Geological Quarterly, 2009, **53** (4): 433–440

A *Grallator*-dominated tracksite from the Chinle Group (Late Triassic), Moab, Utah

Martin G. LOCKLEY and Gerard D. GIERLIŃSKI

Lockley M. G. and Gierliński G. D. (2009) — A *Grallator*-dominated tracksite from the Chinle Group (Late Triassic), Moab, Utah. Geol. Quart., **53** (4): 433–440. Warszawa.

Two roadside localities on the northern fringes of Moab, Grand County, Utah yield previously un-described Upper Triassic vertebrate tracks from the Chinle Group (Rock Point Formation). The first locality, designated the highway 191 site, yields dozens of small theropod dinosaur tracks (*Grallator*) preserved on a single, fallen slab. The tracks form a monospecific assemblage preserved as natural casts. The assemblage is representative of what has been referred to as Rhaetic assemblage II which is dominated by small *Grallator* tracks. *In situ Grallator* tracks are also described from a nearby locality, referred to as the Matrimony Spring site, where they are found in association with the ichnogenus *Brachychirotherium*. Many other sites with similar, often more-diverse, Late Triassic ichnofaunas are known from the region.

Martin G. Lockley, Dinosaur Tracks Museum, University of Colorado at Denver, PO Box 173364, Denver, Colorado, 80217, U.S.A.; e-mail: Martin.Lockley@UCDenver.edu; Gerard D. Gierliński, Polish Geological Institute–National Research Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland; JuraPark, ul. Sandomierska 4, PL-27-400 Ostrowiec Świętokrzyski, Poland; e-mail: gierlinski@yahoo.com *(received: June 09, 2009; accepted: December 18, 2009).*

Key words: Utah, Moab, Chinle Group, footprints, theropod dinosaurs, *Grallator*.

INTRODUCTION

The uppermost Chinle Group (Rock Point Formation) is yields high concentrations of vertebrate tracks at many localities (Hunt and Lucas, 1992; Lockley *et al*., 1992*a*; Lockley and Hunt, 1995). The best documented examples come from the Gateway region of western Colorado and the Dirty Devil River valley region of eastern Utah (Gaston *et al*., 2003; Lockley and Eisenberg, 2006). Representative slabs and replicas from various sites have been collected and illustrated. These show high densities of well-preserved small *Grallator* tracks similar to *Grallator*-dominated assemblages from other western regions including northern New Mexico (Lockley *et al*., 1993; Hunt *et al*., 2000) and northeastern Utah (Lockley *et al*., 1992*a*). These occur in association with other vertebrate ichnogenera such as *Brachychirotherium*, *Rhynchosauroides*, *Eosauropus* (Lockley *et al*., 2006*b*) and *Evazoum* (Nicosia and Loi, 2003) which were previously labeled as *Tetrasauropus* and *Pseudotetrasaurpus* (Lockley and Hunt, 1995; Lockley *et al*., 2006*a*).

The purpose of this short paper is to describe two sites from the Moab region that have been known for some time by not previously described. The first site reveals monospecific, high density assemblage of *Grallator* tracks from the upper part of the Chinle Group, at a location just north of the Colorado River in southern Grand County, near Moab Utah (Fig. 1). The site produced a fallen slab revealing several dozen track casts originating from the underside of an overhang exposed in a road cut east of highway 191 (Fig. 2A). The second site, referred to as the Matrimony Spring site, is an *in situ* outcrop, also in the upper Chinle Group, located on the south side of the Colorado River and on the south side of highway 128 (Fig. 2D). This latter locality is about 500 m east of the former.

On the basis of measurements obtained at the highway 191 site we present preliminary size frequency and locomotor (step and stride) data for the *Grallator* trackmakers that are useful for comparison with other sites, notably the Dirty Devil site (Lockley and Eisenberg, 2006). We also briefly review the geographic and stratigraphic distribution of similar *Grallator* assemblages in the upper Chinle Group and overlying Wingate

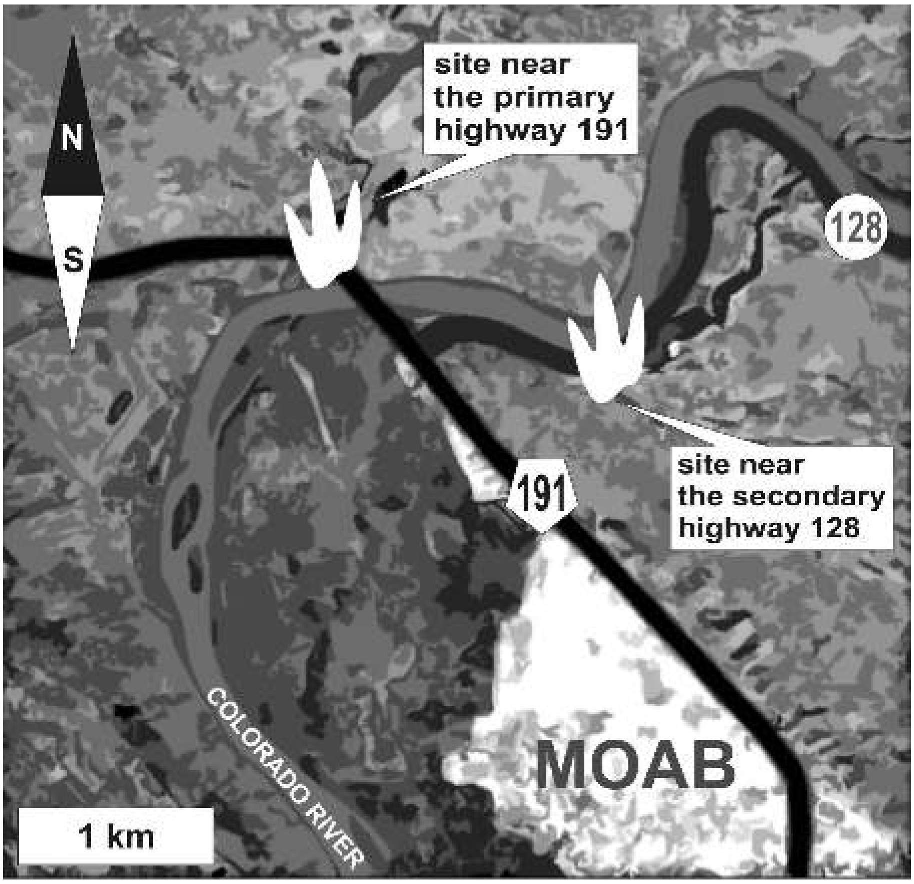

Fig. 1. Location of the tracksites along highway 191 and 128 on the northern outskirts of Moab, Utah

Note that the large slab from the highway 191 site has been removed to a NPS storage facility

Formation of the western United States, with special reference to local sites recorded in a recent survey.

We also note that similar tracksites are distributed regionally (Lockley *et al*., 1992*a*; Gaston *et al*., 2003) and as far a field as Europe (Haderer, 1992; Lockley *et al*., 1996; Lockley and Meyer, 2000).

SITE MONITORING AND DESCRIPTION

Our research group has worked in the Moab area for more than 25 years and produced numerous publications (see Lockley and Hunt, 1995 for summary). Due to the large number of known sites many have yet to be documented in the scientific literature. However, some of these "yet-to-be-published" sites have been documented in surveys by our research group and others. For example in 2004 we conducted a Bureau of Land Management (BLM) sponsored survey that recorded the GPS locations of 60 sites numbered UCD 1 (2004)–UCD 60 (2004). To avoid giving precise GPS co-ordinates we use these designations to refer to a few sites discussed herein.

The locality (UCD 13 2004), herein referred to as the highway 191 site (Figs. 1 and 2A), has been monitored for more than 20 years, without formally being described in any scientific journal. Occasionally tracks found on fallen blocks have been rescued. These include specimens in the University of Colorado at Denver Dinosaur Tracks Museum collection (CU 147, CU 148.1–2 and CU 148.4). The site is near the path of the Moab fault causing the rock outcrops to be fractured and susceptible to collapse. The rocks that fall to road level are routinely removed by the highway department. Therefore, the site is essentially a road cut that is set back some distance (~10–15 m) from highway 191. As a result of the regular removal of material, there is a wide shoulder between the paved road and the rock outcrops. In the past this was a popular parking spot. However, most of the area is within the boundary of Arches National Park, and signs, now in place, forbid parking of vehicles at this location.

The site was re-visited again in October 2008, when we noticed several fallen blocks at the base of the outcrop. On recognizing several *Grallator* tracks we reported the discovery to the National Park Service (NPS) and obtained a permit to document the site. At this time it was decided that Park Service personnel would remove the specimen to a suitable location for curation in the NPS system. Due to the limited time available and the large size of the fallen slab, we confined our survey to photographing the slab and making a tracing of the tracks on transparent acetate film. Prior to photographing and tracing the slab we cleaned off dust with a light brush and marked the tracks lightly with white chalk dust in order to have them show up more clearly during

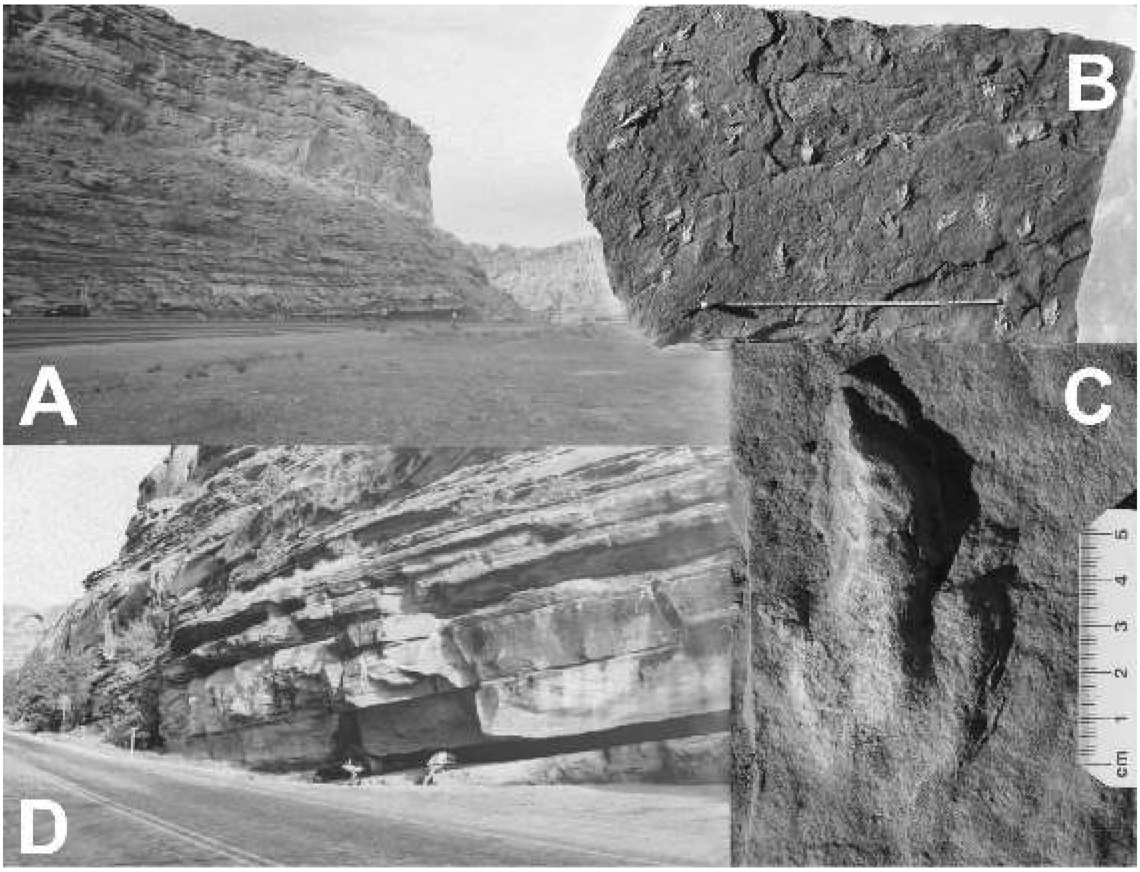

Fig. 2. Highway 191 site (A) and close-ups of the whole slab (B) and the one of *Grallator* tracks (C); view of the highway 128 site (D)

Tape in B is 1.00 m compare with Figure 3 for scale

photography and tracing (Fig. 2B and C). We subsequently numbered the all tracks that appeared to represent individual trackways containing one or more reasonably well-preserved tracks that would yield reliable measurements. Wherever two or more consecutive tracks in a trackway were identified a trackway number was designated (Fig. 3) and the length and width of the best preserved tracks and representative or average steps were recorded directly from our tracing (Table 1). The tracing, designated T 1341 in the CU Denver Dinosaur Tracks Museum archives, was subsequently reduced to a suitable publication size, and reversed to show the positive aspect corresponding to the original footprint impressions, rather than the negative aspect of the natural casts (Fig. 3).

Similar tracks also occur at a nearby locality (UCD 12 2004) known as Matrimony Spring, which is well-known locally as a natural source of drinking water located along side highway 128. This locality, situated on Bureau of Land Management (BLM) land, is ~500 m from the highway 191 locality. The Matrimony Spring site was mapped by the senior author more than 20 years ago but the map was never published. The track-bearing surface is about 9.0 m long and 1.5–2.0 m wide (area ~16 m^2). We herein present the site map (Fig. 4). The outcrop reveals about 40 recognizable tracks, comprising at least 8 trackway segments, and a few isolated tracks, all preserved as deep impressions (concave epireliefs) on the upper surface of a sandstone bed overlain by red mudstone. Two of the trackways, representing a total of 9–10 tracks are identified as *Brachychirotherium*, and a representative plaster cast of one of these footprints is preserved in the CU Denver collections as specimen CU 148.3. (Because of the constant flow of water around this track it was made by simply molding the impression with clay and then replicating the clay cast with plaster in the lab). The remaining tracks (~30) and trackways (~6) represent tridactyl bipeds best attributed to *Grallator*. The best-preserved tracks are about 8 cm long, with clear, narrow digit traces. However, other tracks appear larger (~12 cm) and their outlines are less diagnostic (Fig. 4). Some tracks also reveal poorly preserved metatarsal traces, and yet others are mere oval depressions with no toe traces to help reveal the direction of travel. Thus, unlike the highway 191 assemblage, the Matrimony Spring (highway 128) assemblage shows variable, mostly poor to very poor preservation. Nevertheless, it is possible to infer a *Grallator*-dominated assemblage with two *Brachychirotherium* trackways. It is worth noting that although this site has frequent visitation from tourists and locals availing themselves of the fresh spring water, it appears from our observations that very few people known of the tracks. In any case, removal of the tracks, would be difficult and produce very poor specimens, and to date we know of no vandalism at this site.

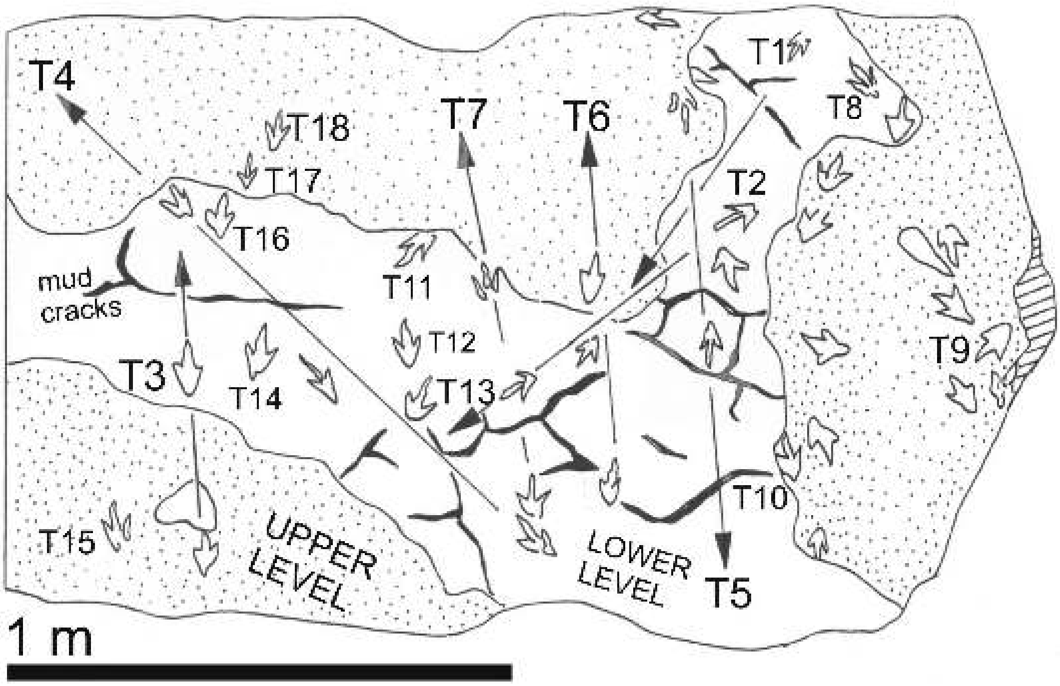

Fig. 3. Map of *Grallator* tracks on fallen slab, made from tracing with transparent acetate film

Compare with Figure 2B

Table 1

Track and trackway measurements [in cm]

Trackway number	Foot length	Foot width	Step-stride
1	7.1	4.2	36.0–72.0
2	9.3	6.4	53.0– x
3	10.3	5.2	35.2–x
4	11.5	5.6	53.0–98.8
5	9.0	5.9	x–x
6	9.7	4.7	x–x
7	8.5	5.8	54.0– x
8	9.7	5.6	x–x
9	10.5	6.0	x–x
10	10.0	5.5	x–x
11	9.8	6.2	x–x
12	9.5	5.8	x–x
13	9.8	6.4	x–x
14	10.5	6.2	x–x
15	9.2	6.0	x–x
16	8.8	5.8	x–x
17	6.3	3.5	x–x
18	7.5	4.8	x–x
Mean Moab	**9.28**	**5.53**	**46.24**
Mean Dirty Devil	**10.76**	**6.02**	**51.53**

DESCRIPTION OF THE LARGE HIGHWAY 191 SPECIMEN

As shown in Figure 3, the track-bearing surface reveals a minimum of 40 complete or partial tridactyl *Grallator* tracks, preserved as sandstone natural casts on the underside of a 30 cm-thick sandstone bed. There are two distinctive track-bearing layers separated by only a thin (~1 cm) fine sandstone unit bounded by very thin claystone drapes. The lower surface of the lower layer reveals the majority of well-preserved tracks and also displays many mud cracks. However, tracks also occur on the upper surface of this layer, which is the lower surface of the overlying and thicker sandstone bed. However, many of these tracks were made at the same time as those on the lower surface: i.e., tracks made on the upper surface registered as well preserved undertracks, or penetrated through to the lower surface giving the appearance of true tracks. This can be proved where the thin lower layer is loose showing single tracks registered on both surfaces.

The surface area of the track-bearing slab is just about 2.5 m^2 (2.1×1.2 m), not including a small area which was covered by another larger slab. Therefore, allowing for tracks that have been lost due to damage of the slab me near the edges, the track density is about 20 per m^2. It was not possible to determine the orientation of the block by reference to the outcrop. Therefore no meaningful trackway orientations can be recorded.

We identified 18 trackway segments crisscrossing the surface from which we could obtain useful measurements. As indicated in Table 1 tracks range in length from about 6.3 to 11.5 cm with variable step lengths from 35 to 54 cm (Table 1). Mean values are 9.28 cm for track length (N = 18), 5.53 cm for track width (N = 18) and 46.24 cm for step length (N = 5). As

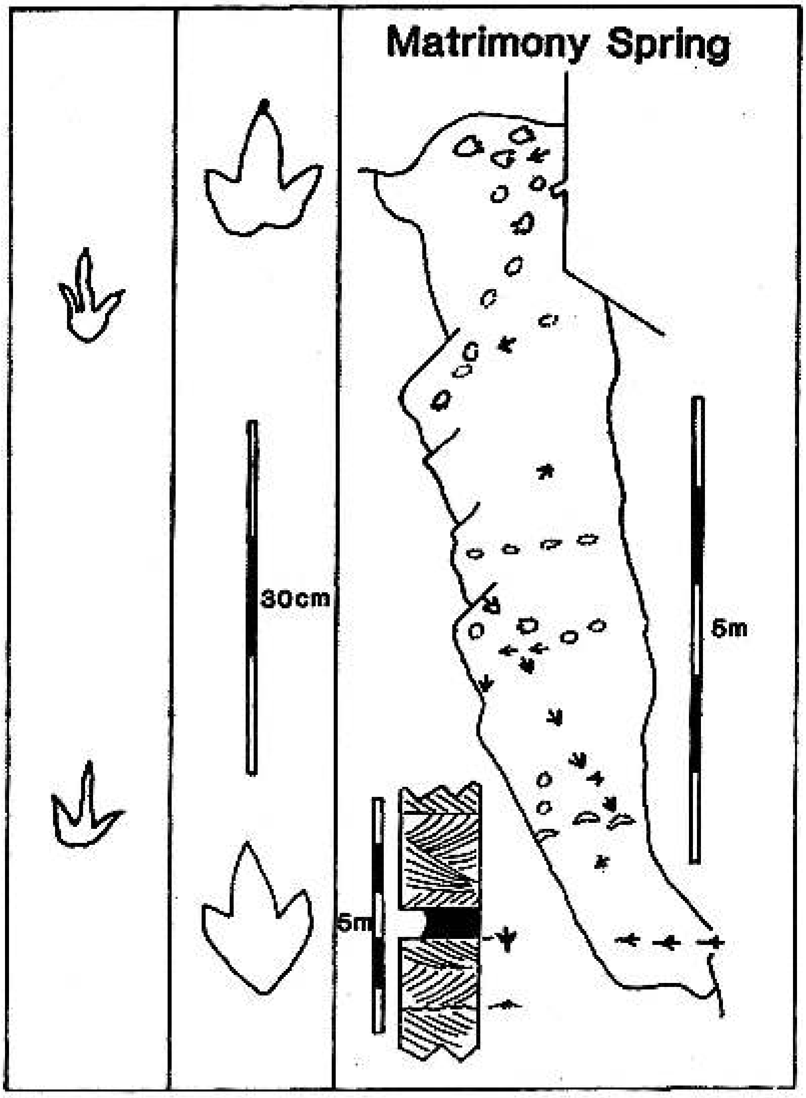

Fig. 4. *Grallator* trackway segments (left and center) from the highway 128, Matrimony Spring site (UCD 12 2004) shown in the map (right)

Inset shows location of track-bearing surface at the contact between sandstone and mudstone units

noted below, these values are similar to those recorded from other small *Grallator* assemblages in the Late Triassic.

TRACKMAKER INFERENCES

Most authors agree that *Grallator* represents a theropod dinosaur, possibly a ceratosaurian dinosaur such as *Coelophysis*. Tracks in the Moab sample have a mean foot length and width of 9.28 cm and 5.53 cm respectively (N = 18). This size would correspond to a dinosaur such as *Coelophysis* (Colbert, 1989) or a similar sized theropod (Thulborn, 1990, fig. 5.3). Although the mean sizes in the Moab sample are 9–15% smaller than those recorded from the Dirty Devil site (10.76 and 6.02 cm respectively), the differences are minor, and a *Coelophysis* or *Coelophysis*-like trackmaker is a reasonable inference in both cases.

As noted by Lockley and Eisenberg (2006) *Grallator* tracks from a Late Triassic site at Lake Powell, probably from a lower Wingate assemblage, yields tracks in the 6–8 cm size range. These are about 20–30% smaller than the Moab assemblage, and about 30–40% smaller than the Dirty Devil assemblage.

STRATIGRAPHIC AND REGIONAL CONTEXT OF TRACKS

The track-bearing surfaces at the highway 191 and Matrimony Springs sites are associated with the upper units of the

Chinle Group referred to as the Rock Point Formation (*sensu* Lucas, 1991). In this area the Rock Point Formation, consists of cross-bedded fluvial sandstones alternating with finer-grained mudstone and siltstone. Higher in the sequence the overlying Wingate Formation consists of cliff-forming sandstones comprised of large scale eolian cross beds, and a few very thin fine grained intervals: i.e., mostly clay drapes. In some areas such as the Echo Campsite (UCD 1 2004), rich vertebrate track assemblages occur very near the Chinle–Wingate contact. Tracks are found at many layers in the Chinle–Wingate Transition zone, and it may be hard to determine the exact horizon of origin of fallen blocks. For example, another slab with about 50 *Grallator* tracks is known from another locality (UCD 51 2004) just north of highway 191 and a few hundred metres west of the aforementioned Matrimomy Spring site (UCD 12 2004). Regardless of the difficulties of identifying the exact horizon of origin of such tracks, complicated in the case of these sites (UCD 13 2004 and UCD 51 2004) by the influence of the Moab Fault, it is still possible to document the track assemblages.

The local stratigraphy is characteristic of the Chinle-Wingate transition in the region: for example in the Gateway area of Western Colorado (Gaston, 2003; Lockley *et al*., 2004) and other sites in the region (Lockley *et al*., 1992*a*, 1993; Lockley and Hunt, 1995). Gaston *et al*. (2003) noted the abundance of *Grallator* tracks in the uppermost part of the Rock Point Formation, where other vertebrate ichnogenera such as *Brachychirotherium*, *Rhynchosauroides* and the enigmatic trace *Evazoum* (Nicosia and Loi, 2003) also occur. For example, in addition to the monospecific assemblage of tracks from the highway 191 site (UCD 13 2004) *Brachychirotherium* (CU 148.1) has also been recorded from this locality.

Tracks previously assigned to *Pseudotetrasauropus* sp. and *Tetrasauropus* sp. are also typical of this interval and are visible at the Echo sites (UCD 1 2004). However, these two ichnogenera, originally based on southern African material (Ellenberger, 1972, 1974) have recently been restudied by D'Orazi Porchetti and Nicosia (2007) who concluded that neither ichnogenus has been identified with confidence in the northern hemisphere. Thus, alternative names have recently been proposed. *Pseudotetrasauropus* sp. (as previously used in the western USA and Europe) is now referred to as *Evazoum* (Nicosia and Loi, 2003; Lockley *et al*., 2006*a*) and *Tetrasauropus* sp. (as previously used in the western USA and Europe) becomes *Eosauropus* (Lockley *et al*., 2006*b*).

All these ichnogenera, except *Grallator* appear confined to the Late Triassic, and are so far unknown from the Lower Jurassic. Lockley *et al*. (2004, 2006*a*, *b*), noted that the Triassic–Jurassic boundary probably lies within the Wingate Formation. The Lower Jurassic contains a different suite of tetrapod tracks including *Otozoum*, *Batrachopus* and *Anomoepus*, so far unknown from the Late Triassic (Chinle Group) in the western United States. *Grallator* is the only ubiquitous ichnogenus that appears abundantly in both the Chinle and Wingate.

GLOBAL CONTEXT

Grallator is a long-ranging ichnotaxon and therefore of little biostratigraphic utility. However, changes in the median and maximum size of tracks in the Late Triassic and Early Jurassic have been noted. For example, Haubold (1986, p. 194) refers to three successive footprint assemblages. The oldest (I) is a Carnian–Norian assemblage which contains a diverse ichnofauna which includes "a number of small tridactylous footprints". The second assemblage (II) is described as Rhaetic, and "less…diverse, and mainly consist[ing] of small tridactylous bipeds (grallatorids)", but with a few "larger tridactyls (*Eubrontes*)". The third assemblage (III) is described as Lower Jurassic and contains the aforementioned "zonal indices" *Otozoum*, *Batrachopus* and *Anomoepus*, and associated abundant *Eubrontes* and grallatorids.

We infer that the preponderance of "small tridactylous bipeds (grallatorids)" at the Moab site likely places it in the Jurassic–Triassic transition zone (Rhaetic). In this region, there are many sites with abundant small *Grallator* tracks occurring in monospecific assemblages. These include the recently-described and visually-spectacular Dirty Devil site (Lockley and Eisenberg, 2006) as well as several sites in the Gateway (Colorado) area (Gaston *et al*., 2003) and various sites in Europe (Haderer, 1992; Lockley *et al*., 1996).

Both the Carnian–Norian assemblage (I) and the Rhaetic assemblage (II) contain *Grallator* and occur in the Late Triassic Upper Chinle Group. Assemblage II may also occur in the basal Wingate, while *Grallator* may also co-occur in assemblage III with typical Lower Jurassic Tracks. Thus, it is not possible to draw unequivocal biostratigraphic inferences from the occurrence of monospecific *Grallator* assemblages.

Nevertheless, monospecific, and therefore by definition, low diversity assemblages, of small *Grallator* tracks fit Haubold's assemblage zone II category. Haubold (1984, 1986) noted the increase in the size of tridactyl dinosaur tracks (*Grallator* and *Eubrontes*) across the Triassic–Jurassic boundary (Lockley and Hunt, 1995; Olsen *et al*., 2002). However, claims that large tracks (*Eubrontes*) only occur above the boundary (Olsen *et al*., 2002) have been disputed (Lucas *et al*., 2005). Thus, although there is a "general" trend towards a progressive increase in the maximum size of tridactyl theropod tracks in the late Jurassic and Early Triassic the presence of assemblages with only small *Grallator* tracks is not an unambiguous indicator of age.

Acknowledgements. Study of the highway 191 site was conducted under permit: ARCH-2008-SCI-0024, and facilitated by the kind cooperation of J. Troutman and V. Webster from the Arches National Park office Moab. The large specimen has been assigned: Accession # ARCH–351. Study of the other sites on BLM land has been conducted over many years, but was most recently summarized in a 2004 survey co-sponsored by the BLM.

REFERENCES

COLBERT E. H. (1989) — The Triassic dinosaur *Coelophysis*. Mus. Northern Arizona Bull., **57**: 1–160.

D'ORAZI PORCHETTI S. and NICOSIA U. (2007) — Re-examination of some large Early Mesozoic tetrapod footprints from the African collection of Paul Ellenberger. Ichnos, **13**: 219–246.

ELLENBERGER P. (1972) — Contribution à la classification des pistes de vertébrés du Trias: Les types du Stromberg d'Afrique du Sud (I). Palaeovertebrata, Mém. Extraordinaire.

ELLENBERGER P. (1974) — Contribution à la classification des pistes de vertébrés du Trias: Les types du Stromberg d'Afrique du Sud (II partie: Le Stromberg superieur — I. Le biome de la zone B/1 ou niveau de Moyeni: ses biocenoses). Palaeovertebrata, Mém. Extraordinaire.

GASTON R., LOCKLEY M. G., LUCAS S. G and HUNT A. P. (2003) — *Grallator*-dominated fossil footprint assemblages and associated enigmatic footprints from the Chinle Group (Upper Triassic), Gateway area, Colorado. Ichnos, **10**: 151–163.

HADERER F. O. (1992) — Ein weitere grallatorider Fährtenrest aus dem Stubensandstein des Starmborgs (Nordwurttemburg). Jb. Geselsch. Naturkunde Wűrtenburg, **147**: 5–10.

HAUBOLD H. (1984) — Saurierfahrten (2nd Edition). A. Ziemsen Verlag, Wittenberg Lutherstadt.

HAUBOLD H. (1986) — Archosaur footprints at the terrestrial Triassic–Jurassic transition. In: The Beginning of the Age of Dinosaurs: Faunal Change across the Triassic-Jurassic Boundary (ed. K. Padian): 189–201. Cambridge University Press.

HUNT A. P. and LUCAS S. G. (1992) — Stratigraphic distribution and age of vertebrate tracks in the Chinle Group (Upper Triassic), western North America. Geol. Soc. Am., Abstracts with Programs, **24** (6): 19.

HUNT A. P., LUCAS S. G., LOCKLEY M. G. and HECKERT A. B. (2000) — Occurrence of the dinosaurian ichnogenus *Grallator*, in the Redonda Formation (Upper Triassic: Norian) of Eastern New Mexico. In: Dinosaurs of New Mexico (eds. S. G. Lucas and A. B. Heckert). New Mexico Mus. Nat. Hist. Sc. Bull., **17**: 39–41.

LOCKLEY M. G., CONRAD K., PAQUETTE M. and HAMBLIN A. (1992*a*) — Late Triassic vertebrate tracks in the Dinosaur National Monument area. In: Utah Geol. Surv. Misc. Publ. (ed. J. R. Wilson), **92** (3): 383–391.

LOCKLEY M. G. and EISENBERG L. (2006) — A preliminary report on a spectacular dinosaur tracksite in the Chinle Group, Dirty Devil River valley, Wayne County, Utah. New Mexico Mus. Nat. Hist. Sc., Bull. **37**: 263–268.

LOCKLEY M. G. and HUNT A. P. (1995) — Dinosaur tracks and other fossil footprints of the western United States. Columbia University Press, New York.

LOCKLEY M. G., KING M. J., HOWE S. and SHARP T. (1996) — Dinosaur tracks and other archosaur footprints from the Triassic of South Wales. Ichnos, **5**: 23–41.

LOCKLEY M. G., LUCAS S. G., GASTON R. and HUNT A. P. (2004) — Ichnofaunas from the Triassic–Jurassic boundary sequences of the Gateway area, Western Colorado: implications for faunal composition and correlations with other areas. Ichnos, **11**: 89–102.

LOCKLEY M. G., LUCAS S. G. and HUNT A. P. (2006*a*) — *Evazoum* and the renaming of northern hemisphere "P*seudotetrasauropus*": implications for tetrapod ichnotaxonomy at the Triassic–Jurassic boundary. New Mexico Mus. Nat. Hist. Sc. Bull., **37**: 199–206.

LOCKLEY M. G., LUCAS S. G. and HUNT A. P. (2006*b*) — *Eosauropus*, a new name for a Late Triassic track: further observations on the Late Triassic ichnogenus *Tetrasauropus* and related forms, with notes on the limits of interpretation: In: The Triassic-Jurassic Terrestrial Transition (eds. H. D. Harris, S. G. Lucas, J. A. Spielmann, M. G. Lockley, A. R. C. Milner and J. I. Kirkland). New Mexico Mus. Natur. History Sc. Bull., **37**: 193–198.

LOCKLEY M. G. and MEYER C. A. (2000) — Dinosaur tracks and other fossil footprints of Europe. Columbia University Press. New York.

LOCKLEY M. G., SANTOS V. F. and HUNT A. P. (1993) — A Late Triassic tracksite from the Sheep Pen Sandstone, Sloan Canyon, Cimarron Valley, New Mexico. In: The Nonmarine Triassic (eds. S. G. Lucas and M. Morales). New Mexico Mus. Nat. Hist. Sc. Bull., **3**: 285–288.

LUCAS S. G. (1991) — Revised Upper Triassic stratigraphy in the San Rafael Swell Utah. In: Geology of East Central Utah (ed. T. C. Chidsey, Jr.). Utah Geol. Ass. Publ., **19**: 1–8.

LUCAS S. G., HAUBOLD H., KLEIN H., LOCKLEY M. G., HUNT A., HECKERT A. and THULBORN R. A. (2005) — Triassic records of the theropod footprint ichnogenus *Eubrontes*. J. Vertebr. Paleont., **25**: 85A.

NICOSIA U. and LOI M. (2003) — Triassic footprints from Lerici (La Spezia, northern Italy). Ichnos, **10**: 127–140.

OLSEN P. E., KENT D. V., SUES H. D., KOEBERL C., HUBER H., MONTANARI A., RAINFORTH E. C., FOWELL S. J., SZAJNA M. J. and HARTLINE B. W. (2002) — Ascent of dinosaurs linked to an iridium anomaly at the Triassic–Jurassic boundary. Science, **296**: 1305–1307.

THULBORN R. A. (1990) — Dinosaur Tracks. Chapman and Hall, London.