the *Grallator* trackway (tracks 1 and 2) is 158cm (equation 1 and 2) and the hip height (equation 3) is 100cm, giving a speed (equation 5) of 1.7m/s. The *Eubrontes* trackway (tracks 5 and 6), using equation 5 for theropods, does not appear to have been moving much faster, travelling at 2.2 m/s with a stride length

	hip height <i>H</i>	angle of divergence α	angle θ	stride length λ	speed <i>u</i>
tracks 1 and 2 (theropod)	100cm	40°	20°	158cm	1.7ms ⁻¹
tracks 5 and 6 (theropod)	86cm	4°	2°	163cm	2.2ms ⁻¹
tracks 5 and 6 (ornithopod)	112cm	4°	2°	163cm	1.7ms ⁻¹

Table 2. Measurement of velocity of dinosaurs based on tracks 1 and 2, and 5 and 6.

tabla 2.- Medidas de la velocidad de los dinosaurios basadas en trazas 1 y 2, 5 y 6.

of 163cm and a hip height of 86cm. If *Eubrontes* tracks were those of an ornithopod the calculation for the hip height (equation 4) is different and hence the speed is less at 1.7m/s (table 2).

Equation 1. Calculation of θ where α is the angle of divergence of digit III between the right and left pes.

$$\sin(90-(\alpha/4)-(\theta/2))=\cos \theta$$

Equation 2. Measurement of stride length where λ is the stride length, h is the width of the track, LR the pace length, θ is the angle between LR and the direction movement.

$$\lambda=2LR*\cos\theta$$

Equation 3. Measurement of the hip height for small theropods after Thulborn (1984) where H is the hip height, and FL is the track length.

$$H=3.06FL^{1.14}$$

Equation 4. Measurement of the hip height (H) for a generalised ornithopod after Thulborn (1984).

$$H=3.76FL^{1.16}$$

Equation 5. Measurement of velocity following the equation of Alexander (1976) where u is the velocity, g is gravitational constant, λ is the stride length, and H is the hip height.

$$u=0.25g^{0.5}*\lambda^{1.67}*H^{-1.17}$$

If the *Grallator* tracks were made by a theropod then it would have been travelling at a walking gait (Thulborn and Wade 1984), however if the *Eubrontes* were made by a theropod, then it would be trotting at a speed in excess of the walking/trotting threshold of 2.0m/s (Thulborn 1984). If we consider the tracks to have been made by an

ornithopod, then the speed calculated is less than the threshold and would have been walking at about the same speed as the *Grallator* track-maker.

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