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A NEW DINOSAUR TRACK LOCALITY IN THE LATE CRETACEOUS (MAASTRICHTIAN) LARAMIE FORMATION OF COLORADO

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Abstract—A newly discovered Upper Cretaceous (Maastrichtian) dinosaur tracksite in the Laramie Formation near Marshall, Boulder County, Colorado, here called the Cherryvale site, has yielded several dozen dinosaur tracks of theropods and ornithopods. Among the most abundant and distinctive are the slender-toed theropod tracks *Saurexallopus* isp. indet., which dominate the assemblage. Tracks of other theropods and large ornithopods are also present: the latter include *Hadrosauropodus.* The tetrapod trace fossils also include probable ceratopsian tracks and a few turtle swim tracks. The *Saurexallopus* isp. tracks are very well preserved in comparison with poorly preserved *Saurexallopus* isp. indet. tracks in the Laramie Formation 24 km to the south in Golden in Jefferson County. The tracks compare closely with type *S. lovei* and type *S. zerbsti* from Wyoming, as well as type *S. cordata* from British Columbia, Canada, except that most lack hallux traces. This may be due to subtle differences in preservation or a more digitigrade registration of tracks than in the named ichnospecies. This is the sixth report of *Saurexallopus* isp., from western North America, and the third from Colorado. In comparison with the other Colorado sites this is the most significant occurrence for quality of preservation and size of sample.

INTRODUCTION

The Front Range of Colorado, between the Morrison-Golden Fossil Area National Natural Landmark (M-GFANNL) and Boulder, a distance of about 30-35 km, is geologically famous particularly for its Jurassic and Cretaceous vertebrate body and trace fossils. The "mid" Cretaceous (late Albian-early Cenomanian) Dakota Sandstone Formation (Lockley and Hunt, 1995a; Lockley and Marshall, 2014, 2017) is particularly well known as a source of tetrapod tracks including ichnites attributable to avian and non-avian theropods, ornithopod dinosaurs, crocodilians and pterosaurs. These include the types of *Ignotornis mcconnelli, Mehliella jeffersoni* (Mehl 1931; Lockley 2010; Lockley et al., 2009), *Caririchnium leonardii* (Lockley 1987) and *Magnoavipes canneri* (Lockley et al., 2001), respectively attributed to a bird (avian theropod), a crocodilian, an ornithopod, and a non-avian theropod. All these types come from within the M-GFANNL.

The Upper Cretaceous (Maastrichtian) Laramie Formation has also produced tracks of avian and non-avian theropods, hadrosaurs, ceratopsians, a champsosaur, and mammals, mostly from multiple track-bearing levels within the localized area known as Triceratops Trail at Fossil Trace within the M-GFANNL. This locality has also produced the type specimens of the ceratopsian track *Ceratopsipes goldenensis*, the champsosaur track, *Champsosaurichnus parfeti* (Lockley and Hunt, 1995b), and the mammal track, *Schadipes crypticus* (Lockley and Foster, 2003). The only other named tetrapod track from the Fossil Trace locality is *Saurexallopus* isp. indet., (Lockley and Marshall, 2014, 2017). Two other less productive Laramie Formation tracksites have been documented outside the M-GFANNL, as yielding unnamed non-avian theropod, hadrosaur, and turtle tracks (Wright and Lockley, 2001).

This paper describes a new tracksite discovered in 2018 in the lower Laramie Formation. The site, here named the Cherryvale site, is located near Marshall, south of Boulder Colorado, (Fig. 1) and is the fourth Laramie Formation site discovered between Golden and Boulder (Wright and Lockley, 2001).

GEOLOGICAL SETTING

The study area, here referred to as the Cherryvale site, near Marshall, in Boulder County Colorado, represents an area of abandoned coal mines in the Late Cretaceous (Maastrichtian) Laramie Formation, in the Boulder-Weld coalfield and Boulder-Weld fault zone (Roberts, et al., 2001). The area is geologically complex from multiple faulting, which is shown as a prominent feature on the local geological map (Spencer, 1961). Additionally, coal mining operations have led to the collapse of working and burning of coal seams since the late 1880s (Lakes, 1888; Eldridge in Emmons, 1896; Roberts, et al, 2001). Consequently, there are channels or gullies aligned with collapsed workings (rooms) separated by "horsts" of Laramie Formation sedimentary strata ostensibly in situ or little disturbed. The extensive literature on the mechanisms causing the subsidence pits was reviewed by Roberts (2007, p. 31), who stated "effects related to these abandoned underground mines still linger in fields where Laramie coal was produced." These effects included coal mine fires known as Lewis Nos. 1 and 2 in the study area that Roberts (2007, figs. 24-25) illustrated with aerial photographs.

The Laramie Formation bedrock at the study site generally dips 4º to the southeast, but it is difficult to find a place where the rock layers haven't been turned, toppled, or twisted because of the faulting and underlying coal mine collapse. In addition, the undulating sandstones and siltstones which contain the track-bearing surfaces are separated by layers of mudstone that are easily undermined by erosion. Consequently, large blocks of sandstone fracture and break off, then fall into the channels above the collapsed coal workings. In short, little of the outcrop hasn't been thoroughly altered by both geological and man-made forces.

The geologic section consists of the lower beds of the Laramie Formation above the mined-out coal layers (Roberts, et al., 2001) but does not continue up section into the Arapahoe conglomerate, as in the Golden area to the south. At this site, the Laramie is overlain by lag gravels derived from Quaternary deposits that cover the mesa tops (Roberts et al., 2001).

Eldridge*, in* Emmons et al. (1896), was the first to publish a stratigraphic column showing the lithology and stratigraphy of the Laramie Formation in the study area, which was referred to as "the Marshall District," lying in what these authors referred to as the Davidson Syncline. They also commented on the effects of the fault system in breaking up the coal beds that are important

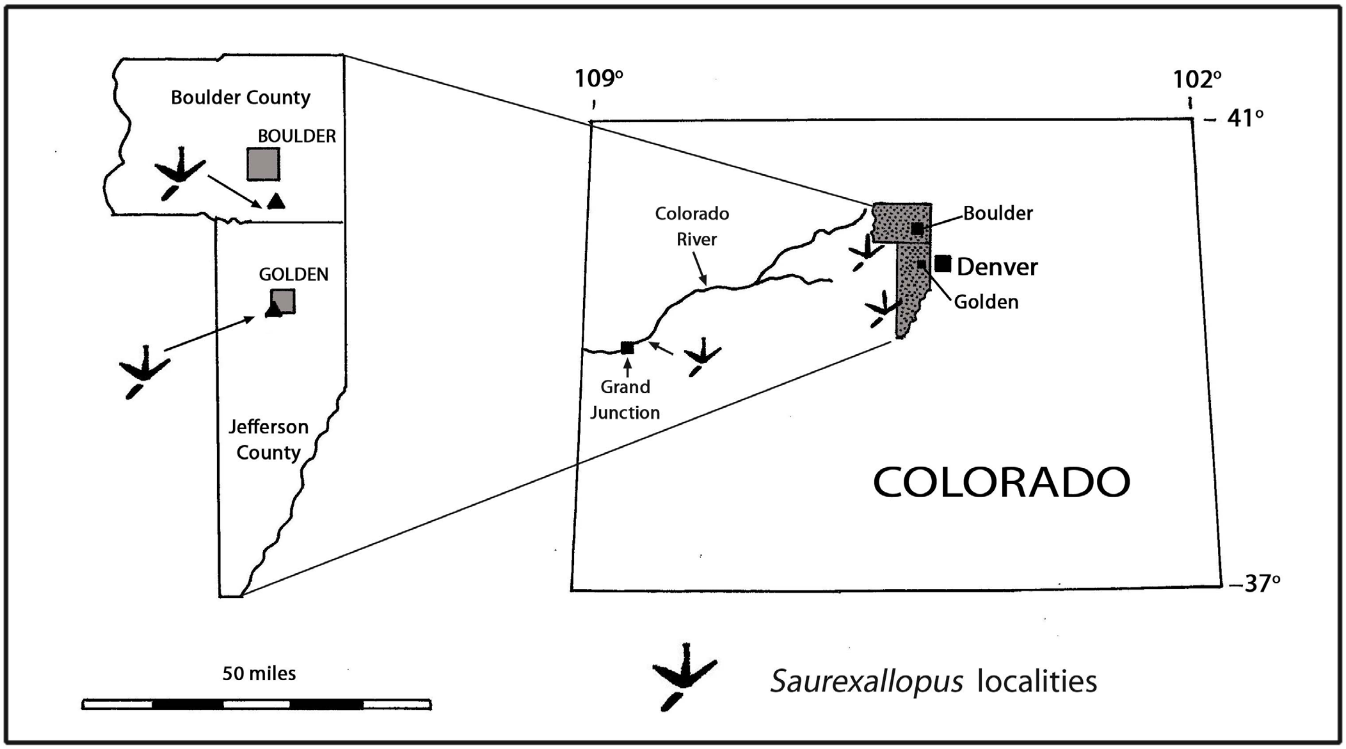

FIGURE 1. Locality map showing location of new *Saurexallopus* locality in Boulder County, and its geographical relationship to other *Saurexallopus* sites in Colorado.

stratigraphic markers (Fig. 2). Given the disturbed geology and legacy of surface and underground disruption to the bedrock, it is impossible to reconstruct completely the local Laramie Formation stratigraphy in the study area, where there are few if any stratigraphic exposures more than 2 m thick. Instead, we measured the thin (<2 m–thick) visible sections in the study area to determine the number and position of the track-bearing levels, and features of the sedimentary geology that help place the tracks in their depositional environment context (Roberts and Kirschbaum, 1995).

MATERIAL AND METHODS

The material from the Cherryvale site has yielded at least 30 diagnostic tridactyl tracks, of which 20 are attributable to theropods and at least eight to large hadrosaurs. The majority of theropod tracks occur as natural impressions (concave epireliefs) of gracile morphotypes (ichnogenus *Saurexallopus*) impressed on an exposed surface (Fig. 3) referred to as the main track-bearing surface. Natural casts (convex hyporeliefs) of large hadrosaur tracks have eroded out just below this surface. The total of ~28 diagnostic tracks is exclusive of a small number of broken casts and a much larger number of incomplete and indistinct impressions that are essentially undiagnostic. These indistinct impressions give a trampled appearance to surfaces correlated with the main track layer, and extend as discontinuous outcrops for several tens of meters from the main track-bearing surface, discontinuous because of faulting and disturbance and subsidence from historic mining activity.

Most theropod tracks on the main track-bearing surface are complete, slender-toed theropod tracks confidently assigned to ichnogenus *Saurexallopus*, with wide digit divarication (Figs. 4-6). The tracks are preserved as compressional features and or partial track infills on the surface of a bioturbated, rust-colored sandstone on which other large but poorly preserved tracks were registered. Recognizable invertebrate traces also occur on the surface of the main track site

The tracks were photographed and traced using transparent acetate film (University of Colorado Museum tracings T 1816-1820, T 1828-1829, and T 1837). Tracings were reduced to provide a map of the track-bearing surface and outline drawings of selected tracks. The *Saurexallopus* tracks were numbered T1-T5 (Figs. 5-6). A series of overlapping photographs were taken as a database for creating a 3D photogrammetric image of the most representative *Saurexallopus* track(s). Morphometric parameters of the tracks including length (L), width (W) and digit divarication angles were measured (Table 1).

A total of 12 tracks were molded and replicated or collected for the University of Colorado Museum of Natural History (UCM) and to make replicas for the City of Boulder, Open Space and Mountain Parks. Two *Saurexallopus* tracks from the main track-bearing surface were molded and replicated as specimens UCM 229.21-22 corresponding to T1.2 and T3, respectively. A third *Saurexallopus* (T 17 = UCM 229.27) was replicated from another ripple-marked surface (Figs. 4E, 5B) which we infer to correlate closely with the surface of the main site (Fig. 5A). Various loose specimens were also collected: T11, a slightly broken *Saurexallopus* track (UCM 229.23), others (Fig. 7) represent large hadrosaur pes track casts (UCM 229.24-25 and 229.29-30), a small theropod track (UCM 229.34), a probable hadrosaur manus track cast (UCM 229.28), unequivocal turtle swim tracks (Fig. 8, UCM 229. 31-32), and other swim traces UCM 229.26 and UCM 229.33. See text, Figs 2-8 and Tables 1-2 for details.

DESCRIPTION OF TRACKS AND TRACES

The *Saurexallopus* Assemblage

The main track-bearing slabs (Fig. 5A) reveals 12 complete and partial tracks, which, with one exception (T16), are attributed to *Saurexallopus*. T1.1- T 1.2 and T2.1- T 2.2 are among the best preserved, showing (tridactyl) morphology characteristic of *Saurexallopus*; i. e., with very slender widely-

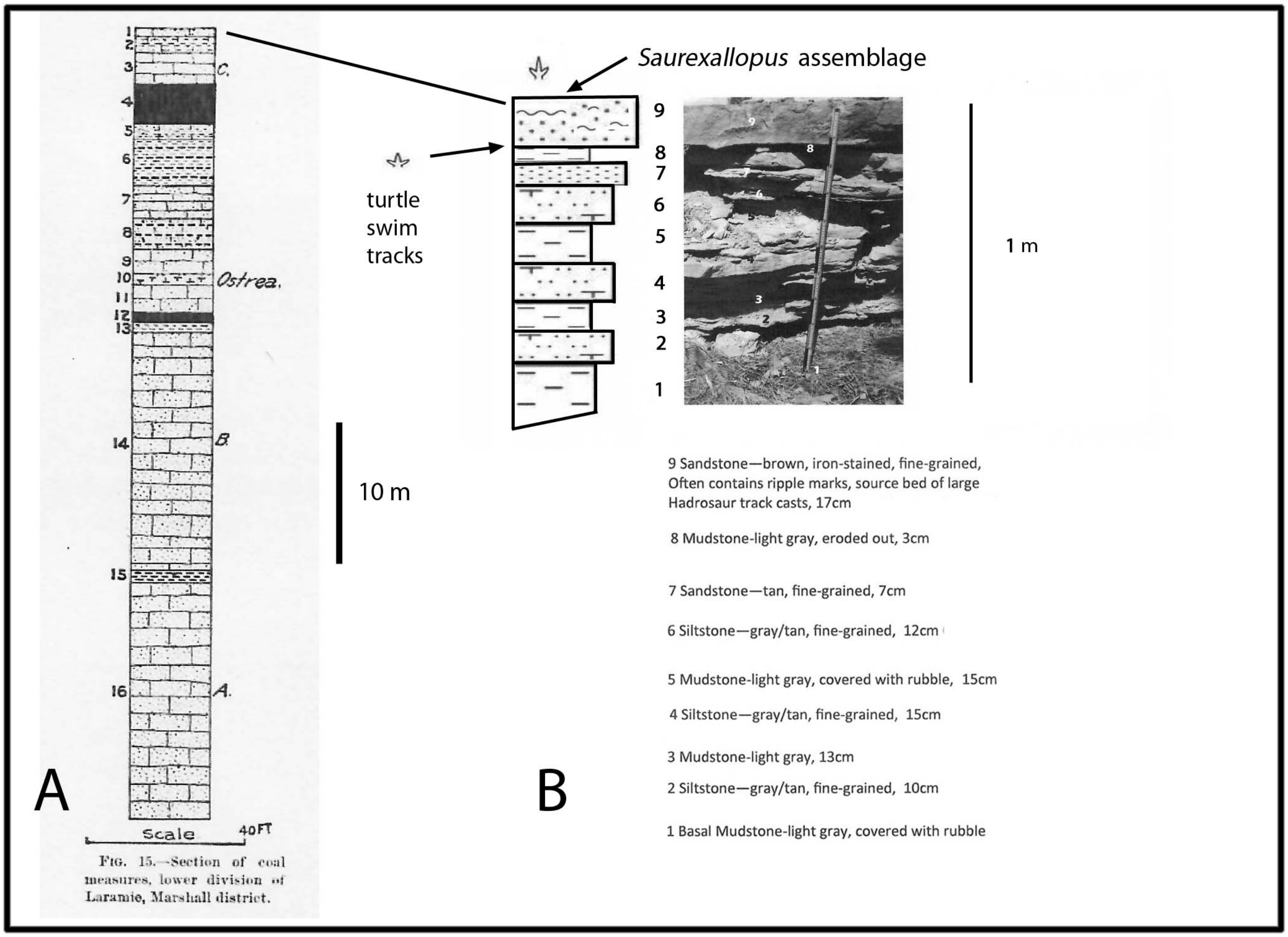

FIGURE 2. **A,** Stratigraphy of the Laramie Formation at the Cherryvale site, based on original stratigraphic column from Emmons et al. (1896) showing main coal seam near top of section (left). Track bearing units described in this study (right) occur at top of an exposed sequence. **B,** Shows detail of representative track-bearing section at top of exposed sequence at Cherryvale site, where few exposures reveal more than 1-2m of continuously exposed stratigraphy.

splayed (divaricating) digits, and may be part of two separate trackways, although this is difficult to discern because all four tracks are similar in size and orientation. However, in this sample no hallux traces have been identified. As discussed below, the lack of hallux traces in most of the sample makes naming the tracks at the ichnospecies level problematic, so we use the label *Saurexallopus* isp. indet.

The size range of *Saurexallopus* isp. is 20.5-33.0 cm for length (L) and 23.0-35.6 for width (W): mean L, W and L/W 25.6 cm, 30.6 cm and 0.84, respectively (N =10), and applies only to the tridactyl portion of the foot registered by digits II- IV in track series T1-4, 6,7, 9, 10 and 17, which are unequivocal examples of complete *Saurexallpus* providing reliable measurements. Other tracks T5, T8, T 11-16 are either poorly preserved, broken or clearly different morphotypes as described below. Digit divarication angles for digits II-IV range from 95°-116° (mean 105.1°) for seven tracks from T1-T4 and T6 series. It is difficult to distinguish left and right footprints in most cases, as there are no unequivocal trackway segments. It is possible the inferred T1.1- T1.2 pair represent a step of 82.0 cm, and the T2.1 – T2.2 pair a step of 93.2 cm, but, this is uncertain as characteristic *Saurexallopus* trackway parameters such as step, stride, angulation, rotation etc., are poorly known from previous reports: see discussion.

Although none of the tracks found on the main surface (Fig. 5) show hallux traces, a single track found on a stratigraphically lower surface and designated as track number T 17 (Fig. 4E and 5B) appears to show hallux trace. This track is 27.0 cm long and wide (L/W without hallux 1.00). The hallux is postero-medially directed and track length with hallux is 28.0 cm.

Hadrosaur Tracks

Eight large complete or near-complete hadrosaur track casts were identified during the present study. The tracks appear to occur in a layer just below the *Saurexallopus* track bearing level, and are all quite deep (Fig. 7). None of the hadrosaur track casts were found in situ due to historic disturbance by mining activity. However, we infer from their large size that none have been moved far from their points of origin. Many tracks show a series of “wrinkle” marks on the underside, often sub-parallel, to the digit outlines (e.g., Figs. 7A, F and G). These wrinkle marks form when large trackmakers press sandy, coarse sediment into softer, ductile, finer-grained sediment layers such as mud, causing the interface between the layers to expand downwards in a series of small extensional horst- and graben-like ridges aligned with the topography of the natural casts (Lockley et al. 1989, 2006; Hwang et al., 2008).

Hadrosaur track casts 1 and 5-7 clearly show a strongly bilobed heel. The mean length (L) and width (W) of tracks is 49.6 and 48.0 cm respectively (L/W 1.03). The specimen shown in Fig. 7D is associated with a semicircular manus 13 cm long, and 22 cm wide, preserved as cast UCM 229.28. Measurements

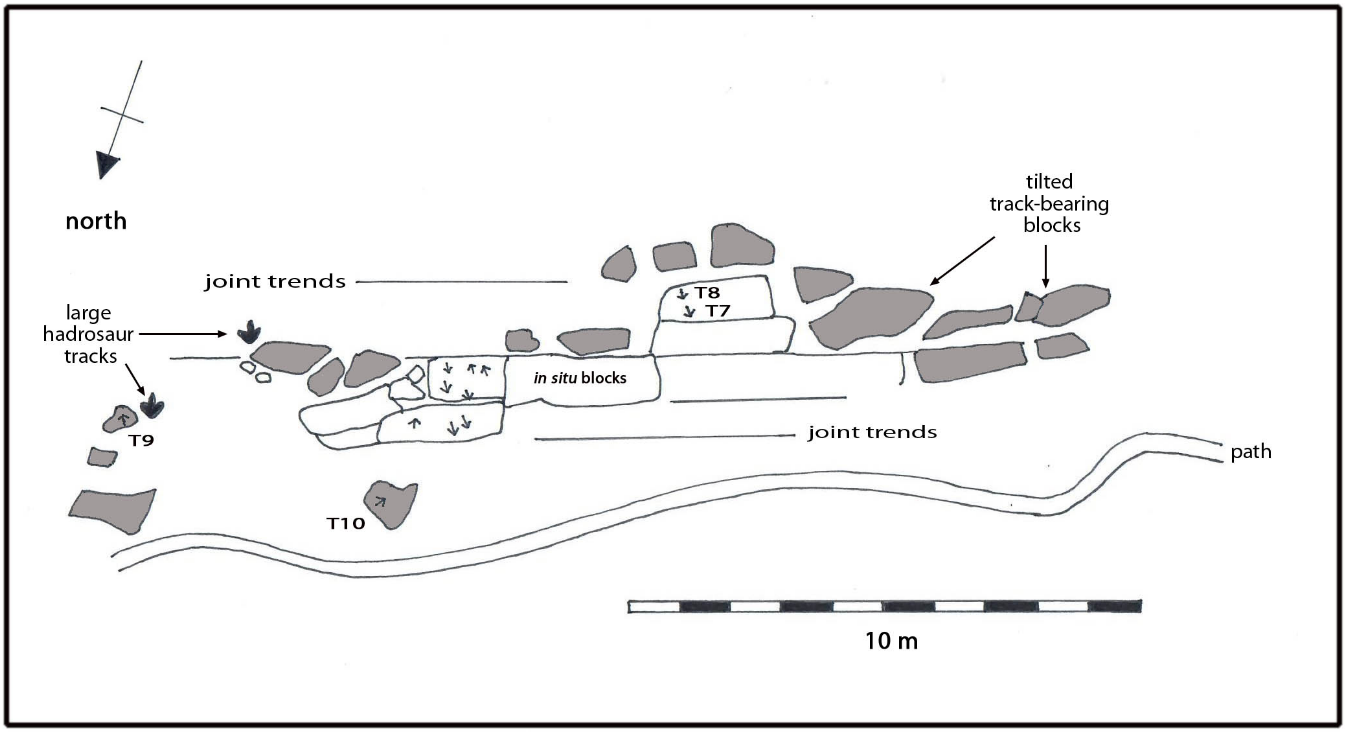

FIGURE 3 Sketch map of main track site, showing track-bearing blocks distributed over an outcrop of about 20 x 5 m (100m^2). Blocks shown in white are in situ, with little or no disturbance. Blocks shown in grey are tilted.

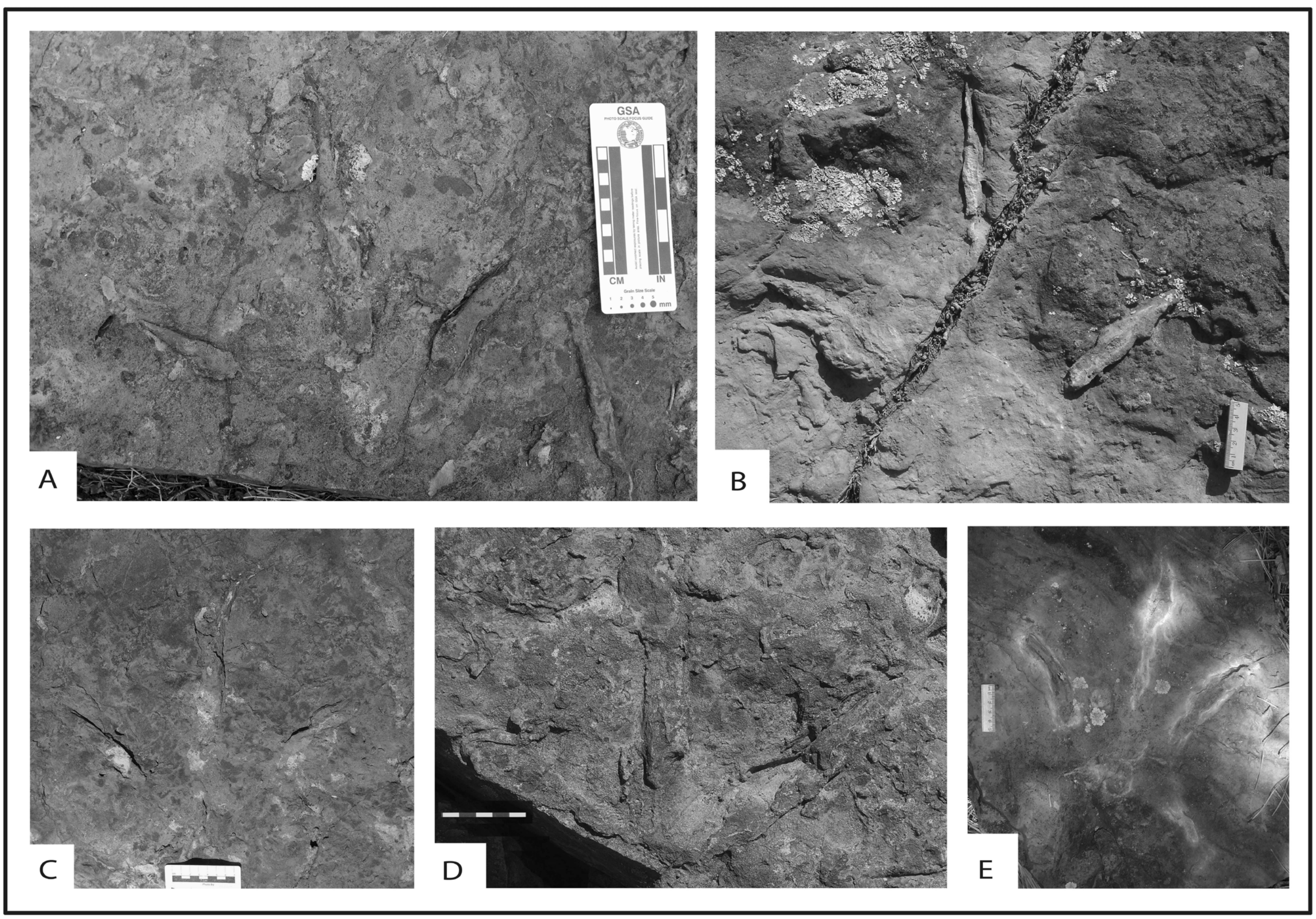

FIGURE 4. *Saurexallopus* isp. **A,** track T1.2, represented by replica UCM 229.1; **B,** track T 2.1; **C,** track T3 represented by replica UCM 229.22; **D,** track T 7; **E,** unnumbered track from lower track-bearing level. Note possible hallux; compare with Figs. 5 and 6.

TABLE 1. Track length (L), width (W), L/W and digit divarication measurements for Cherryvale sample. For tracks T1-T15, measurements (in brackets) indicate uncertain measurements. T1.2 and T3 are represented by replicas UCM 229.21 and 229.22, respectively, and T 11 is an original specimen (UCM 229.23). Divarication angles for digits II-III and III-IV, as well as for II-IV (in brackets), are given for T16 and for type specimens of *S. lovei*, *S. zerbsti* and *S. cordata.* Note that *Saurexallopus* track T 17 and T 18 are from a different area of outcrop from other *Saurexallopus* tracks, but from about the same stratigraphic levels.

Track number	left/right	Length L	Width W	L/W	Digit angles II-IV	Comments
T 1.1		24.5	32.4	0.76	105°	
T 1.2 = UCM 229.21		29.0	32.4	0.90	102°	Step 82.0 cm
T 2.1		25.0	32.1	0.90	115°	
T 2.2		25.5	31.8	0.80	95°	Step 93.2 cm
T 3 = UCM 229.22		33.0	35.6	0.93	103°	
T 4		26.0	32.5	0.80	116°	
T 5		18.0	35.5	(0.51)	(138 °)	broken track
T 6		20.5	23.0	0.89	100°	
T 7		20.5	27.4	0.75		
T 8		11.0	14.0	0.79		indet track
T 9		23.5	28.7	0.82		
T 10		28.2	30.1	0.94		
T 11 = UCM 229.23		26.0	(22.6)	(1.15)		broken track
T 12		36.0	31.7	1.14		indet. track
T 13		21.5	24.5	0.88		indet track
T 14		-	-			
T 15		19.0	18.0*	1.06		? with hallux
T 16= UCM 229.34	right	17.4	15.0	1.16	- 43° - 43° (88°)	indet. track
mean values for T10 - T16		**25.6 N = 10**	**30.6 N = 10**	**0.84 N = 10**	**105.1° (N= 7)**	
T 17 = UCM 229.27	left	26.0	26.0	1.00	75°	with hallux
T18		27.0	27.0	1.00		
S. lovei	right	28.4	31.5	0.90	-40° - 52° (92°)	
S. zerbsti	left	30.0*	30.0	1.00	-43° - 40° (83°)	*L = 35.0 with hallux
S. cordata	right	28.5	21.4	1.33	-23° - 34° - (57°)	
Mean for named ichnospecies		**29.0**	**27.6**	**1.05**		

TABLE 2. Hadrosaur track morphometrics from the Cherryvale site. *Measurements in brackets are uncertain due to sub-optimal or incomplete preservation of specimens.

Track identification label	Length (L)	Width (W)	L/W	Depth
hadrosaur track 1 Fig 7A UCM 229.24	60.0	60.0	1.00	15.0
hadrosaur track 2 Fig 7B UCM 229.25	38.0	46.0	0.83	10.0
hadrosaur track 3 Fig 7C	(42.0)*	45.0	(0.93)	
hadrosaur track 4 Fig 7 D associated ?manus	47.0	47.0	1.00	
hadrosaur track 5 Fig 7 E UCM 229.29	55.0	46.0	1.20	
hadrosaur track 6 Fig 7F	(35.0)*	46.0	(0.76)	
hadrosaur track 7 Fig 7G UCM 229.30	48.0	46.0	1.04	
Mean values	**49.6 (N=5)**	**48.0 (N=7)**	**1.03**	

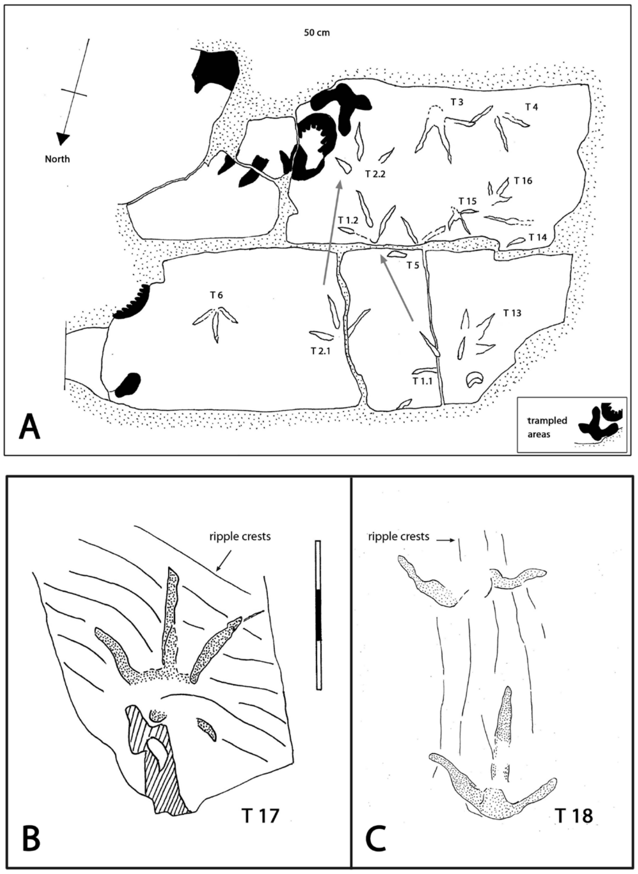

FIGURE 5. **A,** map of slab with complete and partial *Saurexallopus* tracks (T1-T6), other tridactyl tracks (T13-16) and trampled areas. For tracks T 7-T 12 see Fig. 3 and Table 1; **B,** tetradactyl *Saurexallopus* track T 17 impressed on ripple marks (UCM 229.27), compare with Fig. 4E. Cross-hatched area indicates large indentation; **C,** tracing of tridactyl *Saurexallopus* track T 18 on ripple marked surface

for seven tracks (hadrosaur tracks 1-7) are given in Table 2. The well-preserved tracks, especially 6 and 7 (Table 2), are attributed to ichnogenus *Hadrosauropodus* (Lockley et al., 2004).

We have observed at least three large, but incomplete, blunt-toed tracks, two preserved as natural impressions and one as a cast. These are not obviously hadrosaur track casts, and thus we infer they may be of ceratopsian origin. However, none are sufficiently complete or well preserved to warrant illustration or further description here.

Turtle Tracks

Several sets of scratch marks preserved as natural casts (convex hyporelief) are interpreted as a turtle swim tracks (Fig. 8). The most unequivocal examples are UCM 229.31 and UCM. 229.32, which were found in situ as natural casts on the underside of a channel sandstone infilling underlying shale. The larger of these two tracks (UCM 229.31, Fig. 8D) is tridactyl, 4.5 cm long, 6.5 cm wide and 1.2 cm deep, with typical "posterior overhangs" (sensu McAllister, 1989, p. 343), caused by the pushing back of the foot as it dug into the substrate. This configuration is typical of swim tracks. Another smaller tridactytl track is 2 cm long and 3.5 cm wide. Two other specimens UCM 229.26, and UCM 229.33 have different configurations. However, these where not found in situ, so contextual evidence is lacking. UCM 229.26 (Fig. 8C) consists of three narrow, sub parallel scratch marks each ~ 3 mm wide. The maximum width of the trace is 4.8 cm and the maximum length is ~ 11.5 cm. UCM 229.33 (Fig. 8E) is tetradactyl with each digit trace getting longer from left to right in natural impression (concave epirelief) view, maximum length and width 11.0 and 5.6 cm respectively. This configuration is reminiscent of a lizard (lacertilian) track, somewhat similar to the tetradactyl track illustrated by Stanford et al. (2004, fig. 15). However, turtle swim tracks are inherently variable (Lockley et al., 2014) and we therefore consider that specimen UCM 229.33 could be attributed to a turtle.

Other Traces and Features

Outside the scope of this study, which is mainly focused on tetrapod tracks, are other trace fossils and sedimentary structures including invertebrate traces (Fig. 9). Just below the *Saurexallopus* and hadrosaur track-bearing levels, taken to be the highest part of the Laramie stratigraphic section exposed at

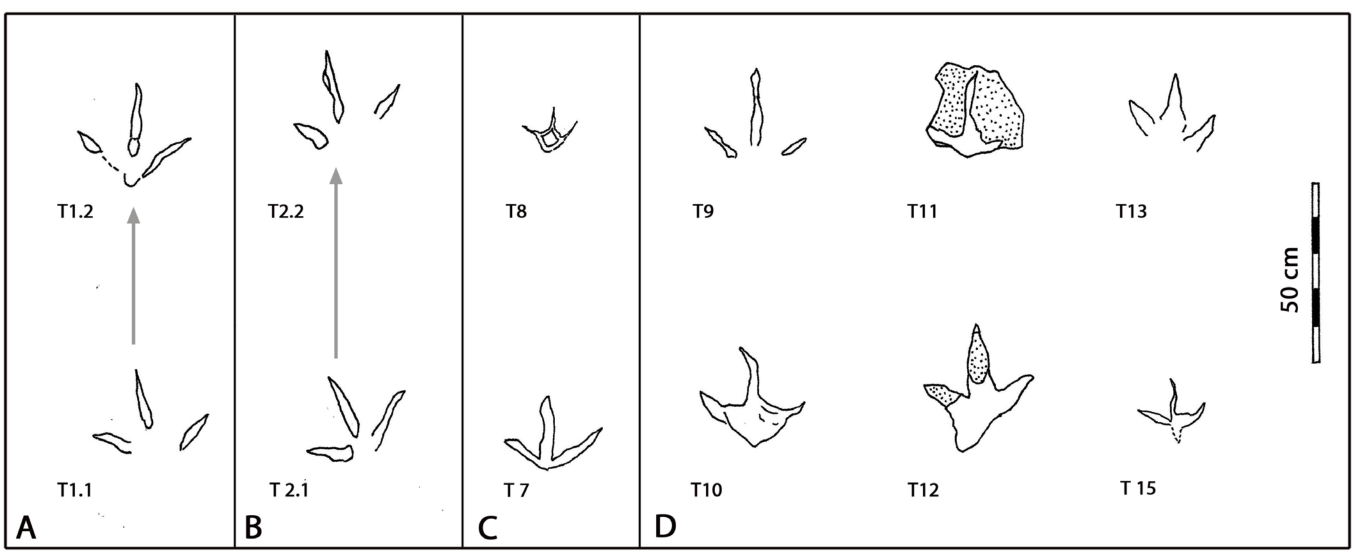

FIGURE 6. **A,** possible T1 trackway segment; **B,** possible T2 trackway segment; **C,** alignment of T7 and T8; **D**, outline drawings of isolated tracks T9-T13 and T 15. See Fig.5, table 1 and text for tracks T3-T6 and T 14

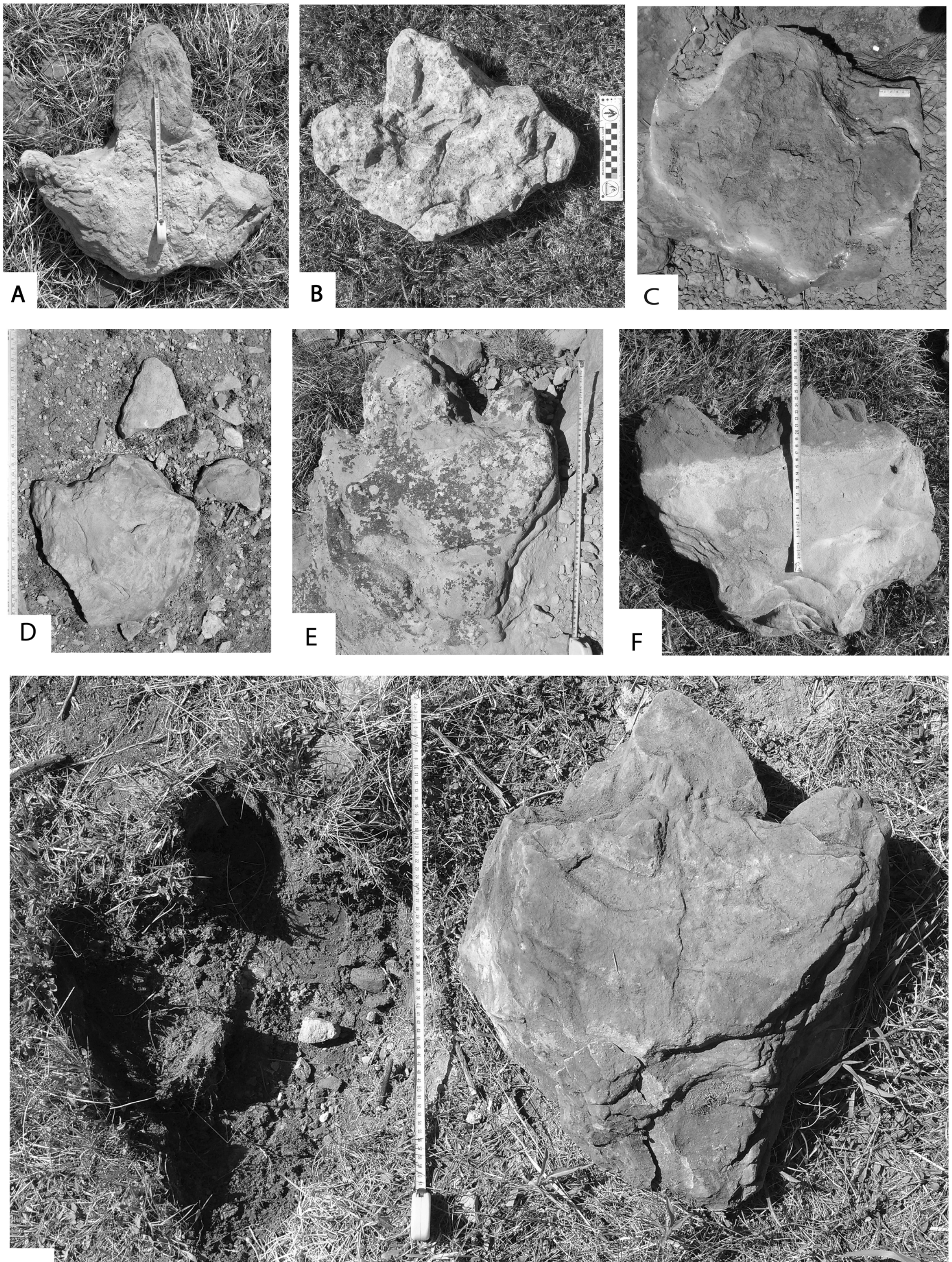

FIGURE 7. Large hadrosaur track casts. **A,** UCM 229.24, underside view, with bilobed heel trace. The toe cast on the right side is broken. Central toe cast shows wrinkle marks parallel to toe trace axis; **B,** UCM 229.25, top view. Toe cast on right side is slightly broken. Underside shows wrinkle marks similar to those seen on cast 229.24; **C,** unnumbered hadrosaur track cast; **D,** hadrosaur track cast with probable semi-circular manus cast UCM 229.28 (right) and possible broken digit III cast (top); **E,** hadrosaur track UCM 229.29; **F,** broken hadrosaur track cast, note bilobed heel; **G,** UCM 229.30, hadrosaur track cast and hole in soil from which it was removed A-C, and E-F show scales in centimeters. Scale in D is in inches.

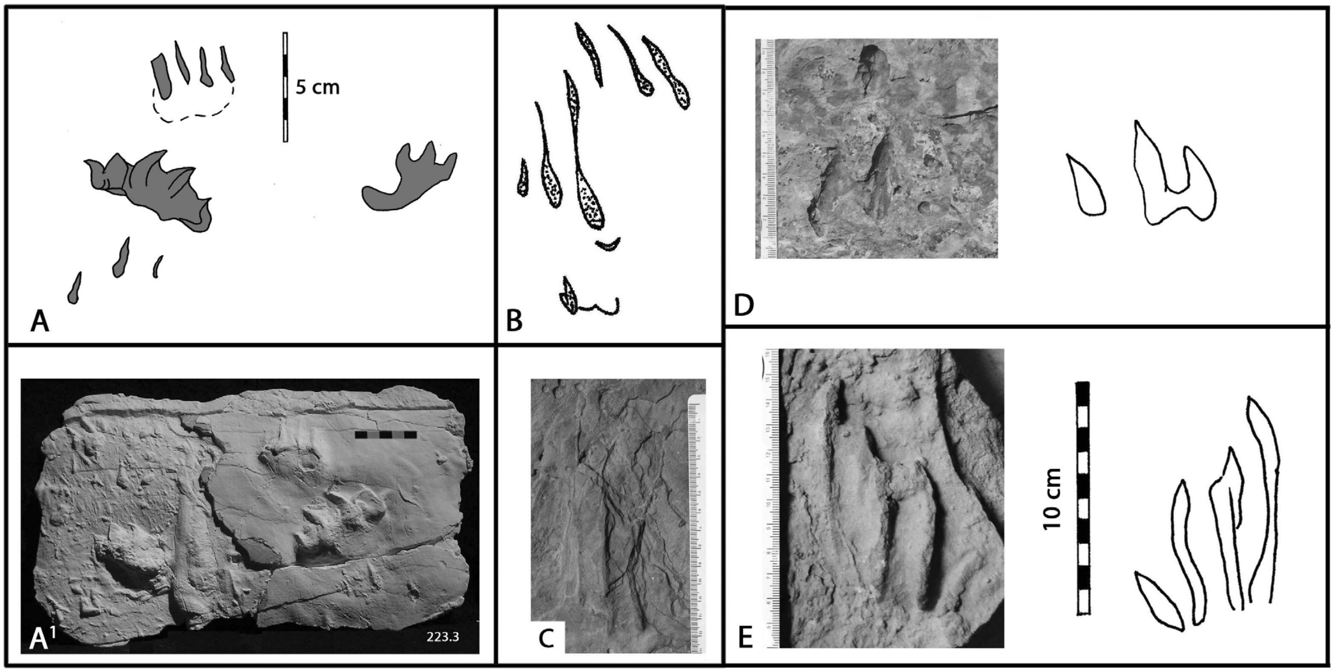

FIGURE 8. Turtle tracks from the Laramie Formation. **A,** swim tracks from the Leyden Gulch site, modified after Wight and Lockley (2001, fig. 5) to show reversal of natural cast (specimen UCM 223.3) shown in A[1]; **B,** turtle swim tracks from Fossil Trace, Modified after Lockley (2003); **C,** probable turtle swim track from the Cherryvale site; **D,** photo and reversed line drawing of tridactyl turtle swim track UCM 229.31 from the Cherryvale site; **E,** photo and reversed line drawing of tetradactyl track UCM 229.33 from the Cherryvale site.

the study site, are distinctive layers marked by circular to sub-circular impressions typically about 10-15 cm in diameter and 5- 8 cm deep (Fig. 10). They are about the size of the purported tortoise (chelonian) tracks described by Fiorillo (2005) from the Upper Cretaceous Judith River Formation of Montana. However, we cannot here state that there is agreement that these features can be attributed to chelonian trackmakers. These features will be described in a subsequent publication.

DISCUSSION

Although Lockley and Hunt (1995b, p. 600) mention that "a single tridactyl track preserved as a natural cast, was … discovered by Jerry Harris…in the vicinity of Marshall..." to the best of our knowledge tetrapod tracks have not otherwise been reported from the Marshall area, or "Marshall District" (sensu Emmons et al., 1896). As noted in the acknowledgements, Jerry Harris (written communication) has provided a brief description of the partial natural cast he discovered, but no archived photograph or specimen has come to light. Therefore, for historical reasons, our designation of the site as the Cherryvale locality distinguishes the locality described in the present report as a newly-documented site within the Marshall District.

The present study clearly shows that in order of rank abundance and quality of preservation *Saurexallopus* is the most important track type, found at the Cherryvale site followed by hadrosaurian tracks and other isolated theropod or tridactyl tracks. The significance of these tracks in relation to other local Laramie Formation sites and sites of similar age in the region are considered.

Harris et al. (1996) and Harris (1997) described and named *Saurexallopus lovei* on the basis of a sample from the Upper Cretaceous (Maastrichtian) Harebell Formation of northwestern Wyoming. This report was followed by the description of a new ichnospecies *S. zerbsi*, from the Maastrichtian Lance Formation of eastern Wyoming (Lockley et al., 2004) and reports of the ichnospecies *S. cordata* from the Upper Campanian to Lower Maastrichtian Wapati Formation of British Columbia (McCrea et al., 2014a,b). A track labelled cf. *Saurexallopus* reported from the Maastrichtian of Poland (Gierlinski, 2009) is the only tentative report of this ichnogenus from outside North America. The differences between the three named North American ichnospecies, all based on small samples, are subtle and based largely on variable digit divarication angles. According to the suggestion of Gierlinksi and Lockley (2013), the *Saurexallopus* trackmaker may have been a large oviraptosaurid. Prior to the naming of the latter two ichnospecies (*S. zerbsti* and *S. cordata*), poorly preserved *Saurexallopus* had been recognized in the Laramie Formation at Golden, Colorado. Although these were only later named in print as *Saurexallopus* (Gierlinksi and Lockley, 2013; Lockley and Marshall, 2014, p.33, 2017, p. 36), they are important as a fourth occurrence, and based on a published map (Lockley 2003, fig. 34) at least a dozen poorly preserved tracks occur, none in recognizable trackways. Recently a fifth occurrence of *Saurexallopus* was recognized in the Campanian Hunter Canyon Formation of western Colorado and listed as a component of the ichnofauna (Lockley et al., 2018), although not yet illustrated or described in detail. This ranks the Cherryvale site as the sixth known *Saurexallopus* locality in North America. Ongoing studies of tracks from a Blackhawk Formation locality in Utah, originally reported by Robison (1991), suggest that *Saurexallopus* occurs in the original collections obtained by Robison, as well as those recently obtained by the senior author. This makes the Blackhawk Formation locality the seventh such North American report: see Gierlinski (2009) for a possible European report.

The majority of well preserved in situ Cherryvale *Saurexallopus* tracks are very similar to the two ichnospecies (*S. lovei* and *S. zerbsti*) described from Wyoming, in size and digit II-IV divarication patterns (Table 1). The main difference is that most of the Cherryvale tracks lack hallux traces. This may be due to differential (more digitigrade) gait or substrate preservation conditions. *S. cordata* from British Columbia is unusual in having narrow digit divarication angles, which may reflect flexibility in the trackmaker foot: i.e., adduction of digits

FIGURE 9. Gallery of invertebrate trace fossils at Cherryvale tracksite.

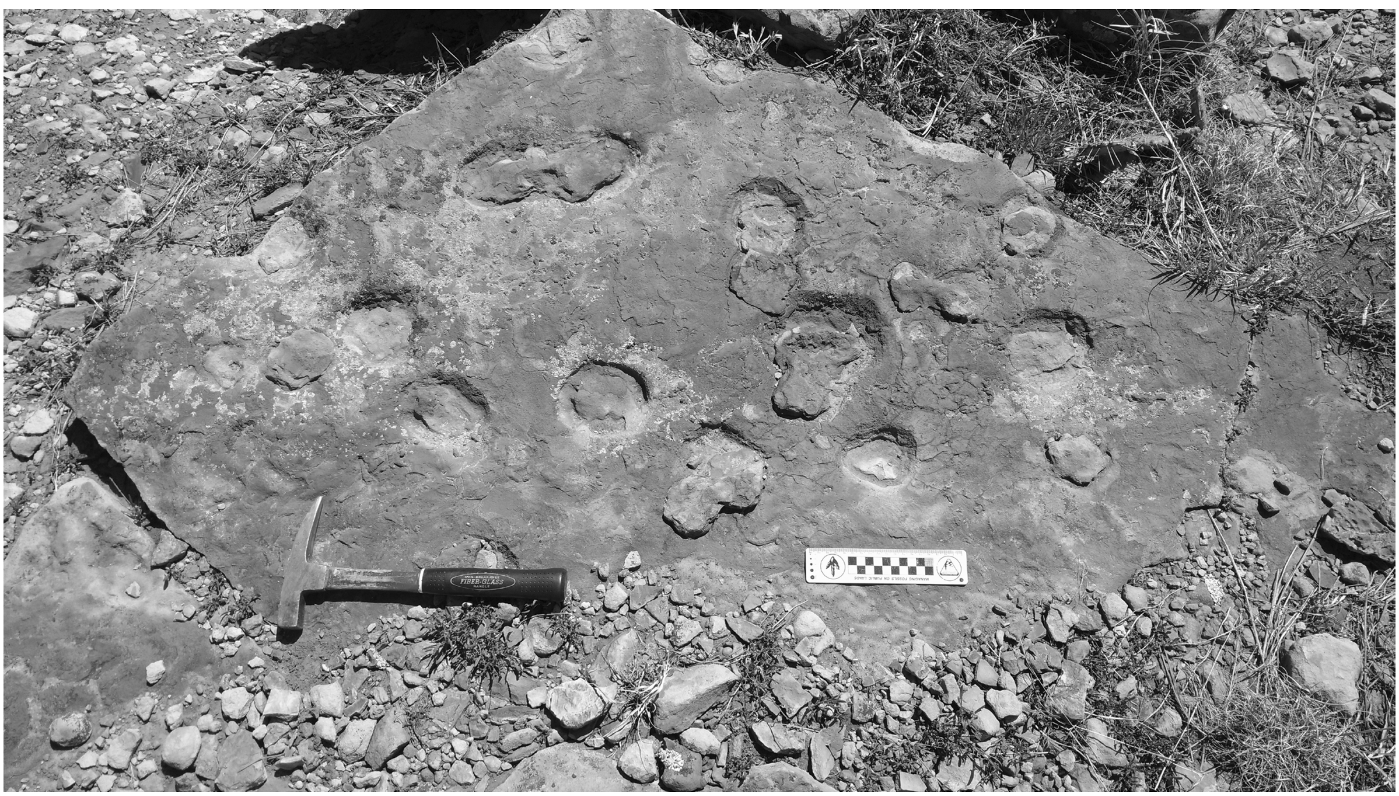

FIGURE 10. One of many slabs with circular to sub-circular indentation/traces features of uncertain attribution (see Acknowledgments).

II and IV towards digit III, which is common in avian and non avian theropods (Gatesey et al., 1999). However, the length of *S. cordata* (28.5 cm) falls close to the mean range of the Cherryvale and Wyoming specimens.

The absence of hallux traces in most tracks from the Cherryvale sample raises the possibility that the tracks might be attributed to ornithomimisaurs. As reviewed by Lockley et al. (2011), slender-toed theropod tracks with wide divarication angles are abundant in the mid Cretaceous (Late Albian to Early Cenomanian) Dakota Sandstone and equivalent deposits and have been named *Magnoavipes* (Lee 1997; Lockley et al., 2001, 2011, 2014), which Lee (1997) attributed to a large bird, as the name implies. These and similar tracks were placed in the ichnofamily Ornithomimipodidae (Lockley et al., 2011), based in part on the ichnotaxonomy of Sternberg (1926,) who named *Ornithomimipus* from the Edmonton Formation, of Canada, the dinosaur track-bearing portion of which is of Campanian to Maastrichtian age. However, none of the ichnogenera considered typical of this ichnofamily by Lockley et al. (2011), i.e., *Ornithomimipus*, *Irenichnites*, *Columbosauripus* and *Magnoavipes,* have hallux traces. Moreover, the latter three are not reported from the Campanian or Maastrichtian. Thus, we infer that the Cherryvale tracks are more likely to represent *Saurexallopus*, which is already known from the Laramie Formation only 24 km to the south. This inference assumes that the Cherryvale trackmakers did not register hallux or clear heel traces, due to a more digitigrade posture, or due to substrate preservation conditions. The inference that the tracks represent *Saurexallopus* is also consistent with the growing number of reports of this ichnogenus in the Late Cretaceous (Campanian-Maastrichtian) of western North America.

Previous studies of *Saurexallopus* have been based on isolated tracks. The first-named ichnospecies, *S. lovei* (Harris et al, 1996; Harris, 1997), was based on a sample of eight measurable tracks, none of which could be placed in trackway sequences. The holotype track of the second named ichnospecies, *S. zerbsti,* was shown to be the second of two tracks registered in a trackway sequence indicating a step of 75 cm (Lockley et al., 2004, fig. 6c). Almost no rotation of the digit III track axis was observed. *S. cordata* (McCrea et al., 2014) is based on a single track, and provides no trackway information.

Thus, the Cherryvale sample, which consists of at least 12 measurable *Saurexallopus* tracks (series T1-7, T9-11 and T17-18 series), as well as tracks T-9-11, and incomplete track T14, provides a sample of at least 14 tracks, the largest currently on record for the ichnogenus. Tracks T1.1-T1.2 and T2.1 and 2.2 are tentatively interpreted as two separate trackway segments. The tracks match well for size, but due to the aforementioned lack of clear hallux and heel traces it is difficult to determine which are the left and right tracks. There is also at least one other track (T5) with the same general orientation (Fig.5), which could be part of the inferred T1 or T2 sequence, but precise measurement of trackway parameters such as step, stride, pace angulation and footprint rotation are hampered by cracks in the track-bearing layer that separate the blocks by several centimeters.

Track T 12, which is a loose natural cast from another layer, is clearly not attributable to ichnogenus *Saurexallopus*. T 13 might be a poorly preserved *Saurexallopus*, but this is uncertain. Likewise T8 and T15 are small tridactyl tracks that are deeper than the well preserved *Saurexallopus*. They show wide digit divarication, like *Saurexallopus*, but cannot be identified unequivocally. T16 is also clearly a distinct morphotype that is more elongate than *Saurexallopus*.

As noted above, at least eight hadrosaurian track casts have been identified, several showing good preservation. All occur as casts separated from the strata from which they originated. Reliable length and width measurements are given in Table 2. We attribute these casts to ichnogenus *Hadrosauropodus* (Lockley et al., 2004).

The diversity of tracks found at the Cherryvale site can be summarized as follows (Table 3). Thus, the present study recognizes at least 30 diagnostic tracks, of which the majority represent *Saurexallopus*. There are at least two other theropod trackmakers represented (T12 and T16) as well as large hadrosaurs. This track assemblage can be compared with the assemblages found in the Laramie Formation in the Golden part of the M-GFANNL known as Fossil Trace or Triceratops Trail. As noted above, this well-known locality previously yielded poorly preserved *Saurexallopus*, as well as miscellaneous theropod tracks and hadrosaur tracks (Lockley and Hunt, 1995a,b; Lockley and Marshall, 2014, 2017). In addition, the Fossil Trace locality has yielded ceratopsian, champsosaur, and mammal tracks (Lockley and Hunt, 1995a,b; Lockley and Foster, 2003). The differences in the diversity and number of tracks found at Fossil Trace in comparison with Cherryvale are likely due in part to the greater area of track-bearing bedding planes, exposed at multiple levels at Fossil Trace. Nevertheless, the assemblage is important and provides more diagnostic information on trackmaker diversity than obtained from the two other Laramie Formation sites at Leyden Gulch, where only a hadrosaur and a few turtle tracks were found, and Broomfield where only unnamed tridactyl tracks were reported (Lockley and Hunt, 1995b; Wright and Lockley 2001, respectively). The turtle tracks reported here (UCM 229.31-32) were registered as isolated swim tracks in a channel, an occurrence similar to that reported by Wright and Lockley (2001).

Many challenges exist with the interpretation of the Cherryvale site. Not least of these is the highly disturbed nature of the stratigraphic section due to faulting and historic mining activity. As briefly noted, the site also reveals extensive surfaces with abundant circular enigmatic indentations /traces that are receiving further detailed study.

CONCLUSIONS

Although the Colorado Front Range is famous for having yielded a number of important tracksites, notably in the M-GFANNL, the present study indicates that significant tracksites may still be found in this well populated area frequented by geologists, outdoor enthusiasts and local residents.

The most significant aspects of the Cherryvale find are the occurrence, abundance and high quality of preservation of *Saurexallopus* tracks. Since their first discovery (Harris et al., 1996), three ichnospecies of *Saurexallopus* have been reported from the Late Cretaceous (Campanian-Maastrichtian). As noted

TABLE 3. Identifiable track types found at the Cherryvale site.

Track type	Number of tracks	Comments
Saurexallopus	17-18	Includes UCM 229.21-23 & 229. 27
indeterminate theropod	1	T 13
indeterminate theropod	1	T 16 (UCM 229.34)
hadrosaur	8	Includes UCM 229.24-25, 229.28-30
turtle	4	Includes UCM 229.26, 229.31-33

above, two occurrences are in Wyoming, one in Canada, and with the Cherryvale site, three additional sites are now known from Colorado, and another form Utah is under investigation. Thus, the ichnogenus appears to be typical of this time interval and quite geographically widespread.

The number of diagnostic *Saurexallopus* tracks from the Cherryvale site (up to 18 tracks) is greater than reported from any previous study. However, despite the good quality of preservation of the majority of these tracks, most lack hallux traces, which were cited as diagnostic features of the three named ichnospecies *S. lovei, S. zerbsti* and *S. cordata* from Wyoming and Canada. This does not mean that the ichnogenus cannot be recognized if hallux traces are not preserved, and in the case of the Cherryvale site one track with a hallux trace is known. It is already known that *Hadrosauropodus* is a characteristic Late Cretaceous ichnogenus (Lockley et al., 2004). Thus, the several occurrences of diagnostic hadrosaurian tracks at Cherryvale are also typical of this time interval. Likewise, the few turtle swim tracks are consistent with similar reports from two other nearby Laramie Formation sites.

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