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A NEW SAUROPOD TRACKSITE FROM THE MIDDLE JURASSIC OF PORTUGAL

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ABSTRACT: **A newly discovered dinosaur tracksite in a quarry near Fátima (Galinha site), Portugal represents the largest and most important Middle Jurassic (Bajocian-Bathonian) tracksite currently known. The site is characterized by the longest sauropod trackways known anywhere (147 m and 142 m) and by some of the largest known trackmakers (pes length 100 cm, width 80 cm: manus length 60 cm, width 75 cm). The trackways all appear to be wide gauge (cf. *Brontopodus*), though some consist only of manus impressions. The manus/pes area ratio is 1/2 as compared with ratios ranging up to 1/4 or 1/5 in other sauropod tracks. This suggests a distinct ichnotaxon. Manus impressions are particularly well-preserved, and include some examples that have very well-preserved traces of digit I. In one trackway these traces consistently reveal the presence of a large claw that was directed in a posterior-medial direction. In other trackways this trace is more rounded. Due to the large size of the site, the long and visually spectacular trackways and the configuration of the quarry with an elevated rim providing excellent overlooks, the site has great potential as an outdoor educational interpretive center. With optimal illumination the site resembles a mudflat only recently crossed by dinosaurs.**

RESUMO: **Esta jazida com pistas de dinossáurios saurópodes recentemente descoberta numa pedreira perto de Fátima (Pedreira do Galinha) é, até ao momento, a maior e mais importante do Jurássico médio (Bajociano-Batoniano). Este local é caracterizado pela presença das mais longas pistas deixadas por saurópodes de que se tem conhecimento (147 m e 142 m) e por um dos maiores saurópodes identificados através do registo fóssil indirecto (pés: 100 cm de comprimento, 80 cm de largura; mãos: 60 cm de comprimento, 75 cm de largura). Todas as pistas parecem ser do tipo largo (cf. *Brontopodus*) embora algumas sejam constituídas apenas por impressões de mãos. Nas pegadas desta jazida verificou-se que a proporção entre a área das impressões das mãos e dos pés é de 1/2, enquanto que noutras pistas de saurópodes conhecidas, este valor varia entre 1/4 e 1/5. Tratam-se de**

valores extremos de heteropodia em pistas de saurópodes, o que sugere estarmos na presença de um icnotáxone distinto na Pedreira do Galinha. As impressões das mãos estão particularmente bem preservadas e, em algumas delas, a marca do dígito I encontra-se muito bem definida. Numa das pistas estas marcas revelam sistematicamente uma grande garra disposta numa direcção média-posterior. Noutras pistas esta marca de garra é mais arredondada. Devido às grandes dimensões da jazida, às pistas longas e visualmente espectaculares, à frente de exploração da pedreira que se eleva verticalmente, providenciando um óptimo ponto de observação e ao fácil acesso ao local, a Pedreira do Galinha tem todas as características para se tornar um importante eco-museu e centro de educação ambiental, integrado no Parque Natural das Serras d'Aire e Candeeiros. Com iluminação rasante à laje o fundo da pedreira parece uma superficie de sedimento por onde passaram, há poucas horas, vários dinossáurios.

INTRODUCTION

In the last few years there has been an unprecedented spate of discovery and research on dinosaur tracksites in Portugal (LOCKLEY & SANTOS, 1993; LOCKLEY *et al.*, 1992, 1994a; LOCKLEY, MEYER & SANTOS, 1994; SANTOS *et al.*, 1992; MEYER *et al.*, 1994). The majority of these sites reveal abundant sauropod tracks from the Upper Jurassic, south of Lisbon. We herein report on a newly discovered Middle Jurassic sauropod tracksite found by one of us (J.C.) in July 1994, at a locality near Fátima (Serra D'Aire), north of Lisbon, refered to as the Galinha site.

Although it is only possible to provide a preliminary report on this site, the site is clearly very important for several reasons. First, Middle Jurassic tracks and the vertebrate record in general are very sparse globally during this epoch; therefore, any new information is valuable. Second, the tracksite is very large, and the tracks are very well preserved, representing the longest known sauropod trackways in the world, as well as what appears to be the world's largest Middle Jurassic sauropod tracksite. Third the tracks preserve excellent details of manus track morphology that help resolve a long standing discussion about the character of claw impressions associated with digit I (BEAUMONT & DEMATHIEU, 1980; FARLOW, PITTMAN & HAWTHORNE, 1989). Fourth, the site has considerable potential as an outdoor educational interpretive site.

GENERAL DESCRIPTION OF THE GALINHA SITE

The site is situated on a single bedding surface that forms the floor of a limestone quarry. The exposed surface area is approximately 140 m wide by 200 m long (about 28,000 m^2). The surface is very smooth and virtually unbroken in most areas (Fig. 1). Preliminary reconaissance reveals the presence of at least 15 sauropod trackways including several that show excellent preservation of both manus and pes tracks, and others that are manus only and manus dominated (LOCKLEY *et al.*, 1994b). The whole site has not yet been mapped in detail, but individual trackways have been mapped and measures, and individual footprints have been accurately traced using transparent acetate overlays (Fig. 2-7).

The limestone at this quarry is a well-bedded micrite rich sequence that has been dated as Upper Bajocian to Lower Bathonian in age (A.C. AZERÊDO, *pers. commun.*, 1994). Traces of probable sauropod tracks have been observed on an other small bedding plane exposure at a higher stratigraphic level, but to date have not been examined in detail. When first recognized the track-bearing surface was covered with debris. Since then efforts have been made to clean the surface as thoroughly as possible to facilitate study of the footprints, and we thank the quarry owner, Mr. Rui Galinha, for his considerable help in this regard. We also thank to Parque Natural das Serras d'Aire e Candeeiros for generous sponsorship of this project. We emphasise that this is a preliminary report, and we anticipate the completion of more detailed publications in future.

DESCRIPTION OF SELECTED TRACKWAYS

In our initial studies we have assigned numbers to all trackways that have been so far identified, and can demonstrate that some show well preserved manus and pes tracks, and that others consist only of clear manus impressions. For the purposes of this preliminary report we describe and illustrate only a few of the more representative trackways without formally assigning them numbers.

The most prominent of the trackways is one of the longest (Fig. 2) consisting of 94 consecutive manus-pes sets extending over a distance of 142 m. This trackway also represents one of the largest trackmakers (pes and manus length:width = 100:80 and 60:75 respectively). The trackway reveals an average stride length of about 3.05 m and belongs to the wide gauge category (internal trackway width about 60 cm). Estimated speed is about 1.0 $m.s^{-1}$ (= 3.6 $km.h^{-1}$).

A second trackway is marginally longer, exhibiting 97 consecutive manus pes sets (194 tracks) extending over a distance of 147 m. This is technically the longest sauropod trackway documented from anywhere in the world. This trackway also represents a large individ-

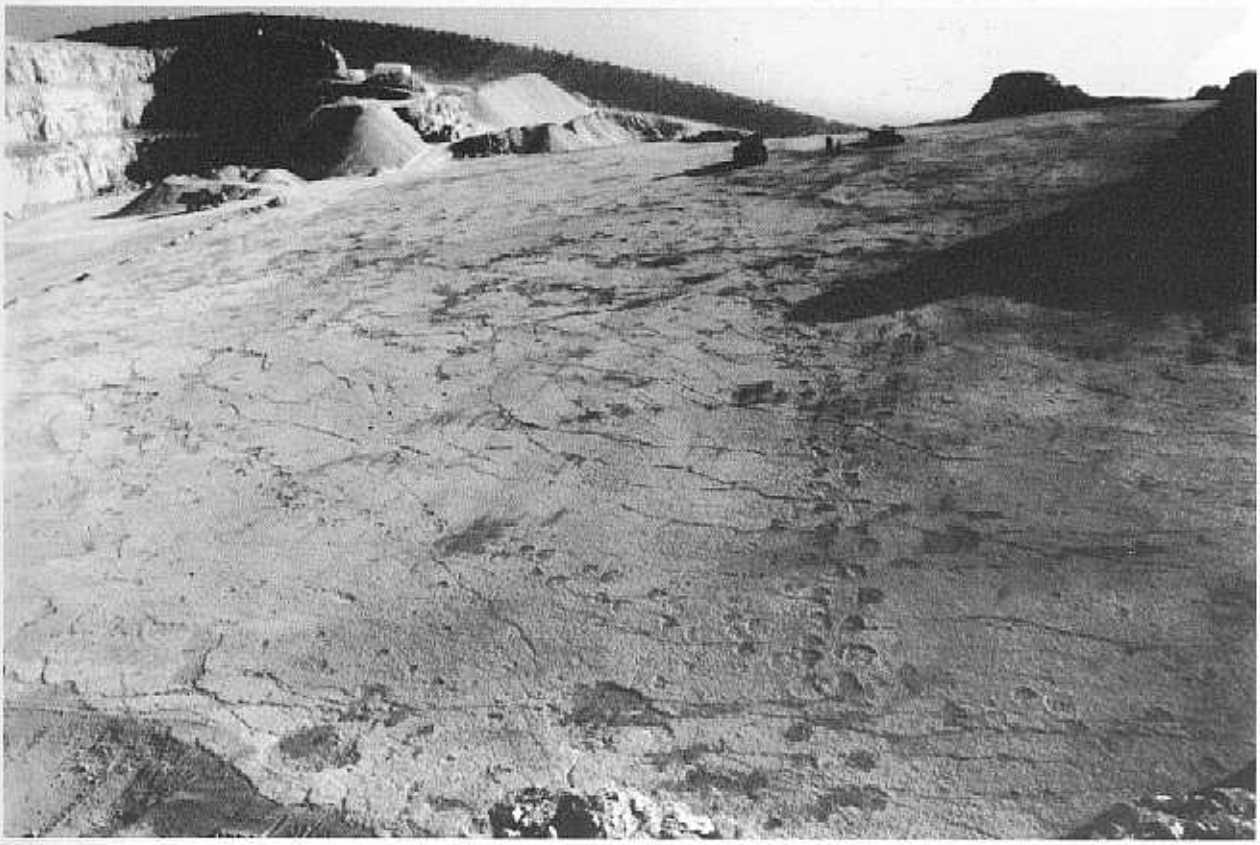

Fig. 1 - General view of the Galinha tracksite. Note cleaning operations in background.

ual (pes and manus length:width = 80:60 and 40:60 respectively), and is important for the well developed manus claw impressions that consistently show throughout the trackway. The trackway is also wide gauge (internal trackway width about 60 cm), with an average stride of about 3.08 m. The estimated speed is about 1.3 $m.s^{-1}$ (= 4.7 $km.h^{-1}$).

Among the several trackways that consist only of manus impressions, or are dominated by manus impressions the trackway illustrated in Figures 4 and 5 are representative of several in the sample. The manus impressions average about 45 cm wide by 26 cm long with an average step of 1.98 m and average stride of 3.04 m. Some of the manus tracks appear to have faint traces of pes toe impressions behind the manus traces. The common phenomenon of manus-dominated and manus-only trackways is further discussed elsewhere in this volume (LOCKLEY *et al.*, 1994b).

SYSTEMATIC DISCUSSION

Clearly the best preserved of the Fátima trackways are wide gauge and therefore similar to *Brontopodus* (FARLOW, PITTMAN & HAWTHORNE, 1989; LOCKLEY, FARLOW & MEYER, 1994). However, the Fátima trackways are distinctive in having very large manus tracks relative to all other known sauropod trackways. We have calculated the manus:pes track area ratio as 1:2 as compared with a 1:3 ratio for *Brontopodus birdi* from the Cretaceous of Texas (FARLOW, PITTMAN & HAWTHORNE, 1989) and a ratio of about 1:4 to 1.5 for sauropod trackways from the Late Jurassic of Colorado (LOCKLEY, HOUCK & PRINCE, 1986) and Morocco (ISHIGAKI, 1988, 1989 and references therein). These ratios can also be expressed as 33.3:66.7, 25:75 and 20:80 of the total manus pes track area (LOCKLEY, 1989; LOCKLEY & RICE, 1990). The area of manus tracks can be affected by overprinting of pes tracks on manus impressions, so measurements should be confined to trackways where manus and pes tracks do not interfere. This is the case in the Galinha site as well as in the case of many "type" *Brontopodus* trackways from Texas and sauropod trackways from Colorado where large samples are available for study. The difference in manus:pes ratio (heteropody) between the Fátima trackways (35.5:64.5 and 34:66; Fig. 6) and those from the Late Jurassic Purgatoire site in Colorado (16:84 and 20:80; LOCKLEY, 1989), currently represent the extreme values of heteropody recorded in sauropod trackways. These figures show a range of manus:pes heteropody from 1:2 to 1:5, which we consider in-

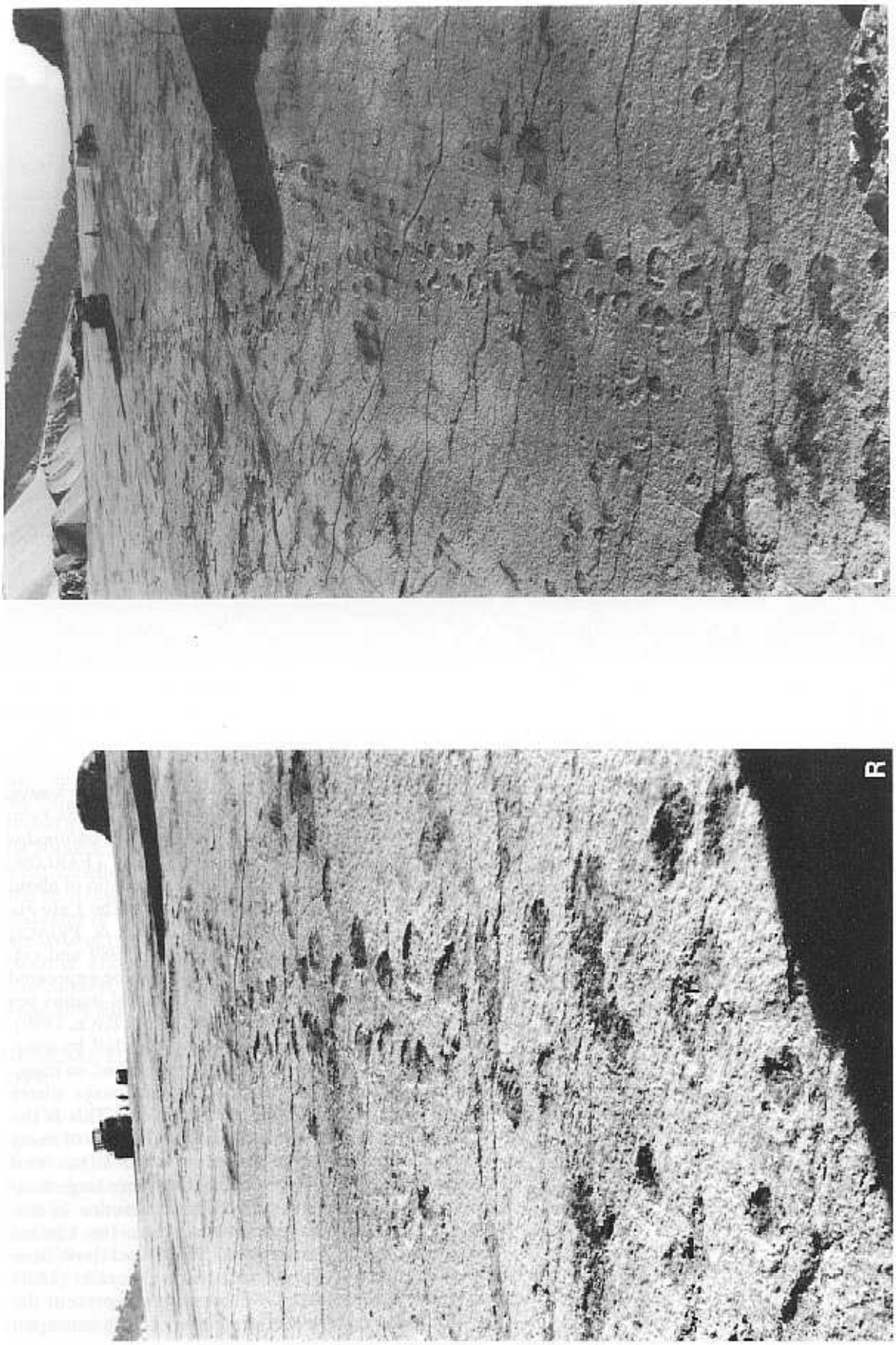

Fig. 2 - Photograph of the most prominent sauropod trackway at the Galinha site, comprising 94 manus-pes sets. Left: view from quarry rim. Right: view from near quarry floor.

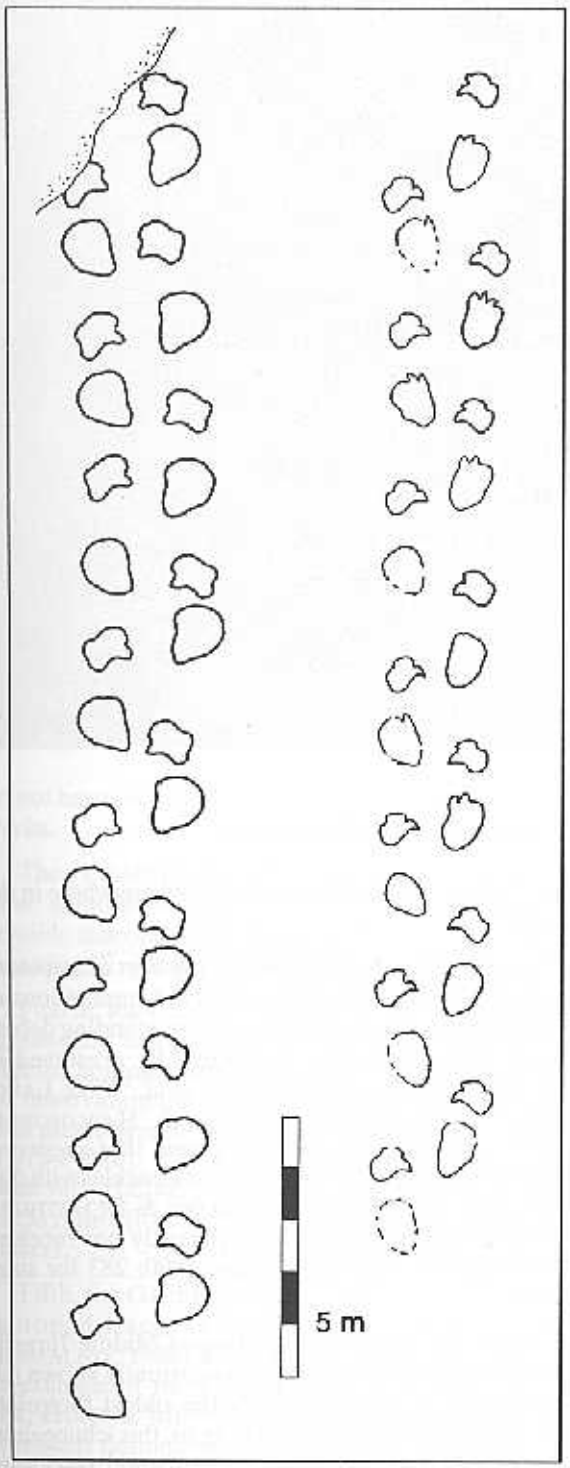

Fig. 3 - Line drawings of segments of sauropod trackway from the Galinha site; compare with Figure 2.

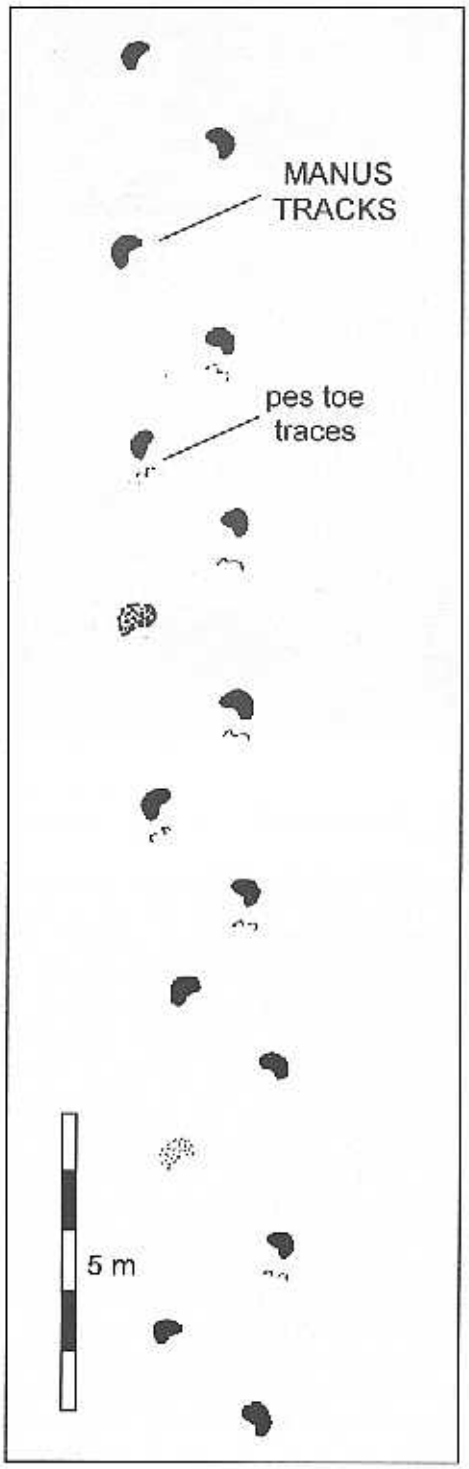

Fig. 5 - Map of manus-dominated trackway, Galinha site; compare with Figure 4. Stippled tracks are unclear on track bed.

Fig. 4 - Photograph of trackways dominated by manus impressions (foreground), Galinha site.

dicative of taxonomic differences among the trackmakers, regardless of other morphological differences such as trackway gauge or claw impression morphologies. Based on these arguments we are in the process of describing the Fátima tracks, and the probable significance of finding such large, wide gauge trackways, with large manus footprints in the Middle Jurassic. Based on pes and manus size the tracks are as large or larger than any sauropod tracks known from the Late Jurassic or Early Cretaceous. Based on trackway width and large manus size the trackways might be attributed to the Brachiosauridae (FARLOW, PITTMAN & HAWTHORNE, 1989; FARLOW, 1992). This family, which is characteristic of the Upper Jurassic had its origins in the Middle Jurassic (DODSON, 1990; WEISHAMPEL, DODSON & OSMÓLSKA, 1990). If this inference is correct then it shows the value of tracks in suggesting the presence of a particular sauropod family in the Middle Jurassic of this region.

DISCUSSION

The Galinha tracksite is remarkable and important for several reasons. First, it is the largest Middle Jurassic tracksite currently known, with the longest known sauropod trackways recorded anywhere in the world.

Second, the tracksite reveals the best examples of sauropod tracks with well-preserved impressions of manus digit I. There has been a long-standing debate about why this claw is not normally preserved in sauropod trackways (GINSBURG *et al.*, 1966; LANGSTON, 1974; FARLOW, PITTMAN & HAWTHORNE, 1989) prompting at least one article that suggested that sauropods could walk on their knuckles with digits rotated backwards (BEAUMONT & DEMATHIEU, 1980). This hypothesis has apparently not received much support (see THULBORN, 1990: 283 for summary).

Third, the tracks are the largest Middle Jurassic wide gauge sauropod footprints currently known (cf. *Brontopodus*), and apparently the oldest footprints that are closely related, or belong to, this ichnogenus. Previously the largest known sauropod trackways from the Middle Jurassic were *Breviparopus* from Morocco (DUTUIT & OUAZZOU, 1980; ISHIGAKI, 1988, 1989). Although these *Breviparopus* tracksites are located near the Portuguese site in space and time, the Moroccan trackways belong to the narrow gauge category (LOCKLEY, FARLOW & MEYER, 1994), and

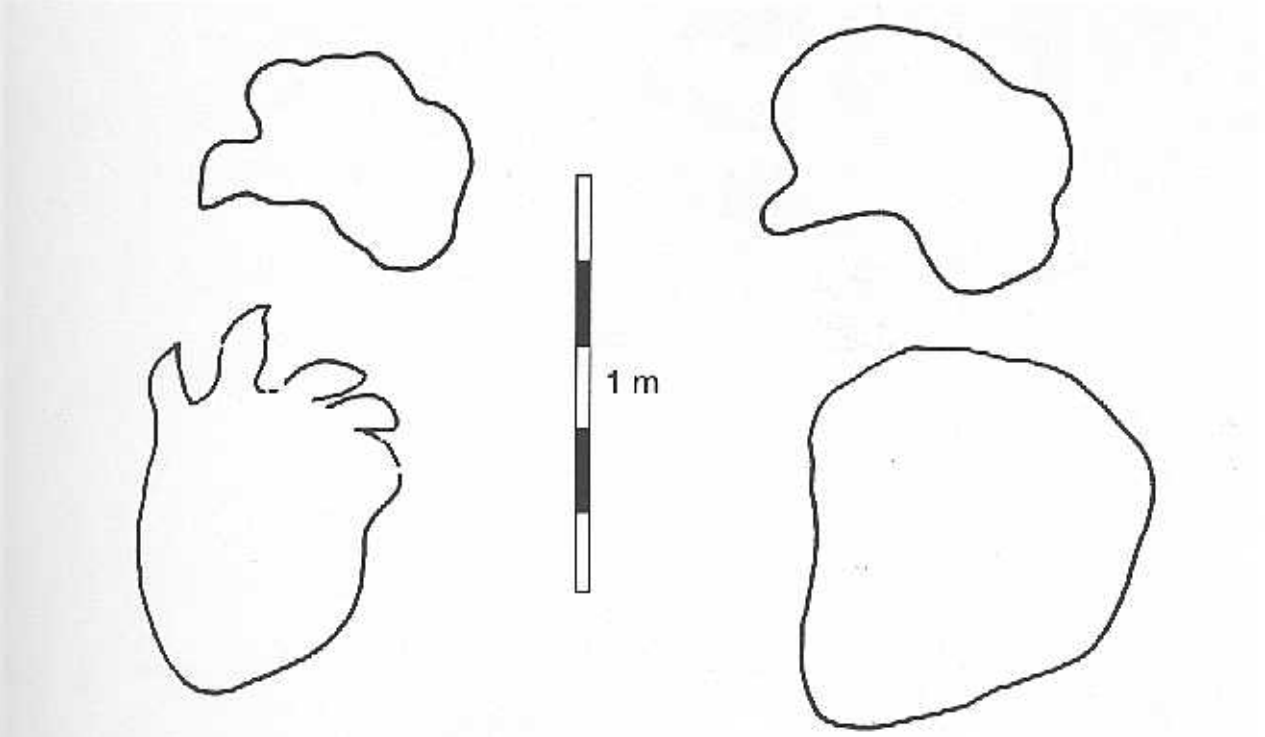

Fig. 6 - Line drawings of manus and pes tracks from two trackways, at Galinha site. Note prominent impression of manus digit I (left).

do not have such large manus:pes ratios as the Fátima tracks.

They evidently do not, therefore, belong to the same ichnotaxon. They are also different from the possible sauropod ichnites reported from the Middle Jurassic of England (WHITE & ROMANO, 1993, 1994).

Fourth, the Galinha tracksite reveals a number of manus-only and manus dominated trackways along with the complete trackways. This evidence supports the observation that manus only trackways are a common phenomenon at sauropod tracksites (LOCKLEY *et al.*, 1994b). This phenomenon evidently results from differential preservation of manus and pes tracks rather than any behavioral activity by the trackmakers.

Fifth, the Galinha tracksite is another example of sauropod tracks in marine platform carbonates (RAMALHO, 1988) and therefore could be cited as an example of the *Brontopodus* ichnofacies (LOCKLEY, HUNT & MEYER, 1994). This ichnofacies was previously defined on the basis of track assemblages in the Upper Jurassic and Lower Cretaceous of Europe and North America, that are found in association with platform carbonates (not on the basis of every sauropod track occurrence). The Galinha site is evidently an example of this distinctive ichnofacies.

CONCLUSIONS

Clearly the Galinha tracksite is a very important addition to the Middle Jurassic track record, and to the sauropod track record in general. Most importantly it provides us with the longest and most complete sauropod trackway segments currently known, at an accessible location. By an interesting coincidence the trackways are a few meters longer than a Cretaceous dinosaur trackway that was recently reported as the world's longest (SANTOS *et al.*, 1992). At that time, the trackway was reported to be 127 m long, but has since been further excavated to expose a segment measuring 141 m (GALOPIM DE CARVALHO, 1994). By comparison, the longest Fátima trackway so far recorded measures 147 m.

The tracksite is also very important because it reveals such well defined manus claw impressions in certain trackways, and because of the manus tracks are so large in relation to the pes tracks. Such evidence strongly suggests the potential to differentiate sauropod trackway types on the basis of heteropody measurements, as well as on the basis of trackway morphology (trackway width, or gauge) and individual track morphologies. The tracksite also helps support the growing evidence for a strong relationship between sauropod tracks and low-latitude carbonate substrates, characterized by the *Brontopodus* ichnofacies.

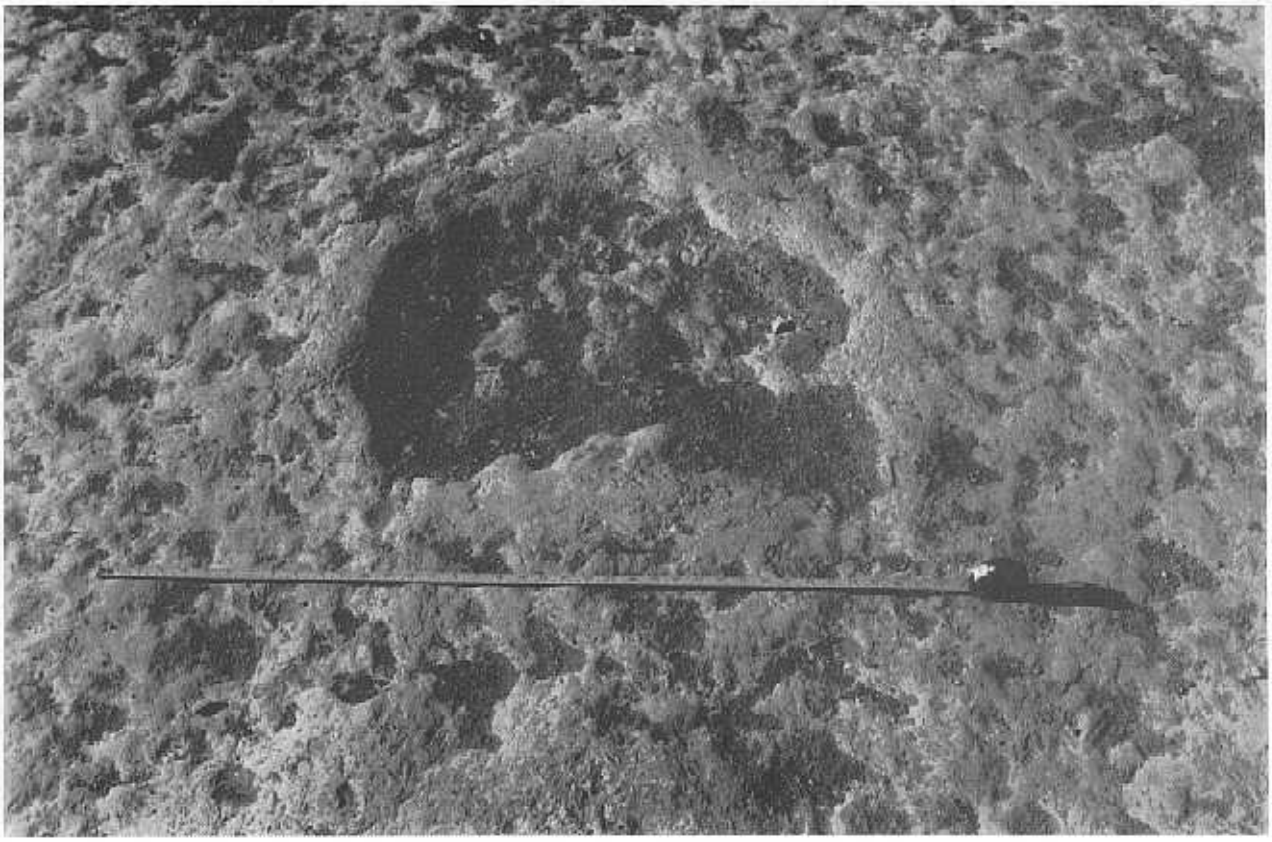

Fig. 7 - Photo of manus track with well developed impression of digit I (scale 1 m). Compare with Figure 6.

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