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OCCURRENCE OF THE DINOSAURIAN ICHNOGENUS *GRALLATOR* IN THE REDONDA FORMATION (UPPER TRIASSIC: NORIAN) OF EASTERN NEW MEXICO

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Abstract—Numerous tridactyl dinosaur tracks from the Upper Triassic Redonda Formation of east-central New Mexico have been referred to the ichnogenus *Grallator*, but most are poorly preserved specimens of the tetradactyl *Pseudotetrasauropus*. UMMP 16161 and MDM 248 are the only two specimens from the Redonda Formation comparable to *Grallator*, but they display apparent morphological differences.

INTRODUCTION

The first records of Early Mesozoic dinosaurs were based on fossil footprints from the Newark Supergroup of Eastern North America described by E. Hitchcock and others in the nineteenth century (Steinbock, 1989). All the earliest discoveries, originally thought to be Late Triassic in age, subsequently were reinterpreted as Early Jurassic (e.g., Olsen et al., 1982). However, Late Triassic tracks had been discovered in 1866 in the Newark Supergroup and were later recognized as such, and in the latter half of the 20th Century many more localities have been found (Olsen and Baird, 1986; Silvestri and Szajna, 1993). In contrast, it was not until the 1930s that fossil footprints were discovered in the extensive exposures of the Chinle Group in western North America, in Wyoming and New Mexico (Branson and Mehl, 1932; Hunt and Lucas, 1989). During the last 15 years, there have been a large number of studies of Chinle tracks, but many taxonomic questions remained unresolved (see Lockley et al., 2000 for a comprehensive review). The purpose of this paper is to clarify uncertainties about the presence of the ichnogenus *Grallator* in the ichnofauna of the Redonda Formation (Chinle Group; Norian) of eastern New Mexico. In this paper, MDM refers to the Mesalands Dinosaur Museum, Tucumcari; NMMNH to the New Mexico Museum of Natural History and Science, Albuquerque; and UMMP to University of Michigan Museum of Paleontology, Ann Arbor.

HISTORY OF STUDY

In 1934, local fossil collector Robert Abercrombie took E. C. Case of the University of Michigan to a footprint locality on the northeast corner of Mesa Redonda, Quay County, New Mexico. Case collected four specimens (UMMP 1644, 16160, 16161 and an uncatalogued slab) (Gregory, 1972; Hunt et al., 1989; Wilson, 1990). In 1961, Abercrombie collected a footprint and counterpart (now lost) for the Royal Ontario Museum (ROM 04569). In the intervening years, J. T. Gregory of Yale University, and subsequently the University of California, Berkeley, reported vertebrate tracks all around Mesa Redonda, although they were most frequent in the vicinity of Abercrombie's locality (Gregory, 1972).

In 1985 and 1986, parties from the University of New Mexico collected additional footprints from Abercrombie's locality (Hunt et al., 1989). In 1986, C. Johnson collected a *Brachychirotherium* footprint (NMMNH P-1059) from the west side of the mesa. Since 1995, field parties from the Mesalands Dinosaur Museum have made collections of tetrapod tracks from Mesa Redonda and Apache Canyon (Cotton et al., 1996)

ICHNOTAXONOMY

Hunt et al. (1989) were the first to discuss the taxonomy of dinosaurian tracks from the Redonda Formation, and they assigned tridactyl tracks to *Grallator* sp. Subsequent study has demonstrated the presence of a tetradactyl track type in the Redonda fauna whose digit I impression is often poorly impressed or lacking entirely (Farlow and Lockley, 1993, fig. 5: Lockley and Hunt, 1995, fig. 3.17: Lockley et al., 2000). Lockley et al. (1992) and subsequent authors have assigned similar tracks to *Pseudotetrasauropus* sp. Tridactyl specimens of *Pseudotetrasauropus* (Fig. 1) are easily distinguished from specimens of *Grallator* (Fig. 2) by the length of the middle toe impression. *Grallator* has a very long middle toe impression (mesaxonic), whereas *Pseudotetrasauropus* has digit impressions subequal in length. Utilizing this criterion, it is clear that the vast majority of "tridactyl" tracks from the Redonda Formation represent *Pseudotetrasauropus*.

Only two specimens from the Redonda Formation are both tridactyl in form and possess a long middle digit impression. These specimens are UMMP 16161, collected from Mesa Redonda by Robert Abercrombie (Hunt et al, 1993, fig. 3C; Hunt et al., 1998, fig. 7A), and MDM 248 collected from Apache Canyon. Olsen et al. (1998) recently published a significant evaluation of the ichnotaxonomy of *Grallator* and related forms, and their study can be used to assess the relationships of these two specimens.

UMMP 16161 is preserved as a mold in concave epirelief, and based on the curvature of the impression of digit II, it is presumed to be a left footprint (Fig. 3). The individual pad impressions are shallow and fairly indistinct. Utilizing the measurement conventions of Olsen et al. (1998, fig. 3), the total length of the track is 128 mm, and the total width is 85 mm. The impression of digit III has three pad impressions that decrease in length from posterior to anterior, whereas the impression of digit II has two subequally-sized pad impressions. It is difficult to distinguish pad impressions on digit IV. Based on the pattern of pad impressions, the inferred length of digit III is approximately 75 mm, whereas digit IV is about 77 mm long and digit II is about 52 mm long, giving III/II and III/IV ratios of 1.44 and 0.97, respectively. The divarication of the digits is 57°. Given the indistinct nature of the pad impressions, it is not possible to calculate exactly the projection ratio of digit II.

UMMP 16161 is comparable to tracks assigned to *Grallator* by Olsen et al. (1998). It differs in being relatively broad with a length:width ratio of about 1.5, in having an impression of digit II that does not project as anteriorly relative to the other digit impressions and in having a wider digit divarication. Given these

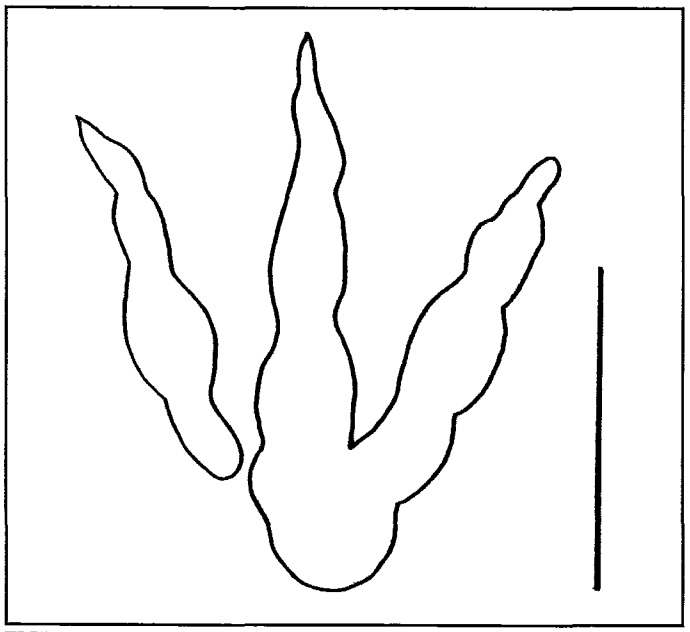
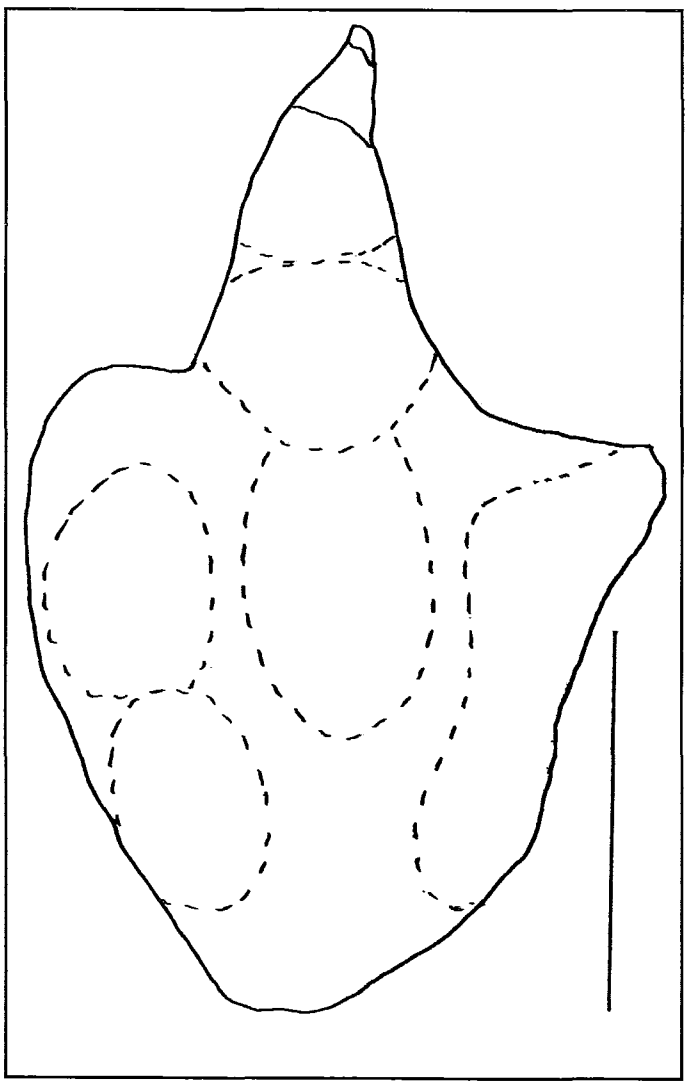


FIGURE 1. Partial preservation of *Pseudotetrasauropus* track from the Redonda Formation exhibiting an apparently tridactyl morphology. Scale bar is 10 cm.



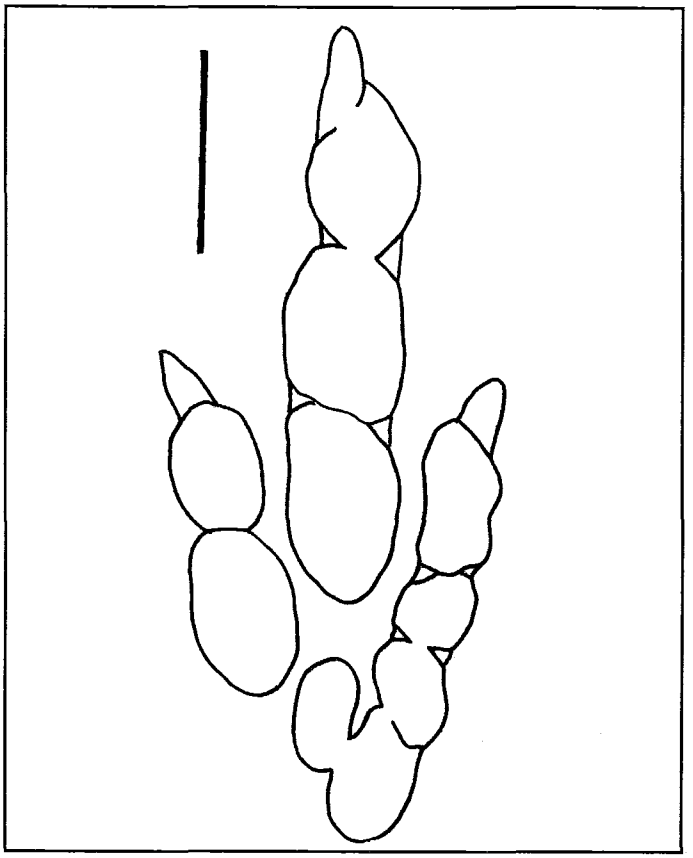


FIGURE 2. Composite outline drawing of genoholotypic trackway of *Grallator parallelus* from the Early Jurassic Portland Formation, Massachusetts. Scale bar is 2 cm. (after Olsen et al., 1998).

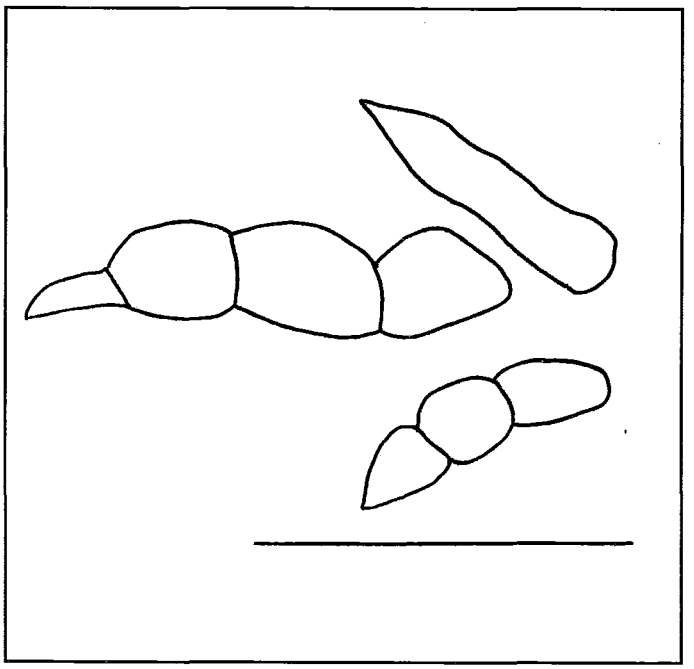


FIGURE 4. (Above) Track of *Grallator* sp. from the Redonda Formation of east-central New Mexico (MDM 248). Scale bar is 5 cm.

FIGURE 3. (Left) Track of aff. *Grallator* sp. from the Redonda Formation of east-central New Mexico (UMMP 16161). Scale bar is 5 cm.

differences, and the relatively poor preservation of this ichnite, we refer UMMP 16161 to aff. *Grallator* sp.

MDM- 248 is preserved as a cast in convex hyporelief (Fig. 4) and represents a right footprint as indicated by the two pad impressions on the left digit impression (= digit II). The total length is 73 mm, and the total width is 53 mm. There are three pad impressions preserved by digit II, and the approximate length of this digit is 52 mm. Two large pads are preserved by digit II, which give an inferred length of 23 mm for this digit. It is difficult to distinguish the outline of the impression of digit IV, but it is about 40 mm long. The digit divarication is 72°.

MDM 248 is more similar to the genoholotype of *Grallator parallelus* than UMMP 16161 in the projection of the impression of digit II relative to the other digits. However, the average divarication of *G. parallelus* is 28° compared to 72° for MDM 248, and the length: width ratio is about 2.2 compared to 1.37 (Olsen et al., 1998). Because of gross similarities in morphology we assign MDM 248 to *Grallator* sp., but it is clear that more taxonomic work is required to document the variation within the ichnogenus *Grallator* and to compare the type materials from the Early Jurassic with similar Triassic specimens in the western United States. These specimens appear distinct from Late Triassic specimens of *Grallator* from the eastern United States (e. g., Silvestri and Szajna, 1993), which are similar to Early Jurassic forms..

CONCLUSIONS

Contrary to some previous reports, there are few specimens from the Redonda Formation that are comparable to the ichnogenus *Grallator*. Only two specimens from the Redonda are morphologically similar to this ubiquitous Jurassic ichnotaxon. Of these, UMMP 16161 may be referred to aff. *Grallator* sp. and MDM 248 to *Grallator* sp.

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DINOSAURS OF NEW MEXICO
PROGRAM OF EVENTS

8:30-9:00 **Registration and check-in**

9:00-10:20 **Podium presentations**

Time	Speaker*	Title
9:00	Spencer G. Lucas *	Introduction to the dinosaurs of New Mexico
9:20	Andrew B. Heckert*	The theropod fauna of the Upper Triassic (Revueltian: early-mid Norian) Snyder quarry, north-central New Mexico
9:40	Alex Downs	Comparing *Coelophysis* and *Syntarsus.*
10:00	Adrian P. Hunt	Taxonomy and taphonomy of Revueltian dinosaurs from the American Southwest and the early diversification of the Dinosauria
10:20	**Break**	
10:40	John Foster	Homogeneity of Upper Jurassic dinosaur localities, Western Interior.
11:00	Mike O'Neill	History of dinosaur collecting on public lands in New Mexico
11:20	Douglas G. Wolfe*	New information on the skull of *Zuniceratops christopheri*, a neoceratopsian dinosaur from the Upper Cretaceous Moreno Hill Formation, New Mexico
11:40	Marcia Jensen*	Migrating Cretaceous theropods? Evidence from oxygen isotope geochemistry, Canada and New Mexico

12:00-1:30 **Lunch Break**

1:30-3:10 **Podium presentations**

Time	Speaker	Title
1:30-1:50	Tracy L. Ford	A review of ankylosaur osteoderms from New Mexico and a preliminary review of ankylosaur armor in general
1:50-2:10	Thomas E. Williamson	A review of New Mexico hadrosaurs
2:10-2:30	Robert M. Sullivan	Some new and interesting dinosaur discoveries from the Upper Cretaceous, San Juan Basin, New Mexico
2:30-2:50	James E. Fassett*	Compelling evidence for Paleocene dinosaurs in the Ojo Alamo Sandstone, San Juan Basin, New Mexico and Colorado
2:50-3:10	Spencer G. Lucas*	Dinosaurs of New Mexico: a summary

3:20-5:00 **Poster Viewing and Collections Tour**

Poster Presentations

Peterson, R.E., Peterson, R.E., D'Andrea, N.V., Lucas, S.G., and Heckert, A.B.	Geology and taphonomy of the Peterson site, New Mexico's most extensive Late Jurassic dinosaur quarry.
Zeigler, K.E., Heckert, A.B., and Lucas, S.G.	Preliminary taphonomy of the Upper Triassic Snyder quarry and significant concentrations of titanium in the specimens.
Williamson, T.E, and Sealey, P.E.	A pachycephalosaurid (Ornithischia: Pachycephalosauria) skull from the Upper Cretaceous Kirtland Formation, San Juan Basin, New Mexico

*Additional authors named in paper.