The Abo Pass tracksite: a lower permian tetrapod footprint assemblage from central New Mexico


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INTRODUCTION

Numerous tetrapod (amphibian and reptile) footprint localities have been documented from the Lower Permian Abo Formation and correlative strata in New Mexico (Hunt et al., 2005a). One of the most prolific of these localities is the Abo Pass tracksite, first published by Lucas et al. (2001). This site is located in the Cañon de Espinoso Member of the Abo Formation just east of Abo Pass in Valencia County (Fig. 1). Lucas et al. (2001) drew attention to and documented records of the ichnogenera Amphisauropus and Varanopus at the Abo Pass tracksite, but did not completely document the tetrapod ichnofossil assemblage. Here, we provide far more thorough documentation and discuss the significance of the Abo Pass tracksite for interpreting Early Permian tetrapod ichnofacies and ichnocoenoses. In this article, NMMNH refers to the New Mexico Museum of Natural History and Science, Albuquerque.

GEOLOGICAL CONTEXT

The Abo Pass tracksite, NMMNH locality 4510 (sec. 9, T02N, R05E), is located in a 0.3- to 1.3-m-thick, thinly-bedded, fine-grained sandstone bed with extensive ripple laminae (Fig. 1). Some of the track-bearing surfaces have mudcracks and raindrop impressions indicative of subaerial exposure. This bed is laterally extensive, with a strike of hundreds of meters. In places the ripples and climbing ripples are within long, shallow trough crossbeds.

The tracksite is located ~140 m above the base of the Abo Formation in the Cañon de Espinoso Member of Lucas et al. (2005a). Indeed, the track-bearing bed is equivalent to bed 23 of the Abo type section of Lucas et al. (2005a, fig. 5). Given that the Abo Formation is ~300 m thick at Abo Pass, the Abo Pass tracksite is approximately in the middle of the formation, not in the lower part of the formation as stated by Lucas et al. (2001). Also note that Lucas et al. (2001) listed the Abo Pass tracksite as NMMNH locality 4394, but it was subsequently reassigned as locality 4510.

The Abo Formation is generally assigned a Wolfcampian age, though the upper part of the formation may be early Leonardian. At Abo Pass, the Bursum Formation, which underlies the Abo Formation, contains early Wolfcampian fusulinids (Myers,
1977). Therefore, it seems likely that the Abo Pass tracksite is of middle or late Wolfcampian age.

SYSTEMATIC ICHNOLOGY

Ichnogenus Batrachichnus Woodworth, 1900

Batrachichnus salamandroides (Geinitz, 1861)

Fig. 2A-B

Referred specimens: Three slabs with multiple tracks from NMMNH locality 4510, one in concave epirelief (NMMNH P-31344) and two in convex hyporelief (NMMNH P-31325, 31355a).

Description: The tracks from Abo Pass that we assign to Batrachichnus are the tracks of a small quadruped in which pes length is less than 20 mm. The pentadactyl pes track is plantigrade to semiplantigrade, digit imprints I-III are closely grouped, and they increase in length from I to IV . Digit imprint IV is longest, and digit imprint V is posterior to the other digit imprints. The manus track is tetradactyl, semiplantigrade and smaller than that of the pes. The digit imprints on the manus track increase in length from I to III, and digit imprint IV diverges laterally. No body or tail drag impressions are evident.

Comments: Batrachichnus is not abundant at the Abo Pass tracksite. Most are poorly preserved undertracks that are plantigrade, with short, thin digit imprints and/or are tetradactyl manus tracks, all justifiably assigned to B. salamandroides (cf. Hunt et al., 1995; Haubold et al., 1995; Voigt, 2004; Lucas et al., 2005b, c). Batrachichnus is the trackway of a small temnospondyl amphibian.

Ichnogenus Amphisauropus Haubold, 1970

Amphisauropus kablikae (Geinitz and Deichmüller, 1882)

Figs. 3-4

Referred specimens: Thirty-seven slabs with multiple tracks from NMMNH locality 4510, 25 in concave epirelief: NMMNH P-31309, P-31316, P-31317, P-31322, P-31323, P-31326, P-31330, P-31331, P-31336–P-31339, P-31342, P-31343, P-31345, P-31349, P-31445, P-31446, P-31663, P-31665, P-31672, P-31673, P-33299, P-33306, P-33307; and 12 in convex hyporelief: NMMNH P-31310, 31312, P-31313, P-31333, P-31318, P-31319, P-31335b, P-31340, P-31443, P-31667 and P-31674.

Description: Both manus and pes tracks are pentadactyl. Pes digit imprint IV is the longest, and digit tip imprints are generally rounded. Both manus and pes tracks are wider than long (average length x width = 55 mm x 35 mm). Manus tracks slightly smaller than pes tracks, and variaration between pes digit imprints I and IV ~ 130°. Trackways (Fig. 4) are those of a quadruiped in which manus tracks are rotated medially and pes tracks are parallel to the direction of travel.

Comments: These tracks are readily referred to Amphisauropus (Lucas et al., 2001). Lucas et al. (2001) referred these tracks to A. latus, but we assign them to A. kablikae, following Voigt (2004), who considered A. latus Haubold, 1970 to be a junior

subjective synonym of A. kablikae (Geinitz and Deichmüller, 1882). Amphisauropus is interpreted as the footprint of a Seymouriamorph.

There is a wide range of extramorphological variation in the footprints assigned to Amphisauropus from NMMNH locality 4510 (Figs. 3-4). This range of variation encompasses specimens from the site assigned (without description) to Gilmoreichnus hermitanus and Hydroichnus sp. by Lucas et al. (2001), and the single specimen (NMMNH P-31333) illustrated and assigned to Ichno-therium cottae by Hunt et al. (2005b, fig. 2D). This specimen is small (52 mm long), has a very short digit imprint V, straight digit imprints (not curved toward the midline) and lacks expanded digit tip imprints, characteristics that distinguish it from Ichnoetherium (e.g., Voigt and Haubold, 2000; Voigt, 2004; Voigt et al., 2007). Instead, we identify this footprint as Amphisauropus.

Footprints assigned to Limnopus by Lucas et al. (2001) were not explicitly listed by specimen number, but the ichnogenetic identification was based on undertracks with rounded digit tip imprints, some of which are tetradactyl, that we identify as Amphisauropus (e.g., Fig. 3C). We infer that the single trackway of Amphisauropus mapped here (Fig. 4) has such undertracks, and also has footprints with pointed digit tip imprints (Fig. 3B, D). These were the basis for identifying Gilmoreichnus (Lucas et al., 2001). We abandon this identification as well as the identification of Hydroichnus by Lucas et al. (2001) based on specimens such as NMMNH P-31324 (Fig. 3F), which we re-interpret as lengthy digit drags associated with an Amphisauropus track (cf. Lucas et al., 2001, fig. 5). Thus, the Abo Pass sample of Amphisauropus shows a wide range of extramorphological variation (also see Lucas et al., 2001, figs. 2-5), well demonstrated by NMMNH P-31343, the trackway mapped here (Fig. 4).

This trackway (Fig. 4) preserves eight somewhat incomplete manus-pes track pairs, with a trackway width of 230 mm, strides that range from 180 to 230 mm, pace range of 90 to 130 mm and an average pace angulation of ~40° (measuring protocol according to Leonardi, 1987, pl. 1). Pes and manus tracks are all plantigrade, but digit imprint counts range from three to five, and digit tip imprints range from rounded and slightly expanded distally to distally pointed. Digit imprint shapes are either straight or variously curved. Manus tracks are usually rotated medially towards the trackway midline, but there is some variation in this, and in the degree of overstepping of pes and manus tracks. All of these variants in manus and pes track shape and orientation are part of a single individual’s trackway, and thus are indicative of considerable extramorphological variation in Amphisauropus from the Abo Pass tracksite (also see Lucas et al., 2001).

Ichnogenus Dromopus Marsh, 1894

Dromopus lacertoides (Geinitz, 1861)

Fig. 2D

Referred specimens: Eight slabs with multiple tracks from NMMNH locality 4510, two slabs in concave epirelief: NMMNH P-31315 and 31350; and six slabs in convex hyporelief: NMMNH P-31304, 31306, 31311, 31320, 31328 and 31444.
**FIGURE 2.** Selected tetrapod footprints from NMMNH L-4510. 

**A-B.** *Batrachichnus salamandroides*, A, NMMNH P-31325, digit tip impressions in convex hyporelief, B, NMMNH P-31335, small isolated track in convex hyporelief. 

**C.** *Varanopus curvidactylus*, NMMNH P-31347, isolated track in concave epirelief. 

**D.** *Dromopus lacertoides*, NMMNH P-31320, trampled surface in convex hyporelief. 

**E.** *Ichnototherium cottae*, NMMNH P-51593, large manus-pes pair in concave epirelief.
FIGURE 3. Selected tetrapod footprints of *Amphisauropus kablikae* from NMMNH L-4510 demonstrating the wide range of extramorphological variation. A-B, NMMNH P-31343, A, paired tracks in concave epirelief (Fig. 4, rp2 and rm2) and B, isolated track in convex hyporelief (Fig. 4, rp1). C, NMMNH P-31345, isolated track in concave epirelief. D, NMMNH P-31343, isolated track in concave epirelief (Fig. 4, rp4). E, NMMNH P-31313, paired tracks with large “sole” imprint in convex hyporelief. F, NMMNH P-31324, tracks with extended digit marks (“scratches”) in convex hyporelief.
Description: Pes tracks are 10-20 mm long, pentadactyl and are plantigrade but generally lack a “heel” imprint. Pes digit imprints are curved and increase in length greatly from I to IV. Digit imprint V is laterally or postero-laterally directed. The manus track is smaller than the pes track but similar. Most of the Dromopus tracks from locality 4510 are didactyl or tridactyl undertracks.

Comments: These tracks are readily assigned to Dromopus lacertoides based on size and morphology (cf. Haubold et al., 1995; Hunt et al., 1995; Voigt, 2004; Lucas et al., 2005b). Dromopus is widely considered to be the footprint of an aaraoescelid reptile.

Ichnogenus Varanopus Moodie, 1929
Varanopus curvidactylus Moodie, 1929

Fig. 2C

Referred specimens: Two slabs with multiple tracks from NMMNH locality 4510: one in concave epirelief, NMMNH P-33301, and the other in convex hyporelief, NMMNH P-31347.

Description: Manus and pes tracks pentadactyl and in close sets. Length and width of both manus and pes tracks approximately 20 mm. Divarication of pes digit imprints I-V is ~155°. The digit imprint lengths increase moderately from I to IV, and pes digit imprint V is as short as digit imprint I and directed outward.

Comments: The proportions and positions of the pes digit imprints, especially the relative length and laterally directed position of digit imprint V, justify assigning these tracks to Varanopus (Lucas et al., 2001). Lucas et al. (2001) only assigned these specimens to Varanopus sp., but subsequent studies of Varanopus have improved understanding of its ichnospecies, thus justifying assigning these specimens to the ichnospecies V. curvidactylus (cf. Haubold and Lucas, 2001, 2003; Voigt, 2004).

Ichnogenus Ichniotherium Pohlig, 1892
Ichniotherium cottae (Pohlig, 1885)

Fig. 2E

Referred specimens: Four slabs with single tracks in concave epirelief from NMMNH locality 4510: NMMNH P-31309, 31310, P-31314, P-31341 and P-51593.

Description: Very large tracks (up to 210 mm long) of a quadruped with pentadactyl and plantigrade manus and pes. Digit impressions are broad and rounded with blunt and broadened tips. Digit lengths increase from I to IV, and digit V is as long as digit II. The pes imprint is longer than wide, whereas the manus imprint is wider than long, and the manus imprint is rotated medially. The pes has a very large and rounded heel (sole) impression.

Comments: These large tracks correspond well to tracks assigned to Ichniotherium cottae by Voigt and Haubold (2000), Voigt (2004) and Voigt et al. (2007). The inferred trackmaker of Ichniotherium is a diadectomorph.

FIGURE 4. Drawing of Amphischauropus trackway, NMMNH P-31343, with manus and pes tracks labeled. Abbreviations: l = left, m = manus, p = pes, r = right.
DISCUSSION

The Abo Pass tracksite provided the first records of Amphisauropus and Varanopus from the Lower Permian red beds of New Mexico (Lucas et al., 2001). Subsequent work in the Cerros de Amado of Socorro County has uncovered more records of Amphisauropus in the Abo Formation (Lerner et al., 2003), but no additional records of Varanopus are known. One striking feature of the Abo Pass tracksite is its near total domination by footprints of Amphisauropus, a feature that distinguishes it from all other Abo Formation tracksites.

When Hunt et al. (2005a) and Hunt and Lucas (2006) drew attention to the Abo Formation records of Amphisauropus, they used the data to identify an Amphisauropus sub-ichnocoenosis within their Batrachichnus ichnocoenosis. They identified this sub-ichnocoenosis from Abo Pass to the Joyita Hills (including the Cerros de Amado) based on the presence of Amphisauropus and rare Ichniotherium. They attributed this sub-ichnocoenosis to inland fluvial settings close to mountain fronts. The Abo Pass tracksite is undoubtedly from an inland fluvial setting, approxi- mately 200 km from the shoreline of the Huco seaway to the south and very close to the Joyita uplift during the Early Permian. However, Abo tracksites to the southeast, in the northern Oscura Mountains of Socorro County, lack Amphisauropus. If sampling of these sites is considered adequate, then the geographic division between the two sub-ichnocoenoses – Amphisauropus and Batrachichnus – is in southern Socorro County.

Nevertheless, we are struck by how abundant Amphisauropus is at the Abo Pass tracksite – it is much more abundant (domi- nant) than at the other Amphisauropus-producing tracksites in Socorro County. This dominance may be anomalous, or simply the result of more seymouriamorphs (the inferred trackmaker of Amphisauropus) having been present in the Abo Pass area than at other sites in the Abo Formation in Socorro County. Such apparent anomalies in track assemblage composition are a factor that can potentially undermine ichnofacies interpretations like those of Hunt and Lucas (2006), especially if the assumption is that ichnofaunal composition is relatively consistent within an ichnocoenosis or ichnofacies in a given unit. Such anomalies may be explained as patchy paleoecological distribution of the track-making fauna or they may potentially be understood by further sampling of a large number of Abo tracksites in as many facies settings as possible. Only with such sampling can the ichnofacies models of Early Permian tracksites advocated by Hunt and Lucas (2006) be fully evaluated.

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REFERENCES