

A new dinosaur tracksite in the Lower Cretaceous of Portugal

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Abstract

Key-words: Dinosaur trackways; Lower Cretaceous; Aptian/ Albian; Olhos de Água; Óbidos; Portugal.

A new Lower Cretaceous (Aptian-Albian) dinosaur tracksite at the Olhos de Água beach is described. It is the first vertebrate fossil finding ever found in the concerned unit, and yielded 128 tracks in 17 trackways within an area of ca. 80 square metres. Three tridactyl footprint morphotypes have been recognized: - Type 1 ("Iguanodontipus-like") - trackways D, F, K, J and P; - Type 2 (large theropod), although larger in size, typically from a *Grallator*-like theropod footprint, i.e. A, B, G, H and O trackways; - Type 3 (medium size theropod); M is the only track of this type. There are other, poorly preserved, unidentified trackways. The theropod, swinging trackway B was produced by an animal that was limping. The theropod track M starts eastwards but drastically changes westwards, speeding up at the same time; this dinosaur decided to turn around and run in the opposite direction.

This site shows three main trackway directions: to the South, to the East, and westwards. Except for the trackway O, large theropods A, B, G and H walked southwards. Perpendicularly to these, ornithopods, small theropods and unidentified trackmakers walked towards East (5) and West (7). The segregation of trackmakers and directions, with large theropod trackways southwards and other dinosaurs' west or eastwards, may mean that large theropods patrolled a walkway area to an important resource, most probably water, often frequented by ornithopods and smaller theropods. There is no evidence of social behavior or gregarism: footprints' overposition shows that the large, southwards walking theropods passed on different occasions. Three trackway sequences can be established by chronologic order.

Resumo

Palavras-chave: Pistas de Dinossauros; Cretácico inferior; Aptiano/ Albiano; Olhos de Água; Óbidos; Portugal.

É descrita uma nova jazida de pistas de dinossauros no Cretácico inferior (Aptiano-Albiano) na praia de Olhos de Água, a primeira ocorrência de fósseis de vertebrados na Unidade estratigráfica em causa. Foram observadas 128 pegadas e 17 pistas numa superfície de ca. de 80 m², permitindo reconhecer três morfotipos de pegadas tridáctilas: - Tipo 1 ("Iguanodontipus") – pistas D, F, K, J e P; - Tipo 2 (Terópode de grande porte), pegadas típicas de terópode, semelhantes a *Grallator*, i.e. pistas A, B, H, H e O; Tipo 3 (Terópode de porte médio), representadas só na pista M. Além destas há algumas pistas mal conservadas, não identificadas. A pista B, de terópode, é sinuosa e foi produzida por um animal que coxeava. Outro caso interessante é o da pista M, dirigida de início para Este mas que muda drasticamente de direcção, para Oeste, ao mesmo tempo que o movimento se acelerou; o dinossauro decidiu virar-se e correr em sentido oposto.

Esta jazida evidencia pistas segundo três direcções principais: para Sul, para Este e para Oeste. Com a excepção da pista O, os grandes terópodes dirigiam-se para Sul (pistas A, B, G e H). Perpendicularmente a estas, há pistas de ornitópodes, pequenos terópodes e dinossauros não identificados dirigidas para Este (5) e para Oeste (7). A repartição segregada em grupos de pistas e de direcções (com pistas de grandes terópodes dirigidas para Sul e de outros dinossauros para Oeste ou para Este pode significar que grandes terópodes vigiavam áreas de acesso a um recurso importante, muito provavelmente água, frequentemente procurada por ornitópodes e terópodes de menor porte. Não há indícios de comportamento social ou de gregarismo; a sobreposição de pegadas mostra que os grandes terópodes que se dirigiam para Sul passaram em várias ocasiões. Foi possível caracterizar três sequências de pistas por ordem cronológica.

Introduction

Portugal is rich in dinosaur footprints. A new tracksite was discovered by António Miranda who reported it to the Museu da Lourinhã. The site is in the Lower Cretaceous beds at the Olhos de Água beach, Óbidos Municipality, central western Portugal (UTM-sector obtained by GPS: 0478262E, 4362995N). According to the Carta Geológica de Portugal 1:50.000 Folha 26-C (França *et al.*, 1960), the site concerns the Aptian-Albian unit "Complexo gresoso de Olhos Amarelos e Pousio da Galeota". This is the first fossil evidence of vertebrates ever found in this unit (Table 1).

Trackways, tracktypes and trackmakers

Currently, 128 footprints in 17 narrow-gauge trackways are exposed at the Olhos de Água site within an area of ca. 80 square metres (table 2). Three tridactyl footprint morphotypes numbered as Type 1, Type 2 and Type 3 have been recognized.

Type 1 (iguanodontid)

The trackways D, F, K, J and P are assigned to type 1. Medium to large sized tracks with wide and round digit marks.

Footprint size range: between 35 and 60 cm long and 35 to 42 cm wide.

Length/width of the footprint ratio: between 1 and 1.4.

The fingers are large, well-defined and separated, and ellipsoid in shape. Small claw prints are sometimes visible in all fingers. The angles between digits II-III and III-IV are nearly similar.

The "heel" print is curved. This results into the rounded shape of the hind part of the footprint.

The pace angle ranges between ca. 130 and 150°; the trackway is narrow-gauged.

The manus print is visible in the trackway D.

Although the claw prints are sometimes visible, the general shape is a typical of an "Iguanodon" track.

The morphotype is *Iguanodontipus* or *Caririchnium* that indicates an iguanodontid trackmaker (Sarjeant *et al.*, 1998).

Type 2 (large theropod)

Trackways A, B, G, H and O.

Elongate, medium and large size footprints with long, indented fingers with claw marks.

Length from 30 cm up to 38 cm and width between 24 and 27 cm.

The aspect ratio is between 1.2 and 1.4.

The angle between the digits II and III is smaller (ca. 20°) than between digits III and IV (ca. 30°). The morphology allows us to assign these footprints to theropods due to the angle between the digits, to the well marked ungueal phalanges, the longer than wide track, the well defined hind of the foot, the impression of each digit being separated from the others, and the well-visible claws and finger pads. The pace angle ranges between 160 and 178°. A well-defined track is 2 cm deep. There are no marks from digit I.

Although larger in size, the shape of these tracks is *Grallator*-like. The morphotype is *Grallator* or *Eubrontes*. The different between these genera has been motif of debate. According to Weems (1992) *Eubrontes* differ from *Grallator* by a footprint longer than 25 cm. The trackmaker is a large theropod.

Type 3 (medium theropod)

The trackway M is the only undoubtedly of this morphotype.

Small and medium footprints with narrow digits and well-defined claws.

The footprint is longer (25 cm) than wide (20 cm). The aspect ratio is about 1.25.

The digits are very narrow (the digit length is more than seven times its width) with well marked claws. The angles between the three fingers are nearly the same.

The "heel"-print is poorly visible or absent.

The pace angle is about 160°.

The elongation index, marks of the claws, and the long and thin toes allow the attribution to a medium size theropod.

Unidentified

The mostly poorly preserved trackways E, J, N and P are made by medium-sized ornithopods or theropods.

Table I

Lower Cretaceous dinosaur tracksites (by stratigraphic order) known in Portugal, including this new finding (*).

Site	Track maker	Age and Geological Unit	Reference
Olhos de Água (Óbidos) (*)	Theropoda and Ornithopoda	Aptian-Albian ("Complexo gresoso de Olhos Amarelos e Pousio da Galeota" Unit)	This study
Praia Grande do Rodízio (Sintra)	Theropoda, Sauropoda and Ornithopoda	Lower Aptian/ Bedulian	Madeira & Dias, 1983; Antunes, 1984; Santos, 1998: 10
Praia da Salema (Vila do Bispo)	Iguanodontid (one site) and small theropods (two sites)	Barremian	Santos <i>et al.</i> , 2000c
Praia Santa (Vila do Bispo)	Iguanodontidae	Barremian	Santos <i>et al.</i> , 2000c: 20
Lagosteiros (Sesimbra)	Theropoda, Sauropoda and Ornithopoda	Hauterivian ("Formação de Ladeiras" Unit)	Antunes (1976), Meyer <i>et al.</i> (1994), Santos <i>et al.</i> (1992)

The trackways C, I, L and N have most probably been produced by ornithopods while Q seems to be a theropod track. There are a few more poorly preserved and isolated tracks at the southwestern part of the site, in a surface much eroded by the sea.

Particularities and behaviour

The theropod trackway B was produced by an animal that has a pace length asymmetry, suggesting that it was limping. All the left foot steps are 1 to 30 cm shorter than the right steps. Besides that, this trackway is swinging while others are relatively straight (except for the theropod G that curves westwards and for M). The right/left pace asymmetry cannot be caused by tectonic deformation because it is observed only in the trackway B and along its whole length.

The theropod trackway M starts eastwards but drastically changes its direction westwards, to its right, speeding up at the same time. For some reason, this dinosaur (either predator or prey) decided to turn around and run (with longer strides) in the opposite direction.

This site shows three main trackway directions: south, east and westwards. Except for the theropod trackway O, large theropod trackways A, B, G and H trend southwards. Perpendicularly to these, ornithopods, small theropods and unidentified trackmakers walked towards the East (in 5 cases) and West (in 7).

This segregation of trackmakers and directions (large theropods southwards and other dinosaurs west or eastwards) may mean that large theropods patrolled a walkway area to an important resource, most probably

water, that also was often frequented by ornithopods and smaller theropods.

There is no evidence for social behavior or gregariousness. Footprints' superposition shows that the large, southwards walking theropods passed in different occasions, without apparent time order. Three temporal trackway sequences (named A to Q) can be established: L, A, P, H, B, F; M, B; and P, J, G (fig. 3).

Conclusions

1. A new Early Cretaceous (Aptian-Albian) dinosaur tracksite at the Olhos de Água beach is described. This is the first vertebrate fossil finding ever found in the concerned unit.

2. The Olhos de Água site yielded 128 footprints in 17 trackways within an area of ca. 80m².

3. Three tridactyl footprint morphotypes, described in the text, have been recognized:

- Type 1 (Iguanodontid), trackways D, F, K, J and P;
- Type 2 (large theropod), although larger in size, the elongate, medium and large size footprints with long, indented fingers with claw marks are typically from a theropod (*Eubrontes* morphotype), i.e. A, B, G, H and O trackways;
- Type 3 (medium size theropod), small and medium footprints with very narrow fingers and well-defined claws; M is the only track of this type. The elongation index, marks of the claws, and the long and thin toes allow us to ascribe it to a medium size theropod.

4. There are other, poorly preserved, unidentified trackways - E, J, N and P from medium-sized ornithopods or theropods, while the trails C, I, L and N seem to have been produced by ornithopods, and Q by a theropod.

Table 2

Metric data of the Olhos de Água tracksite.

The hip height (*h*) is estimated as four times the foot length, while the velocity (*v*) is given by the formula ($v=0,7826.SL^{1,67}.h^{-1,17}$) where SL is the stride length (Alexander, 1976; Lockley & Meyer, 1999: 5).

Trackway	Length (m)	No. of tracks	Possible trackmaker	Foot length (cm)	Foot width (cm)	Stride length (cm)	Step length (cm)	Pace angle (°)	Velocity <i>v</i> (m/s)	Height to the hip <i>h</i> (cm)
A	18,87	17	Theropod	39	31	232	118	178	1,9	156
B	18,02	19	Theropod	32	25	200	100	160	1,9	128
C	1,6	3	Ornithopod	30	30	160	81		1,4	120
D	2,6	4	Ornithopod	41	34	187	92	178	1,2	164
E	2,15	4	?	~30	~25	144	80	150	1,2	120
F	3,3	4	Ornithopod	50	41	220	123	120	1,3	200
G	13	12	Theropod	42	34	230	120	160	1,7	168
H	11,9	12	Theropod	35	27	220	110	150	2,0	140
I	6,2	8	Ornithopod	60	42	173	87	130	0,7	240
J	2,1	3	?	30	22	210	107	150	2,2	120
K	4,9	7	Ornithopod	35	35	152	93		1,1	140
L	3,25	6	Ornith. or Ther.	30	26	150	83	160	1,2	120
M	10	14	Theropod	25	19,5					100
N		3	Theropod?							
O	1,1	2	Theropod	47	49		110			188
P	2,05	3	Ornithopod							
Q	5,4	7	Theropod?							

5. The theropod, swinging trackway B was produced by an animal that was limping, all the left foot steps being shorter than the right ones; near all other trackways are relatively straight.

6. The theropod track M starts eastwards but drastically changes westwards, speeding up at the same time; this dinosaur decided to turn around and run in the opposite direction.

7. This site shows three main trackway directions to the South, the East and westwards. Except for the theropod trackway O, large theropods A, B, G and H walked southwards. Perpendicularly to these, ornithopods, small theropods and unidentified trackmakers walked towards today's East (5 trackways) and West (7).

8. The segregation of trackmakers and directions, with large theropod trackways southwards and other dinosaurs' west or eastwards, may mean that large theropods patrolled a walkway area to an important resource, most probably water, that also was often frequented by ornithopods and smaller theropods.

9. There is no evidence of social behavior or gregariousness.

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Fig. 1 - Tracksite at Olhos de Água, Óbidos Municipality. Top view.

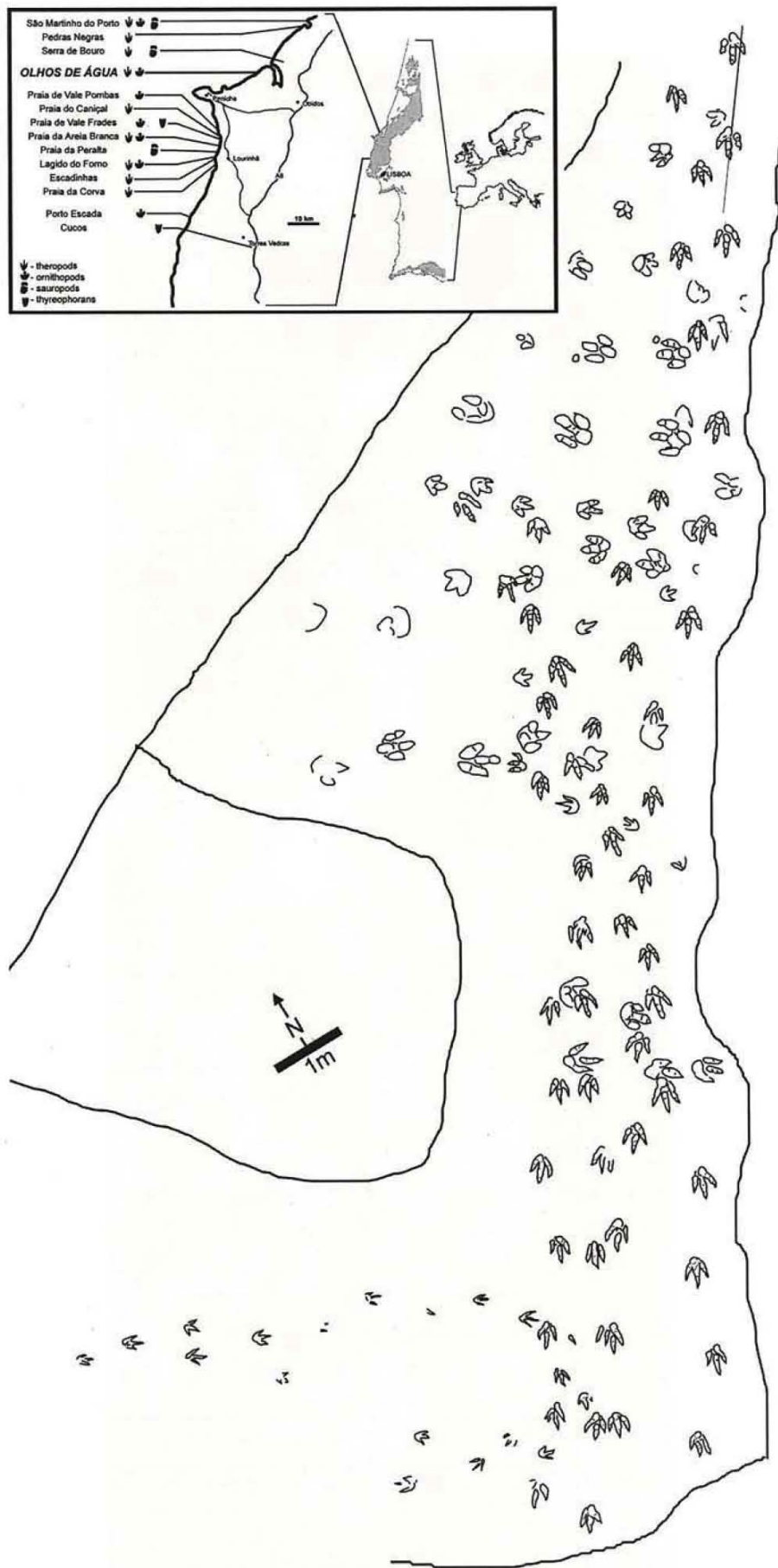


Fig. 2- Map of the Olhos de Água tracksite.

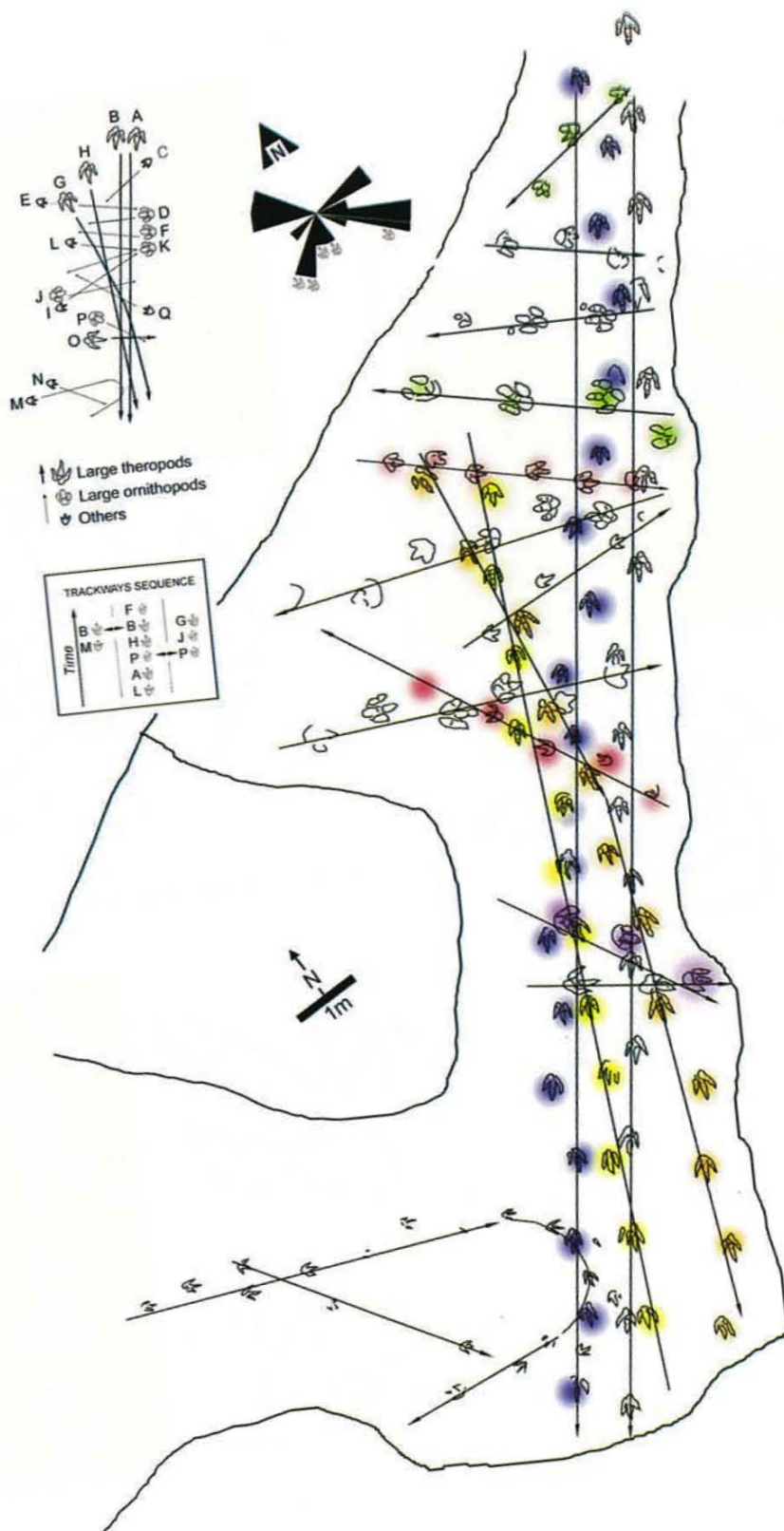


Fig. 3- Interpretative map of the Olhos de Água tracksite. The small insets show the trackways A to Q. The rose diagram concerns trail directions and the overstep time sequence.

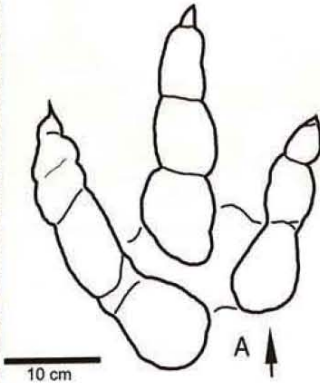
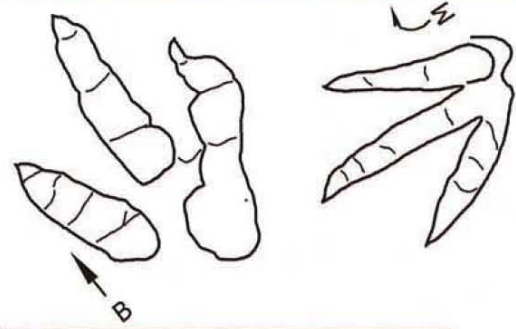
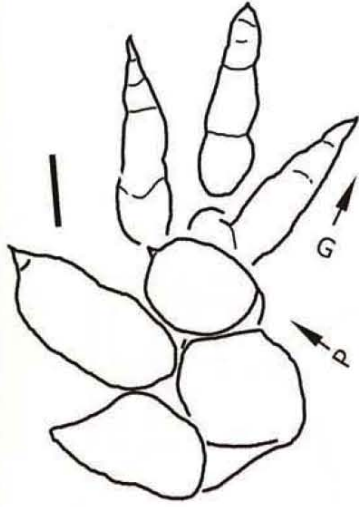


Fig. 4- Some tracks at the Olhos de Água site. The letters identify the corresponding track.

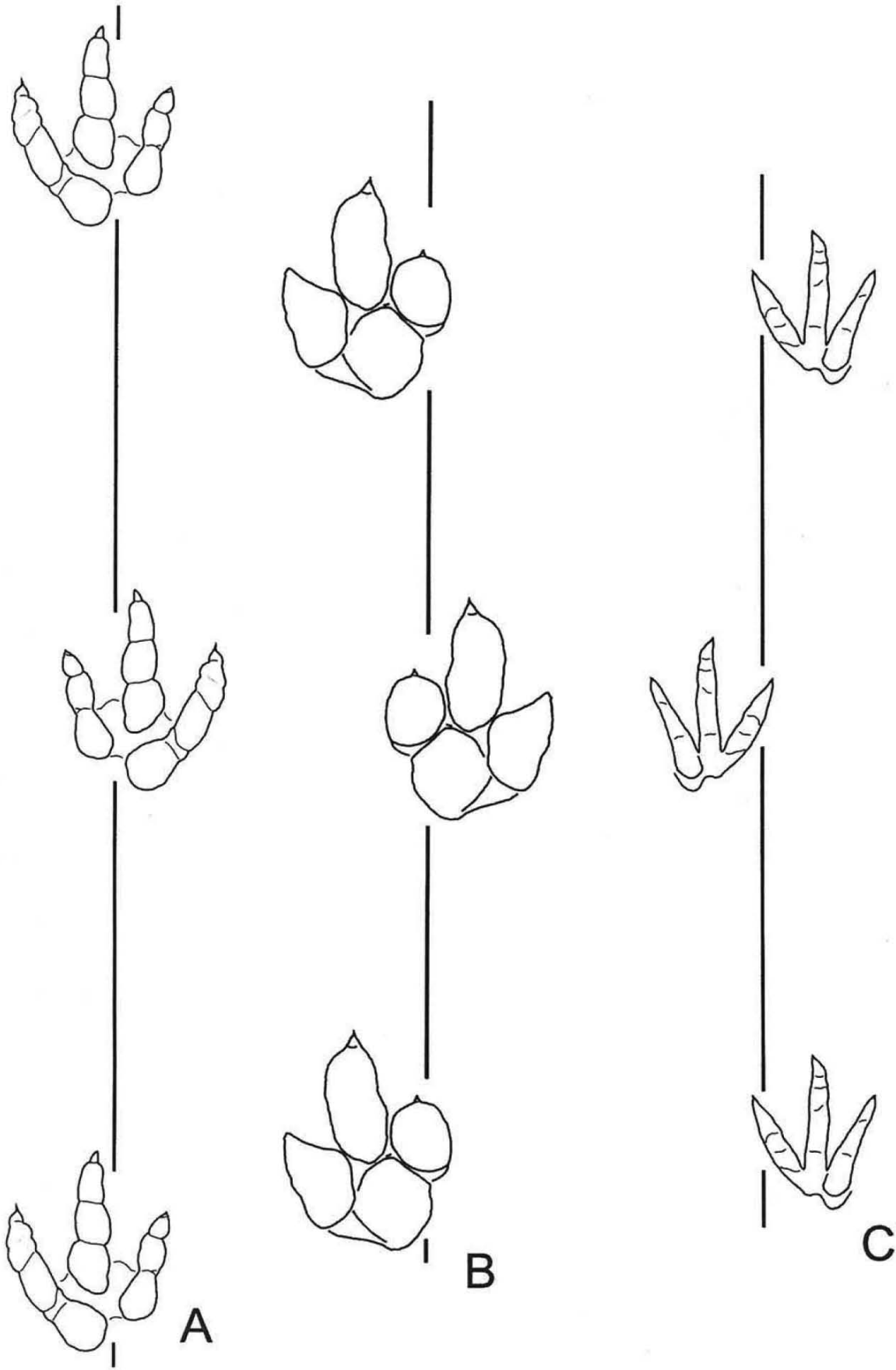


Fig. 5- Tracks at the site: A- large theropod, B- iguanodontid, and C- medium-sized theropod (same scale).