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First record of *Otozoum* from Namibia

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The first incontrovertible *Otozoum moodii* of Gondwana is described from the Etjo Formation (Waterberg Plateau, Namibia). Distinct *Otozoum* trackways and isolated footprints are reported from the Omuramba Omambonde tracksite, in the Otjozondjupa Region (North–central Namibia). Previously known only from North America, Europe and possibly Lesotho, the occurrence of *Otozoum* is a definitive time constraint for an Early Jurassic age of the Etjo Formation. The presence of *Otozoum* in the hyperarid facies and specifically in interdune setting of the Etjo Formation is in accordance with previous claims of environmental selectivity for this ichnomorph. □ *Etjo Formation, Gondwana, Lower Jurassic, Namibia, Otozoum.*

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The dinosaur track record of Namibia is poorly known, even though it has been investigated from time to time by specialists and amateurs (von Huene 1925; Gürich 1926; Heinz 1932; Wiechmann 1983; Pickford 1994, 1995; Pickford & Senut 2002). The Otjihaenamaparero tracksite is the only one in Namibia that has been described in paleontological literature (von Huene 1925; Gürich 1926; Heinz 1932) and that appears in compilations attempting to summarize the worldwide record of dinosaur localities (Weishampel 1990; Weishampel *et al.* 2004). Nonetheless, reports of other tracksites have been published in non-technical journals. About thirty years ago, Wiechmann (1983) reported in a local newspaper about a fossil trackway at the Omuramba Omambonde locality north of the Waterberg Plateau (Fig. 1), which was originally discovered by the Portuguese Fernando Palla Apperte in 1976. Wiechmann (1983) gave a preliminary description of the footprints, albeit no ichnotaxonomic labelling and no zoological attribution was attempted by the author. Martin (1984) recognized the importance of this material, but he did not publish further on this matter. The presence of fossil footprints in the area was successively listed by others (Pickford 1995; Holzförster *et al.* 1999; Wanke 2000) and attested by Grote (1984) who actually documented in more detail the tracksite in an unpublished report for the Namibian Geological Survey. Also in this case, no ichnotaxonomic statement and no specific attribution to a trackmaker were given.

In this work, we analyse in detail the material originally discovered by F. Palla Apperte and we acknowledge the importance of his find, comparing the material to similar forms known worldwide and evaluating its ichnotaxonomic position and biostratigraphical significance.

Geological setting

The Karoo Supergroup crops out widely in Namibia. At least five large basins recorded Karoo *sensu strictu* (Catuneanu *et al.* 2005) sediments (namely the Karasburg, Aranos, Waterberg, Huab and Owambo Basin), both in the north and in the south of Namibia. Topographically, younger units of the Karoo Supergroup have a distinct physiographic mark on the territory, and they appear as plateaus emerging for hundreds of metres above surrounding lowlands. This is the case for the Großer Waterberg Plateau and its minor relatives (e.g. 'Kleiner Waterberg'). In the Waterberg Basin, two main lithostratigraphic units recorded the Mesozoic Karoo sequence: the older Omingonde Formation and the younger Etjo Formation. The former has been partly correlated (Pickford 1995; Smith & Swart 2002) with the *Cynognathus* B zone of the Beaufort Group and is considered as Early Triassic to early Middle Triassic in age (Smith & Swart

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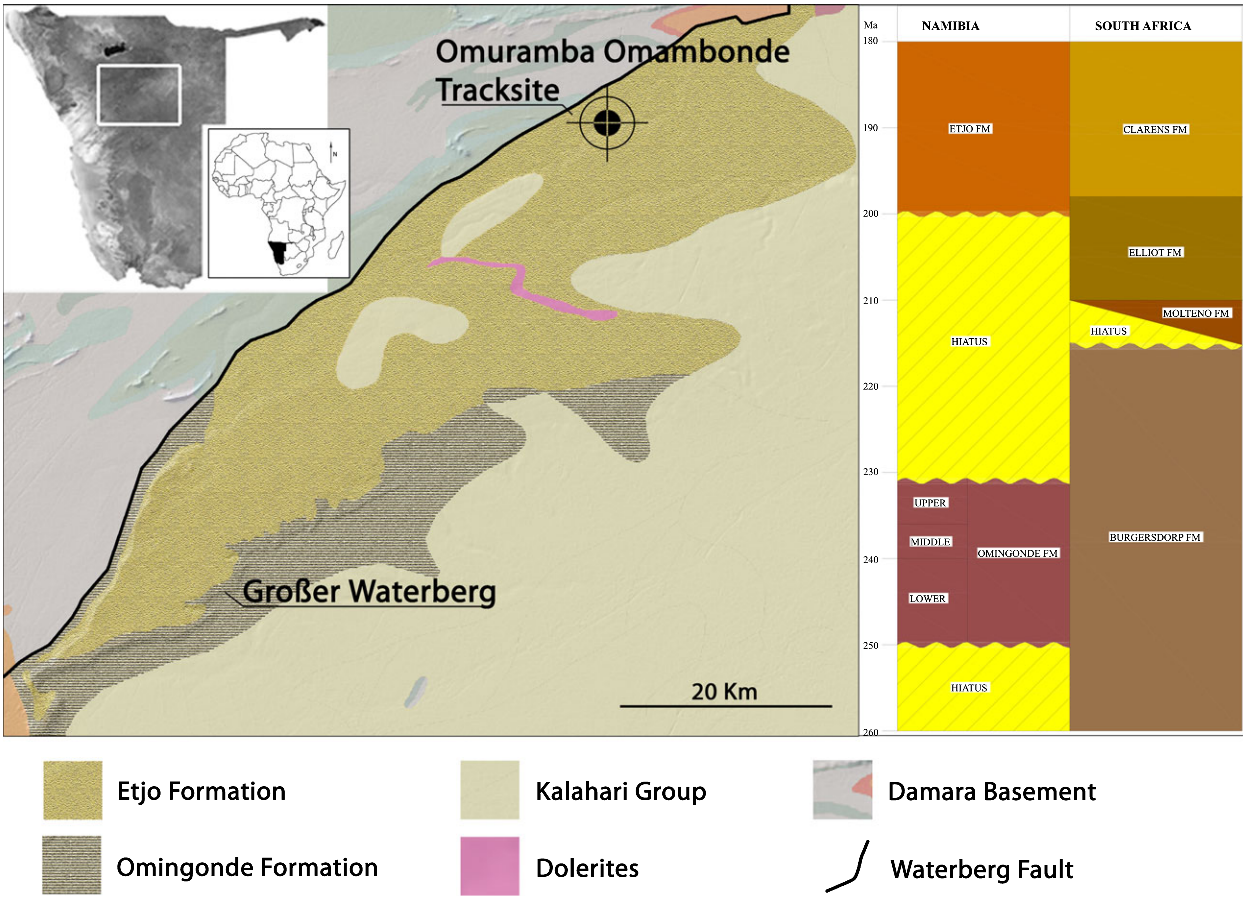

Fig. 1. Location of the study area (left side). Black pointer pinpoints the tracksite position. Base map generated in GeoMapApp 3.3.8 (http://www.geomapapp.org; Ryan *et al.* 2009) with the Etjo Fm and the Omingonde Fm highlighted. To the right, stratigraphy of the Waterberg area compared to the upper Karroo units from South Africa, adapted from Smith & Swart 2002 and Holzförster *et al.* 1999.

2002), with highest units being equivalent to the Burgersdorp Formation of South Africa and Lesotho.

The Etjo Formation in the Waterberg Basin is considered to be equivalent to the Clarens Formation of Southern Africa (Holzförster *et al.* 1999). The Etjo sequence is about 140 m thick in the Waterberg Basin (Holzförster *et al.* 1999) and disconformably overlies the Omingonde Fm (Wanke 2000) from which it is chronologically separated by a ~35 My hiatus (Smith & Swart 2002). Sedimentologic features of the Etjo Fm are characteristic of semiarid facies, punctuated by ephemeral lakes, to some extent similar to the current physiography of the modern Kalahari Desert, evolving towards drier, hyperarid conditions up-section (Holzförster *et al.* 1999). This sequence of facies enabled Holzförster *et al.* (1999) to divide the Etjo Fm into three informal units (lower, middle and upper members).

The Waterberg Plateau dips gently towards NE and its height decreases constantly moving eastward. The Omuramba Omambonde tracksite is located northeast of the borders of the Waterberg National Park, where the Etjo Formation is more or less at the same elevation of the surrounding area. At the tracksite area, the most prominent geological features are eroded pillars of the Etjo Formation, a few metres high (Fig. 2A). The tracked surface belongs to a decimetric sandstone body, which is less erodible than the enclosing sandstone beds and tends to form large terraces in the study area (Fig. 2B). The track-bearing layer rests with a clear first-order bounding surface over a set of high-angle cross-bedding strata (Fig. 2C) and is composed of different sets of *laminae* with a very low angle of stratification (Fig. 2D) interpreted here as interdune deposits. The sandstone is reddish in colour, and the tracked layer is comprised of homogeneous, well-sorted grains.

Detailed stratigraphical correlation with tracksites at the Otjihaenamaparero Farm 92 and at the Waterberg National Park is beyond the scope of this study and will be investigated elsewhere (Wagensommer, A., Latiano, M., Mocke, H.B. & D'Orazi Porchetti, S. in prep). According to Holzförster *et al.* (1999),

Fig. 2. A, pillars are the most prominent geological features in the study area; human for scale (180 cm). B, detail of the outcropping sequence. The high-angle cross-bedding sandstone is much erodible than the tracked layer, which forms the terrace (black arrow) where footprints have been found. Hammer for scale (within the white circle). C, detail of the first-order bounding surface (white arrow); hammer for scale (within the white circle). D, detail of the tracked layer, very thin laminae in two successive generations are interpreted as translatent strata. Camera lens cap for scale (58 mm).

dinosaur tracks all occur in the uppermost unit of the Etjo Formation, and this assumption is retained here, pending further analysis. The Omuramba Omambonde tracksite is associated with abundant sets of cross-strata. This architectural pattern has been recognized by Holzförster *et al.* (1999) as being exclusive of the upper unit of the Etjo Fm and related to the hyperarid facies of aeolian dunes. *Otozoum* therefore occurs in the uppermost member of the Etjo Formation.

Materials and methods

Some issue concerns the correct naming of the locality. Originally designated as Omuramba Omambonde by Wiechmann (1983), the author himself reports that the river running close to the site was also known as Omuramba Ondegaura in the recent past, but that this name is no longer used. Local farmers at the Guest Farm Kamrav (about 1 km from the site) know the river under a different name, Omuramba Omatako. Apparently, local toponymy is not stable even in the short term of a few decades. We chose to indicate the site with the name adopted by Wiechmann (1983) and recommend the consistent use of the designation Omuramba Omambonde to avoid confusion.

The material consists of 32 footprints (Fig. 3A, B), partly isolated but for the most part recognizable as components of trackways. We counted five trackways, the longest with 21 footprints (12.5 m) records southwestward locomotion (Fig. 4). The outcrop is about 40 square metres; geographical coordinates are reported in Table 1.

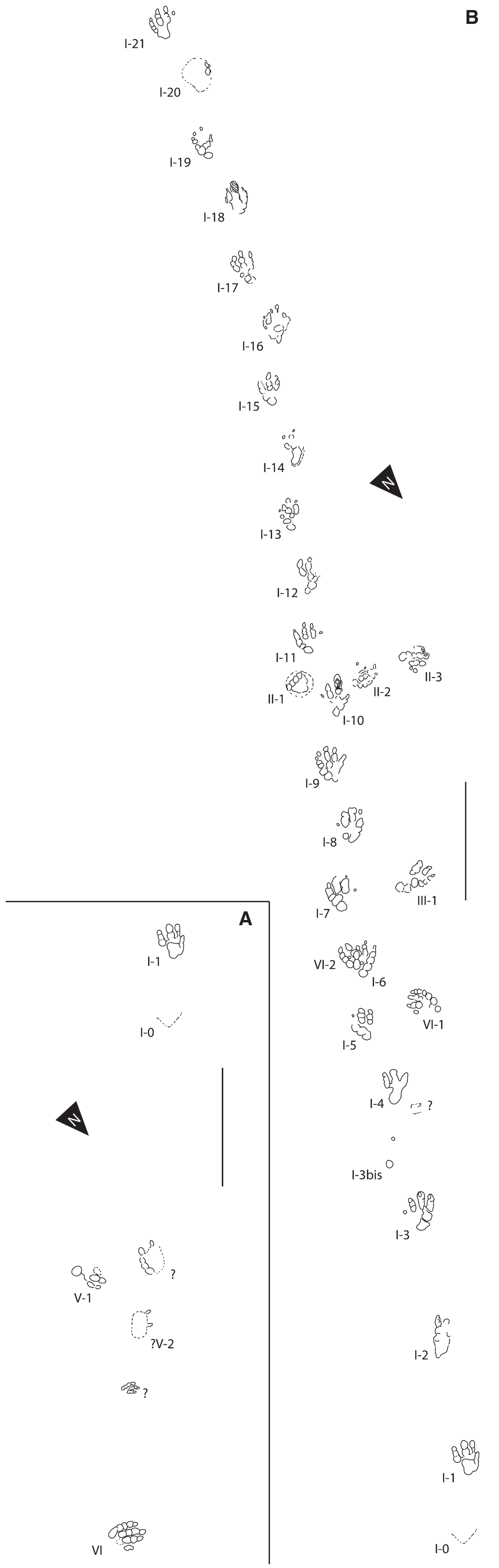

Fig. 3. Schematic drawing of the tracked surface at Omuramba Omambonde. The trackway is divided in two portions A, B for graphic reasons. Footprints OMO-I-0 and OMO-I-1 are repeated to allow reconstructing the entire trackway. Scale bar is 100 cm.

Fig. 4. Photograph of the main trackway from footprints OMO-I-3 on. The animal was moving towards Southwest. Hammer for scale.

The material is labelled with the acronym OMO (Omuramba Omambonde) followed by a roman number indicating the trackway and an Arab number representing the position inside the trail (e.g. OMO-I-1). Isolated footprints are labelled by roman numbers only (see Tables 1, 2 for details). Footprints were reproduced by hand drawing on a transparent foil of acetate film and photographed singularly. Linear measurements have been taken in the field, whereas angular values (i.e. pace angulation) were obtained from scaled reproduction of the trackways. Photogrammetry on selected footprints (Fig. 5) was performed with a 10.0 megapixel Olympus E-520 reflex camera following the methodology described by Falkingham (2012). Silicon/plaster cast of selected specimens (OMO-I-3; I-8; I-9; I-21) have been produced and are now stored at the Museum of the Geological Survey of Namibia under the repository numbers F1220; F1221; F1222; and F1223. Footprints are generally shallow, and the quality of preservation is sub-optimal. No skin impressions have been observed. The material, based on historical reports, has been exposed at least since

Table 1. OMO-I database. Measurements are in cm where not directly stated.

Locality	OMURAMBA OMAMBONDE	GPS coordinates	19°59′11.6″ S/17°46′28.8″ E
Acronym	OMO-I-1	Trackway orientation	SW 210°
Date	9 July 2013	Trackway Length	12.5 m

Num	Tot L	Tot W	Footprint orientation	Stride	cm	Pace	cm	Pace angulations
N 1	29	22.5	205°	1 to 2	107		n/a	n/a
N 2	?32.5	n/a	215°	2 to 3	105		n/a	n/a
N 3	33	27	210°	3 to 4	107		n/a	n/a
N 4	30	?21.5	210°	4 to 6	111	4 to 5	58	148.10°
N 5	28	?18	210°	5 to 7	112	5 to 6	57.5	153.98°
N 6	31	24	225°	6 to 8	112	6 to 7	60	144.83°
N 7	31	25	195°	7 to 9	111	7 to 8	60	142.41°
N 8	30	22	215°	8 to 10	114	8 to 9	57	148.56°
N 9	?32	26	200°	9 to 11	109	9 to 10	63	136.83°
N 10	?35	?24.5	220°	10 to 12	104	10 to 11	53	140.22°
N 11	27.5	25	215°	11 to 13	108	11 to 12	57	156.99°
N 12	32.5	n/a	220°	12 to 14	109	12 to 13	53.5	157.98°
N 13	28	?18	220°	13 to 15	109	13 to 14	59	156.07°
N 14	?31	n/a	215°	14 to 16	108	14 to 15	54	154.57°
N 15	?29	?18.5	210°	15 to 17	107	15 to 16	59	148.35°
N 16	n/a	n/a	n/a	16 to 18	109	16 to 17	55	157.08°
N 17	27	?20	210°	17 to 19	109	17 to 18	58	152.95°
N 18	n/a	n/a	220°	18 to 20	106.5	18 to 19	55	148.10°
N 19	28	?17	215°			19 to 20	59	153.98°
N 20	n/a	n/a	n/a			20 to 21	51	n/a
N 21	?28	25	210°					
Average	29.6	24.6			108.7		57	149.92 (dv st 6.83)

Table 2. Data on trackways OMO-II to V and isolated footprint (OMO-VI). Measurements are in cm where not directly stated.

Footprint	Length (cm)	Width (cm)	Orientation
OMO-II-1	n/a	n/a	n/a
OMO-II-2	n/a	n/a	n/a
OMO-II-3	26.5	?23	310°
OMO-III-1	34.5	19	265°
OMO-III-2	n/a	n/a	n/a
OMO-IV-1	34.5	19	140°
OMO-IV-2	n/a	n/a	n/a
OMO-V-1	30.5	17.5	320°
OMO-V-2	n/a	n/a	300°
OMO-VI	32	24	285°

the mid 1970s and has undergone a certain degree of deterioration. No expulsion rims have been noticed on the surface. We cannot state beyond any doubts if these actually are true tracks or just undertracks. In any case, the material allowed defining a precise morphological pattern on several footprints.

Discussion

The material shows the following features: four functional digits oriented forward. Digit I is the shortest and is usually represented by a single round mark, possibly left by the claw touching the sediment. In some cases, a second proximal pad is present. Digit II is usually isolated and made by two pad traces associated with a claw mark. Digit III is the foremost in terms of anterior extension and shows three pads and a clear claw print. Digit IV is as long as or slightly shorter than digit III and is made of a sequence of four pads and a claw mark. A coalesced metatarsal–phalangeal pad lies close to the proximal end of digits III and IV. A basal roundish pad is the posterior-most mark of the print and is supposed to be in relation to a vestigial digit V. Digit II–IV are slightly bent inward, and pads are usually elliptical with the long axis being orthogonal to digit shafts. The stride is short (mean 108.7 cm) and the pace angle relatively high (mean 150°). Foot length is on average 29.6 cm, and the mean width is 24.6 cm (see Table 1 for details). These footprints are labelled as *Otozoum moodii* on the basis of the following diagnostic features: pentadactyl, digitigrade *pes* with four functional digits (I–IV) oriented forward and distal portion of digit V impressed at the rear of the footprint. Well-padded sub-parallel digits (group II–IV), digit III dominant and digit IV slightly bent inward. Metatarsal–phalangeal pads of digits III and IV coalesced to form a single, rounded pad. Homologies with the original material described by Hitchcock (1847) and revised by Rainforth (2003) are striking, and the dimensions are well within the variation of the material referred to the holotype (Rainforth 2003).

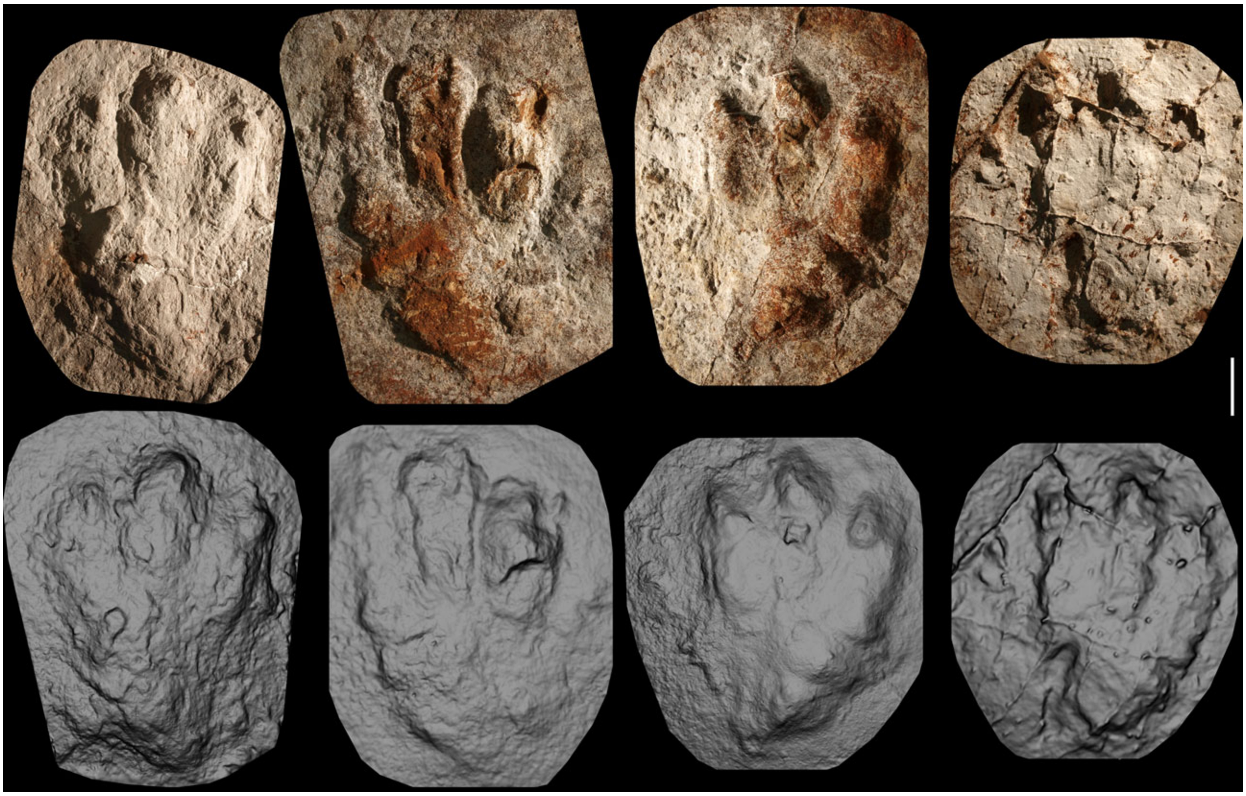

Fig. 5. Upper line, from left to right, specimen casts OMO-I-3 (left foot), I-8 (left foot), I-9 (right foot) and I-21 (right foot). Lower line, 3D reconstruction based on field and museum photographs following the methodology described by Falkingham (2012). Close range photogrammetry helps visualizing footprint volume. Digit IV is deeply impressed in all footprints, whereas digit one is usually very shallow. Scale bar 58 mm.

Otozoum is described as a functionally tetradactyl bipedal footprint, with a vestigial fifth digit covered by a rounded basal pad, occasionally showing *manus* prints (Rainforth 2003). According to Rainforth (2003), *Otozoum* is restricted to the Lower Jurassic of North America (Massachusetts, Connecticut, Nova Scotia, Arizona and Utah) and Southern Africa (Lesotho). A European occurrence from the Zagaje Formation (lower-middle Hettangian, Lower Jurassic) of the Holy Cross Mountain (Poland) is reported by Gierliński & Niedźwiedzki (2005) at the lower Gromadzice site, in delta plain deposits. Recent re-evaluation of the record from the American Southwest attested the presence of *Otozoum* in Wyoming (Lockley 2011; Lockley *et al.* 2011). Five parallel *Otozoum* trackways are described (Lockley *et al.* 2004) from the upper portion of the Wingate Formation (Gateway area, Colorado). Lockley *et al.* (2011) report on a single *Otozoum manus–pes* set at the Bear Lake locality, Idaho, the second specimen from the American Southwest with an associated *manus* print known so far (the other specimen is from the Navajo Sandstone near Moab, Lockley *et al.* 2006). The distribution in time and space of *Otozoum* is summarized in Table 3.

The *manus* trace in *Otozoum* has been repeatedly investigated as a useful feature for trackmaker identification (Olsen & Galton 1984; Thulborn 1990; Farlow 1992; Gierliński 1995), but it is very rarely present in the record. Depending on the authors, it has been interpreted as a tetradactyl (Rainforth 2003) or pentadactyl print (Hitchcock 1858; Lockley *et al.* 2006). Even if some smaller prints are preserved on the surface at Omuramba Omambonde (Fig. 3), none of these can be confidently interpreted as a fore foot print and the tracks appear to be exclusively made by *pes*.

The occurrence of *Otozoum* in southern Africa was debatable prior to the discovery of the Namibian material, although other functionally tetradactyl ichnites are known from Lesotho (Ellenberger 1970, 1972). Its formal presence in the Clarens Formation of Lesotho is linked to a taxonomic issue on a small bipedal trace named *Kalosauropus* (Fig. 6) by Ellenberger (1970) but never described properly by this author. Hence, *Kalosauropus* was by many authors considered as a *nomen nudum* (Nicosia & Loi 2003; Rainforth 2003). Rainforth (2003) proposed to synonymise *Kalosauropus* with *Otozoum*, thus expanding the distribution of this ichnotaxon to southern

Table 3. Distribution and facies relationships of *Otozoum*. Asterisk for the type specimen and small circle for the topotype (after Rainforth 2003). Apex (#): here, we adopted Rainforth's interpretation on the number of digits in AC5/14. All data, except for the material described herein are reported as from the original study, credits are in the reference section of the table.

Material	Taxonomy	Locality	Age	Stratigraphy	Lithology	Facies	Climatic setting	References	Notes
YPM-2046; -3410; -56115	*Otozoum moodii*	Horse Race Gill, MA (USA)	Hettangian	Turner Falls Fm	Siltstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
YPM2100	*Otozoum moodii*	Canal, Montague, MA (USA)	Hettangian	Turner Falls Fm	Siltstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
AC6/3; AC4/2; -/3; -/4; -/5; YPM3411;	*Otozoum moodii*	Ferry, Turner Falls, MA (USA)	Hettangian	Turner Falls Fm	Siltstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
HPHS; WU183; -556; DSPWU680; -725; -2011; YPM2101a; -2101b; -2101c; -3412;	*Otozoum moodii*	?Brownstone quarries, Portland, CT (USA)	Hettangian	Portland Fm	Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
AC 3/1; -4/1a*; -4/1b; -5/1; -5/13; -5/14°	*Otozoum moodii*	Moody homestead, South Hadley, MA (USA)	Hettangian	Portland Fm	Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	AC 5/14° manus (4# digits)
WU595	*Otozoum moodii*	Middlefield, CT (USA)	Hettangian	?Portland Fm	?Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
DC72	*Otozoum moodii*	South Hadley, MA (USA)	Hettangian	?Portland Fm	?Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
DC44	*Otozoum moodii*	Connecticut Valley, CT (USA)	Hettangian	n/a	n/a	n/a	n/a	Rainforth (2003)	
MCZ244	*Otozoum moodii*	Connecticut Valley, CT (USA)	Hettangian	Portland Fm	?Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
FGM998GF53; NSM986GF17.1	*Otozoum moodii*	McKay Head, NS (CANADA)	Hettangian	McCoy Brook Fm	Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
YPM8669	*Otozoum moodii*	Blue Sac, NS (CANADA)	Hettangian	McCoy Brook Fm	Sandstone	Lake margins, fluvial/alluvial systems	Arid	Rainforth (2003)	
MWC181.10; -181.11; -181.25; -184.40; CU 184.41	*Otozoum moodii*	Moab, UT (USA)	?Early Pliensbachian, Late Toarcian	Navajo SS	Sandstone	Aeolian	Hyperarid	Rainforth (2003)	CU 184.41 manus (5 digits)
n/a	*Otozoum* isp.	Wyoming (USA)	?Early Pliensbachian, Late Toarcian	Navajo SS	Sandstone	Aeolian	Hyperarid	Lockley *et al.* (2011)	
n/a	*Otozoum* isp.	Bear Creek County, ID (USA)	?Early Pliensbachian, Late Toarcian	Navajo-Nugget SS (Glen Canyon SS)	Sandstone	Aeolian	Hyperarid	Lockley *et al.* (2011)	Manus (? digits)

(continued)

Table 3. (continued)

Material	Taxonomy	Locality	Age	Stratigraphy	Lithology	Facies	Climatic setting	References	Notes
Dino 15652	*Otozoum isp.*	Dinosaur National Monument, UT (USA)	?Early Pliensbachian, Late Toarcian	Navajo-Nugget SS (Glen Canyon SS)	Sandstone	Aeolian	Hyperarid	Lockley (2011)	
CU-MWC 177.18	*Otozoum* isp.	Gateway, CO (USA)	Early Sinemurian	Wingate Fm	Sandstone	Aeolian	Hyperarid	Lockley *et al.* (2004)	
UM2LES232 series; -LES233; -LES234	*Otozoum pollex*	Leribe (LESOTHO)	?Hettangian-Sinemurian	Clarens Fm	Sandstone	Aeolian	Hyperarid	Rainforth (2003)	
Muz. PIG 1560.II.66	*Otozoum* cf. *pollex*	lower Gromadzice site, Holy Cross Mt, (POLAND)	lower-middle Hettangian	Zagaje Fm	Siliciclastic	delta plain deposits	n/a	Gierliński & Niedźwiedzki (2005)	
MMGSN-OMO-I series	*Otozoum moodii*	Omuramba Omambonde (NAMIBIA)	Lower Jurassic	Etjo Fm	Sandstone	Aeolian	Hyperarid	This study	

Institutional abbreviations – AC, Hitchcock Ichnology Collection, Pratt Museum of Natural History, Amherst College, Amherst, Massachusetts, USA; CU-MWC, Museum of Western Colorado, Grand junction, Colorado, USA; DSP, Dinosaur State Park, Rocky Hill, Connecticut, USA; FGM, Fundy Geological Museum, Parrsboro, Nova Scotia, Canada; HPHS, Hartford Public High School, Hartford, Connecticut, USA; MCZ, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA; MMGSN, Ministry of Mines – Geological Survey of Namibia, Windhoek, Namibia; Muz. PIG, Geological Museum of Polish Geological Institute in Warsaw, Poland; NSM, Nova Scotia Museum of Natural History, Halifax, Nova Scotia, Canada; UM2, Laboratoire de paléontologie de l'Université de Sciences et Techniques du Languedoc (Université de Montpellier II), Montpellier, France; WU, Wesleyan University, Middletown, Connecticut, USA; YPM, Peabody Museum, Yale University, New Haven, Connecticut, USA.

Africa, a proposal successively criticized (Lockley *et al.* 2006; Lockley & Lucas 2013) based on specific characters of the footprint. However, there is a strong resemblance in shape between *Otozoum* and *Kalosauropus*, as they both share the I–IV digit group facing forward, a metatarsal–phalangeal pad coalesced for the third and fourth axes, a rounded basal pad representing the posterior region of the footmark. *Otozoum moodii* and *Otozoum* (*Kalosauropus*) *pollex* are coeval, according to independent dating of the Clarens Formation (Olsen & Galton 1977). Other tetradactyl and bipedal tracks, especially those named *Pseudotetrasauropus* are considered as either badly preserved *Brachychirotherium* traces (Olsen & Galton 1984; Rainforth 2003; Klein *et al.* 2006) or an independent ichnotaxon (Lockley *et al.* 2006; D'Orazi Porchetti & Nicosia 2007), but in any case morphologically distinguishable from *Otozoum*. Additionally, the purported age of the units in which these tracks are preserved is considered as Late Triassic (Lower Elliot Formation).

So far, the strongest age constraint to the Etjo Formation was based on the purported presence of *Massospondylus* in the Großer Waterberg (Holzförster 1999; Holzförster *et al.* 1999). The find consists of a block of sandstone containing casts of bones of a portion of the skeleton, but this material lacks any formal description at present. Dinosaur tracks have been tentatively adopted to constrain the relative age of the Etjo Formation, and the tridactyl dinosaur tracks from the Otjihaenamaparero 92 Farm were compared (Löffler & Porada 1998; Stanistreet & Stollhofen 1999) to some ichnites from Lesotho (*Quemetrisauropus princeps* and *Prototrisauropus crassidigitus*), originally described by Ellenberger (1972). The unrevised material from Lesotho is rather problematic under the ichnotaxonomic aspect (see Olsen & Galton 1984), and it is of limited help in biostratigraphic terms. The status of the Namibian tridactyl footprints in terms of trackmaker attribution and ichnotaxonomic labelling was in need of revision as well. A complete re-evaluation of this material has been carried out by the authors, and results are discussed elsewhere (Wagensommer, A., Latiano, M., Mocke, H.B. & D'Orazi Porchetti, S., in prep). The paternity of *Otozoum* has been extensively discussed by several authors, and many affinities have been proposed so far. A sauropodomorph origin (Prosauropoda *sensu* Yates & Kitching 2003) is commonly assumed (Rainforth 2003; Mallison 2010; Lockley 2011), but other putative trackmakers have been identified among ornithischian ornithopods (Thulborn 1990), basal ornithischian (*Scelidosaurus*) (Gierliński 1995) or even crurotarsans (Baird 1980; Haubold 1984, 1986;

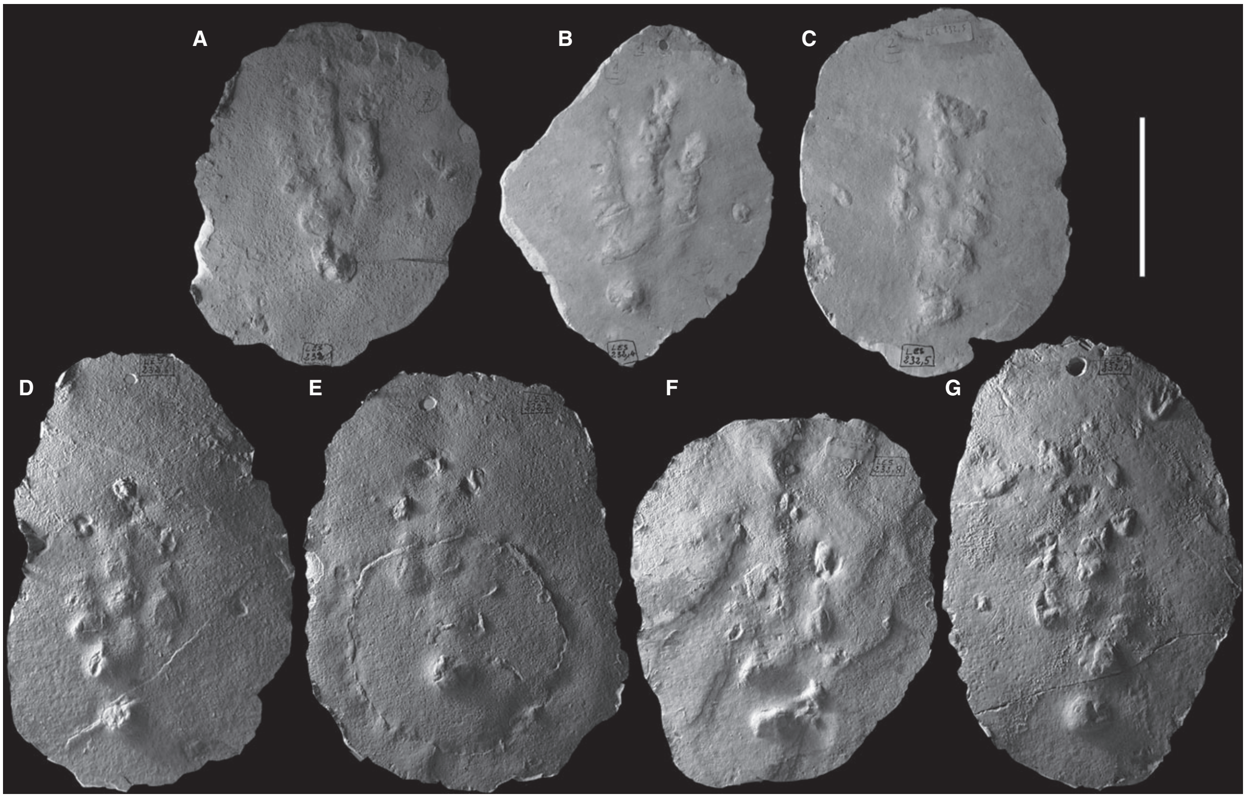

Fig. 6. Moulds of the trackway sequence (7 steps) of *Otozoum* (*Kalosauropus*) *pollex* (ex var. *victor*). A, UM2-LES 232,1. B, UM2-LES 232,4. C, UM2-LES 232,5. D, UM2-LES 232,6. E, UM2-LES 232,7. F, UM2-LES 232,8. G, UM2-LES 232,9 from the Ellenberger Collection at the Laboratoire de Paléontologie de l'Université de Sciences et Techniques du Languedoc (Université de Montpellier II), Montpellier, France. Scale bar 10 cm.

Olsen & Galton 1984; Olsen & Padian 1986). No further hypothesis is presented here, as far as the evaluation of *Otozoum* origins is beyond the scope of this study.

It is otherwise understood that *Otozoum* is a reliable biochronologic marker. Its oldest occurrence is in fact from the Hettangian of the Newark Supergroup and possibly in Poland, whereas the youngest unit to yield *Otozoum* is possibly the Navajo Sandstone that is considered as ?Early Pliensbachian to Late Toarcian in age. The presence of *Otozoum moodii* in the Etjo Formation is therefore the most reliable evidence for a Lower Jurassic age of this unit.

Otozoum is recurrent in arid paleoenvironments (Lockley & Hunt 1995; Rainforth 2003; Lockley *et al.* 2004). A large amount of the current record of *Otozoum* is from hyperarid desert environments dominated by aeolian sand dunes, and inside this facies, it seems to be specifically linked to interdune settings (Lockley 2011). The absence of *Otozoum* from the lee faces of dunes has been interpreted by Rainforth (2001) as a result of a taphonomic process in which footprints would suffer erosive processes after self-induced sand avalanches. Loope (2006), however, describing deep *Otozoum* traces from leeward faces of dunes at Coyote Buttes (Navajo Sandstone, Arizona-Utah border, USA), provided evidence against the negative preservational potentialities of large tracks on the lee faces of dunes. In Namibia, *Otozoum* occurs in a interdune area and even if the record from the Etjo Formation is far from being statistically significant, it is a fact that the Omuramba Omambonde *Otozoum* was found in this specific sub-environment, reinforcing an apparent selectivity for these ichnites in the larger framework of erg settings.

Conclusions

The Mesozoic Karoo sequence in Namibia has great potential in terms of fossil footprints content. Arid and hyperarid facies of the Etjo Formation have long been known for the presence of dinosaur footprints. Among them, the Omuramba Omambonde locality yielded an unrecognized abundant record of *Otozoum moodii*. This ichnotaxon is well-known in the Northern Hemisphere, but its presence in Gondwana was doubtful prior to this discovery. The temporal distribution of *Otozoum* is limited to the

Early Jurassic and it is therefore a reliable constraint to the age of this unit. The upper member of the Etjo Formation represents a hyperarid environment, actually an aeolian sand dune field. The recurrence of *Otozoum* in such a setting is in accordance with the hypothesis of a facies relationship of these ichnites. More specifically, the Omuramba Omambonde *Otozoum* is found in a flat interdune area, potentially a more specific environmental preference for the *Otozoum* trackmaker.

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