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# AN UNUSUAL THEROPOD TRACKSITE IN THE CRETACEOUS DAKOTA GROUP, WESTERN COLORADO: IMPLICATIONS FOR ICHNODIVERSITY

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**Abstract**—Ongoing studies of "mid" Cretaceous (Albian-Cenomanian) Dakota Group tracksites in and around the newly designated Dominguez-Escalante National Conservation Area on the Western Slope of Colorado have revealed a theropod-dominated tracksite that contains theropod ichnotaxa different from any previously reported from the Dakota Group. Thus, in contrast to the Eastern Slope where *Magnoavipes* is the only identified theropod track ichnogenus, the theropod ichnofauna of the Western Slope also includes *Irenesauripus*-like tracks. Whereas theropod tracks are well-preserved, ornithopod tracks at this site are poorly preserved and include unusual toe drag marks. This combination of distinct preservation styles indicates different phases of track-making on the same surface.

## INTRODUCTION

At least 80 dinosaur tracksites are known from the Dakota Group on the Eastern Slope of Colorado: i.e., east of the continental divide (Lockley et al., 1992). Here we capitalize "Eastern Slope" and "Western Slope" in accordance with conventions used by the Colorado Geological Survey. As discussed elsewhere in this volume, the first of these sites was discovered in 1902, and since then all others have been reported with increasing frequency through the end of the 20th and into the 21st centuries (Kukihara and Lockley, 2012; Matsukawa et al., 1999, 2001). In contrast, about 40 tracksites have been discovered in the Dakota Group on the Western Slope in the last three years (2011-2013 inclusive). As also noted elsewhere in this volume, the Western Slope ichnofauna is significantly different from the Eastern Slope ichnofauna with respect to the high proportion of anklylosaur and pterosaur tracks (Lockley et al., this volume).

The discovery of a new theropod tracksite, here referred to as the Escalante Rim site (Fig. 1) indicates that the theropod ichnofauna is different from anything yet reported from the Eastern Slope. We here describe the site in detail and discuss the ichnotaxonomy of the theropod tracks and the implications for ichnodiversity and regional paleoecology.

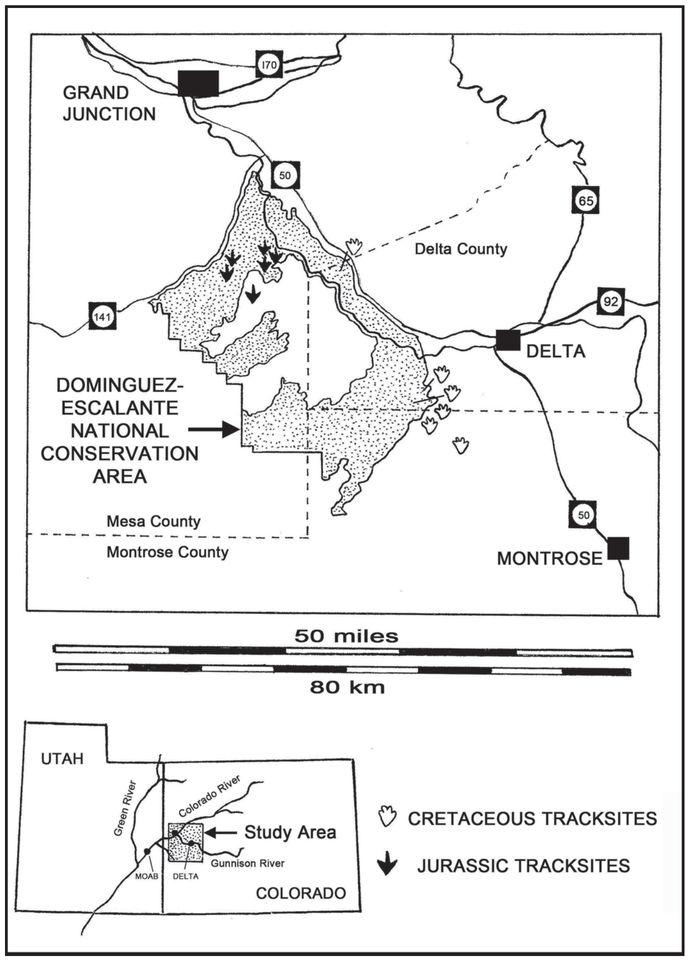


FIGURE 1. Map showing location of study area in western Colorado in and around the Dominguez-Escalante National Conservation Area (D-E NCA). The stippled area is the non-wilderness part of the D-E NCA, which encloses a wilderness area (white). Note concentration of Cretaceous tracksites in the southeastern part of the area (modified after Lockley et al., this volume).

## GEOLOGIC SETTING

The geological context of the track-bearing beds in the Dakota Group of this region has been described elsewhere (Lockley et al., this volume; Noe et al., this volume). In the terminology of Young (1960) the Dakota Group of eastern Utah and western Colorado includes both the Cedar Mountain Formation, the lower unit, and the Naturita Formation, the upper unit. However, the terms Burro Canyon Formation and Dakota Group, respectively, are used east of the Colorado River: i.e., in the present study area in western Colorado. Moreover, the Burro Canyon, equivalent to the Cedar Mountain Formation, is no longer considered part of the Dakota Group. The Dakota Group is distinguished from the conglomeratic Burro Canyon Formation by high carbonaceous content, including many thin coal seams, which indicate a coastal plain setting with a mosaic of swamps, estuaries, fluvial channels and lagoons, on the western shore of the Cretaceous Western Interior Seaway.

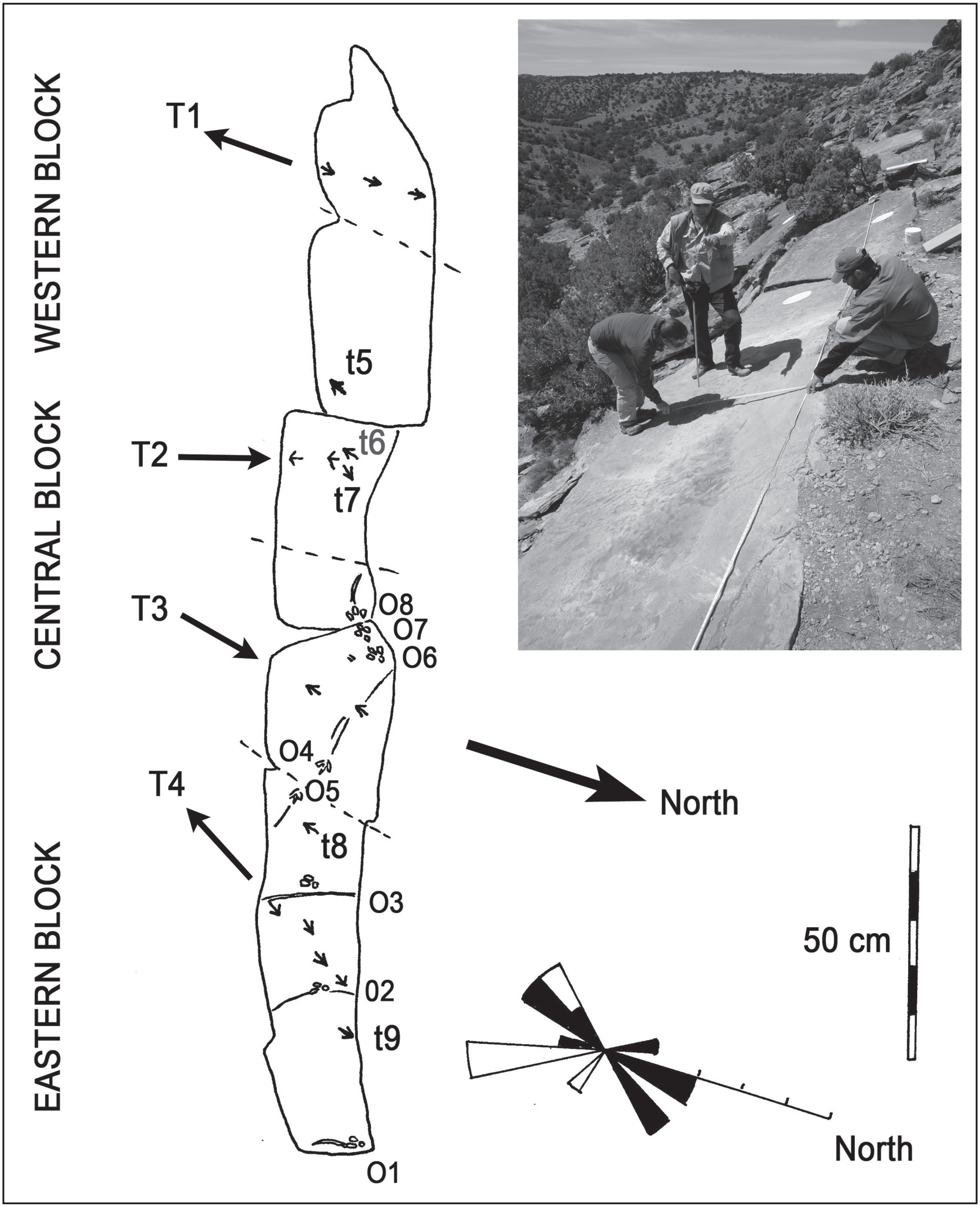


FIGURE 2. Map of the Escalante Rim tracksite showing eastern, central and western blocks. Eastern and western blocks are more or less *in situ*, but the position of the central block has been restored to its inferred position. See photo (inset) for general view, with white latex molds visible. T1-T4 refers to theropod trackway segments: t5-t9 to isolated theropod tracks and O1-8 to ornithopod tracks and trackway segments. Note toe drag traces associated with the ornithopod tracks. See text for details.

## METHODS

After removal of loose debris the site was photographed and mapped by laying out a meter grid with tape measures and chalk. Individual tracks and trackways were photographed and tracings of tracks and trackway segments were made using clear acetate film. Three representative tracks were molded in latex and used to make hard copies from plaster of Paris that are reposited in the University of Colorado Museum of Natural History collections (UCM 207.105-107).

## SITE DESCRIPTION

The track-bearing surface is a sandstone bedding plane about 23 m long and 2-3 m wide, broken into three large pieces (Fig. 2) and referred to as the western, central and eastern blocks. As a result of soil creep, all three blocks have moved slightly from their original *in situ* positions. However, the two largest blocks (east and west) have only tilted along their long axis, so that only the inclination (dip) of these two blocks has been altered. Thus, the east and west blocks retain their original orientation and serve as a reliable record of trackway orientation. The position and orientation of the third block, which has slid downslope a few meters, can be determined by reorientation into the space from which it originated. The length of the central block (about 4.5 m) fits in the gap between the eastern and western blocks precisely.

## RESULTS

A total of 24 tracks were identified in addition to a number of elongate traces. The tracks can be divided into two categories: shallow tracks of probable ornithopod affinity, associated with the elongate traces that appear to be toe drag marks; and relatively deep and well-preserved theropod tracks that show details of pad impressions and claw traces. Due to these differences in preservation it is inferred that the ornithopod and theropod tracks were made at different times.

### Theropod Tracks

A total of 16 theropod tracks were recognized (Figs. 3-4), including four trackway segments designated as trackways T1-T4 and four isolated tracks (t5-t9). Trackway T1 consists of three tracks in sequence (Fig. 3A) at the west end of the west slab. Trackway T2 occurs on the middle slab and consists of two tracks, of which only one (UCM 207.105) is well-preserved and assigned to ichnogenus *Magnoavipes* (Lee, 1997; Lockley et al., 2001) based on the characteristic slender digit traces and wide digit divarication (Fig. 3C). Trackway T3 on the west end of the eastern slab consist of two tracks that are very well-preserved (Fig. 3B), and the second track in this sequence (UCM 207.106) was molded. Trackway T4 consists of four tracks in sequence. All other theropod tracks are isolated and designated numbers (t5-t9). Track t8 (Fig. 3F) was replicated as UCM 207.107 and t9 is shown in Fig. 3E.

With the exception of trackway T2 (*Magnoavipes*) all other theropod tracks are provisionally attributed to the ichnogenus *Irenesauripus* (Sternberg, 1932), even though this ichnogenus is in need of revision. *Irenesauripus* is a more robust track than *Magnoavipes* without pronounced digit divarication. *Irenesauripus* was first reported from the Lower Cretaceous of western Canada by Sternberg (1932) on the basis of material, which did not have diagnostic digital pads. Nevertheless, this track type is widespread in North America in the Early Cretaceous (McCrea et al., this volume), and may show digital pad traces, as in the examples shown here. Subsequently *Irenesauripus* was identified in the Lower Cretaceous of Texas (Langston 1974), where it has been attributed to *Acrocanthosaurus* (Farlow, 2003). The Escalante Rims site specimens are smaller than the Texas specimens, and also smaller than tracks identified as *Irenesauripus* from the Cedar Mountain Formation in eastern Utah (Lockley et al., 2014a,b this volume)

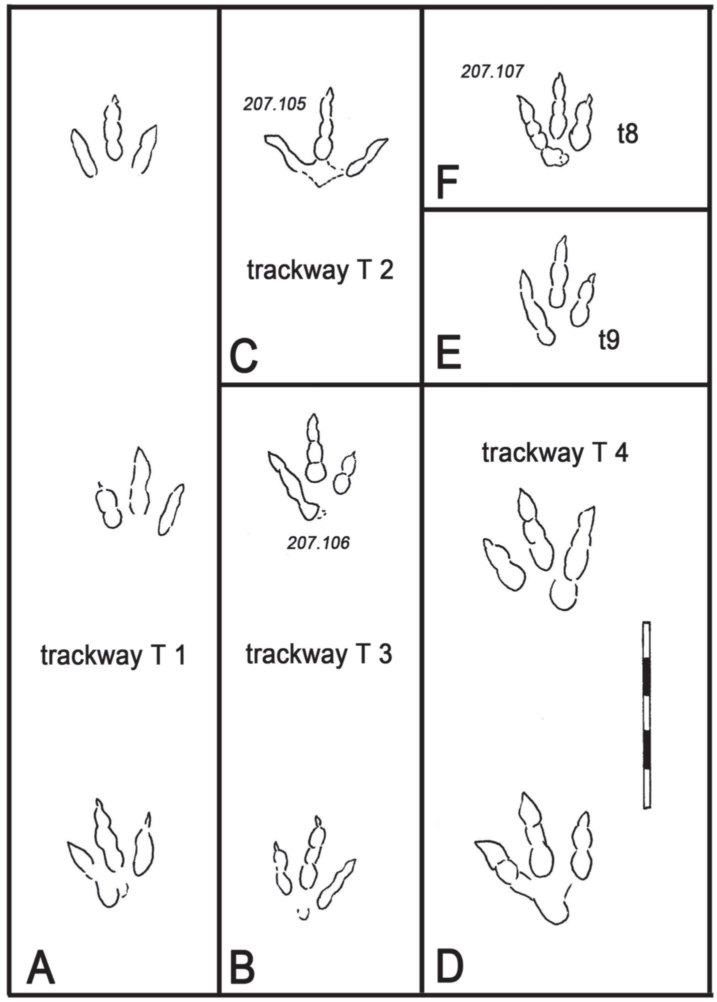


FIGURE 3. Tracings of theropod tracks and trackway segments from the Escalante Rim tracksite. A, Trackway T1, B, Trackway T3, with second track in sequence represented by UCM 207.106, C, Trackway T2 (*Magnoavipes*) represented v by UCM 207.105, D, Trackway T4, E, Track t9, F, Track t8 represented by UCM 207.107. All based on tracings T 1602 and T 1605 in the UCM collections.

### Ornithopod Tracks

A total of eight tridactyl pes tracks (O1-O8) of presumed ornithopod affinity (Fig. 5) have been recognized in five separate trackways, all of which are associated with elongate toe or tail drag traces between 50 cm and ~2 m long. Three of these tracks (O1, O2 and O3) are isolated and occur on the east end of the eastern block in association with three parallel toe drag traces 2-3 m apart (Fig. 2). Track O1 shows unambiguous continuity between the trace of digit III and the corresponding toe drag trace, strongly suggesting that the these elongate traces are not tail traces. Tracks O1-O3 are

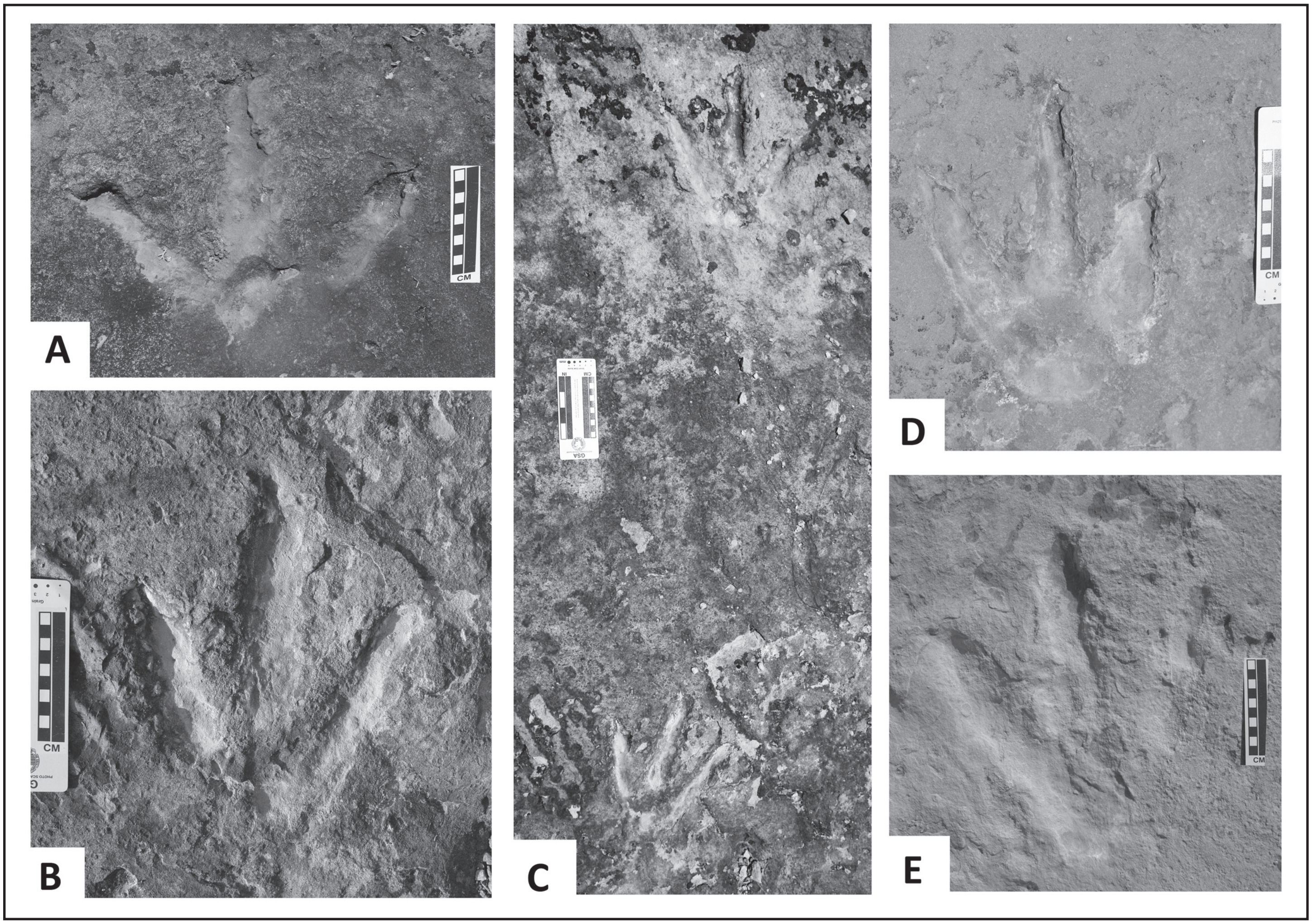


FIGURE 4. Photographs of theropod tracks and trackway segments from the Escalante Rim theropod tracksite. A, *Magnoavipes* (UCM 207.105), B, Photograph of track from trackway T1, C, Two tracks in trackway T3: second track in sequence is replicated as UCM 207.106, D, Track t8 (UCM 207.107), E, Track from trackway T4.

all poorly preserved. Tracks O4 and O5 occur in a sequence on the west end of the eastern block, and although clearly tridactyl they are also poorly preserved. Tracks O6-O8 occur in a sequence that trends from the west end of the eastern block to the east end of the central block (Fig. 5). Tracks O6 and O7 are faint, but the outline of the typical quadripartite iguanodontid track morphology is clear, and we assign these tracks to *Caririchnium* (Lockley 1987). Pes track O6 appears to be a left footprint associated with a manus track (see Fig. 5). The toe trace associated with track O8 is also in obvious contact with digit III, as in O1.

## DISCUSSION

Despite the abundance of tracksites in the Dakota Group on the Eastern and Western slopes of Colorado, we know of no other site where the theropod and ornithopod track assemblage shows the same features as recorded here. In short, this is the first report of *Irenesauripus* from the Dakota Group, and the first report of two distinct named theropod ichnotaxa at the same locality in this unit. Likewise, we are also not aware of another Dakota site where all ornithopod tracks are associated with toe drag traces. Thus, the site yields two distinctive ichnological features not previously reported from the Dakota Group.

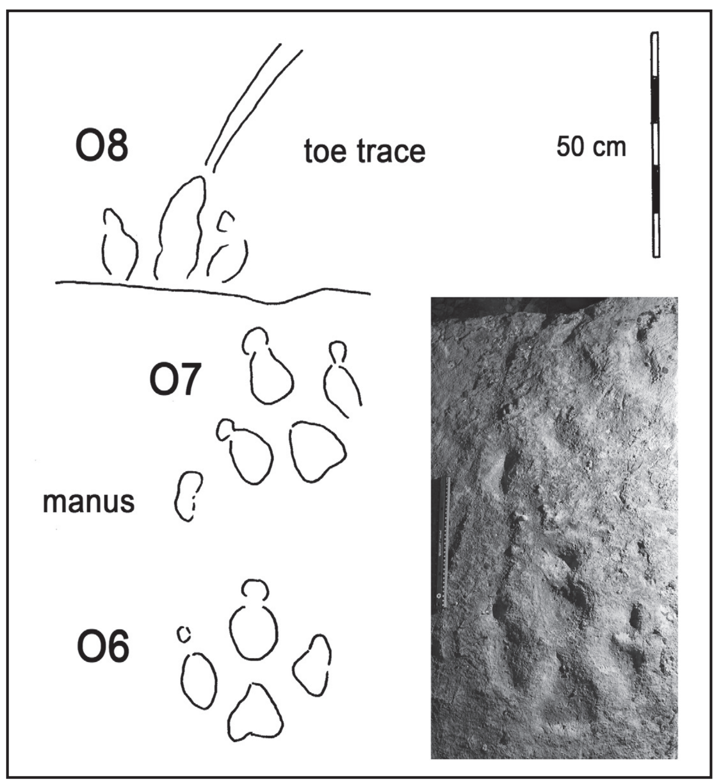


FIGURE 5. Ornithopod tracks O6-O8 from the Escalante Rim tracksite represent a single trackway with O6 and O7 on the southern block and O8, inferred to be part of the same trackway on the central block. Photo right shows O6 and O7 at same scale as line drawing (based on UCM tracing T 1603).

The differences in preservation between the deeper and clearer theropod tracks and the shallow and indistinct ornithopod tracks suggest two different phases of trackmaking. Based on the assumption that well-preserved tracks on a sandy substrate would easily be eroded by traction currents that move sandy bed load, we infer that the ornithopod tracks were made first, possibly as the current that deposited the sand was waning. Possibly then the theropod tracks were made later, as slack water deposited finer silt and mud that helped to preserve the finer details of theropod track morphology we observed.

Theropod trackway orientations indicate bimodal NNE-SSW orientations. (Fig. 2) In contrast, the ornithopod trackways show a preferred SSE orientation. This suggests some support for our inference of different timing of theropod and ornithopod trackmaker activity. However, the sample is small, and this inference is tentative.

The lack of large theropod tracks at sites on the Eastern Slope suggests there were few dinosaurian predators in this region, despite the abundance of potential ornithopod prey as evidenced from many tracksites. Although *Magnoavipes* is moderately abundant on the Eastern Slope, it represents a gracile, emu-sized trackmaker inferred to be an ornithomimid that likely did not prey upon, and may have co-habitated with large ornithopods. Thus, for Eastern Slope sites, it has been inferred that crocodylians were the major predators, which, based on track size, could well have reached 4-5 meters in body length (Houck et al., 2010; Kukihara and Lockley, 2012; Lockley et al., 2010; Lockley and Lucas, 2011). Evidence from the Escalante Rim tracksite suggests that theropods are more diverse in this region than on the Eastern Slope, and that some were significantly larger and more robust than the *Magnoavipes* track maker. This means we may reasonably infer an active predatory role for the large theropod track makers. However, track evidence of large crocodylians on the western slope (Lockley et al., this volume) indicates that this group also played a significant predatory role.

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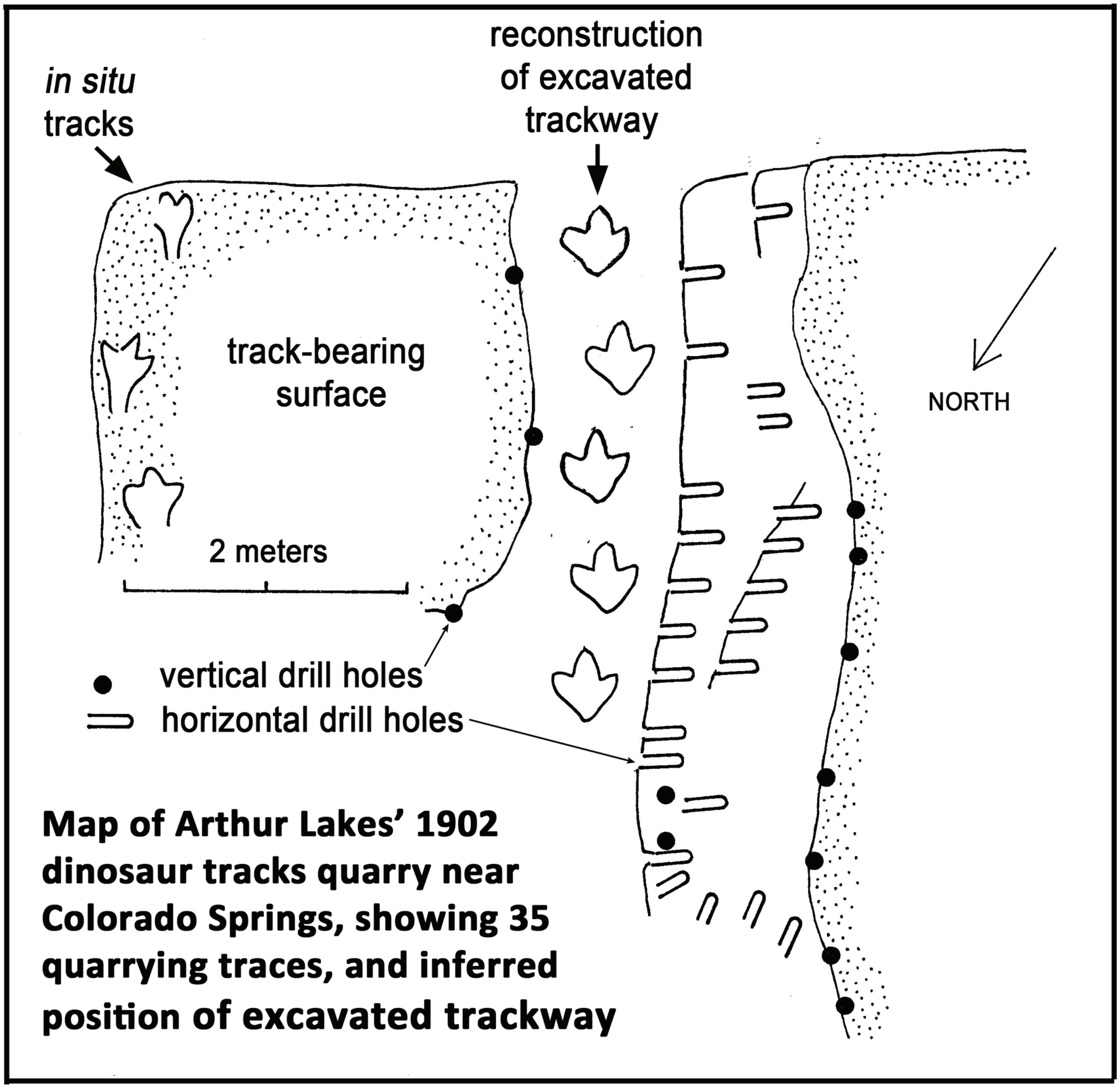


**Map of Arthur Lakes' 1902 dinosaur tracks quarry near Colorado Springs, showing 35 quarrying traces, and inferred position of excavated trackway**