

1 **The oldest vertebrate trace fossils from Comb Ridge (Bears Ears Region, southeastern**
2 **Utah)**

3
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11 **Abstract**

12 Vertebrate trace fossils are common in Upper Triassic deposits across the American
13 southwest. These ichnofauna are dominated by *Grallator*, *Brachychirotherium*, and
14 *Pseudotetrasauropus* and lack ichnotaxa traditionally considered to be Early Jurassic in age,
15 such as *Eubrontes* and *Anomoepus*. While known from Indian Creek and Lisbon Valley,
16 vertebrate trace fossils have not been previously reported from Comb Ridge. This is despite
17 lithostratigraphic work having been conducted at the elsewhere-fossiliferous “Big Indian Rock
18 Beds” at the US Highway 163 roadcut since the 1990s. 2016 fieldwork by the Museums of
19 Western Colorado: Dinosaur Journey recovered two sandstone slabs that had been dislodged
20 from a river channel sand in the Church Rock Member of the Chinle Formation. The slabs
21 preserve the first documented vertebrate trace fossils from Comb Ridge: a single pes impression
22 of the ichnogenus *Grallator*, and several manus and at least one pes impression of a small
23 archosaur. We tentatively refer this second track set to the ichnogenus *Brachychirotherium*.
24 Taken together, these specimens provide evidence for a more diverse vertebrate fauna in the
25 Church Rock Member of the Chinle Formation at Comb Ridge than indicated by the body fossil
26 record.
27

28 Institutional Abbreviations: MNA, Museum of Northern Arizona; MWC, Museums of Western
29 Colorado
30

31 **Introduction**

32 The Chinle Formation at Comb Ridge, Utah has received only cursory paleontological
33 and geological research in the past century (Stewart et al., 1972; Lucas et al., 1997; Molina-
34 Garza et al., 2003; Martz et al., 2014; Gay and St. Aude, 2015). Ongoing fieldwork by teams
35 lead by RG have begun documenting numerous fossil localities in the Chinle Formation across
36 the western face of Comb Ridge, but until recently these sites have either produced only
37 invertebrate (unionid bivalves and molluscs) or vertebrate remains (Gay et al., 2016). This
38 changed during the summer of 2016 when the authors discovered a new locality in the Church
39 Rock Member of the Chinle Formation that preserved the first unambiguous vertebrate trace
40 fossil remains from the Chinle of Comb Ridge.

41 Unlike the Chinle Formation, the Navajo Sandstone at Comb Ridge has received
42 significant ichnological attention. This may be due in part to the easier access to exposures, as
43 the Navajo is exposed on the gently-sloping eastern face as opposed to the nearly vertical
44 western one. The tracks that have previously been identified from Comb Ridge have almost all
45 been from rocks that are firmly Jurassic in age and include a typical Jurassic ichnofauna such as
46 *Eubrontes*, *Otozoum*, and *Anomoepus*, along with Triassic-Jurassic ichnotaxa such as *Grallator*
47 (Loope et al., 2004; Lockley et al., 2006).

48 Triassic-aged rocks, such as the Chinle, Dolores, Nugget, and Wingate Formations in
49 Utah, northern Arizona, and western Colorado have produced abundant vertebrate trace fossils,
50 including those of *Grallator* (Riggs, 1904; Bunker, 1957; Parrish and Lockley, 1984; Conrad and
51 Lockley, 1986; Hamblin and Foster, 2000; Foster et al., 2001; Gaston et al., 2003; Santucci et al.,
52 2006; Milner and Lockley 2006, Hunt and Lucas, 2007; Martz et al., 2014). Comparatively
53 *Brachychirotherium* is rarer (Hamblin and Foster 2000, Sprinkel et al. 2011, Martz et al., 2014;
54 Irmis et al. 2015) though it too is known from southeastern Utah (Martz et al., 2014). These
55 ichnotaxa have traditionally been interpreted as having been made by small theropod dinosaurs
56 (Olsen et al., 1998) and aetosaurs respectively (Heckert et al, 2010), though some authors have
57 suggested that grallatoroid traces may have been made by several unrelated animals with similar
58 pedal morphology (Farlow et al., 2014).

59

60 **Materials and Methods**

61 Specimens were collected as float just below MNA Loc. 1776. Craftsman metal sliding
62 calipers and a metric tape measure were used to measure specimens. Specimens were
63 photographed using a Nikon D5200, while locality photos were taken using a Samsung Galaxy
64 S6 and a Nikon D5100. Data for the geologic map in this contribution were collected from
65 USGS Bluff SW 7.5' topographic map and aerial photography of the same, along with on-the-
66 ground observations on 6/24/2016 and 9/2/2016. The specimens described here were collected
67 under Bureau of Land Management paleontology permit UT14-001S issued to RG and are
68 repositated at the Museum of Northern Arizona.

69

70 **Locality and Geological Setting**

71 MNA Loc. 1776 is located within the "Bread Bowl" area of Comb Ridge in southeastern
72 Utah (Figures 1, 2). The entirety of the slope-forming portion of the "Bread Bowl" exposures are
73 from the Church Rock Member of the Chinle Formation and are dominated by reddish-brown
74 mudstones and shales. The embayment or bowl in the western face of Comb Ridge also has
75 several prominent ledge-forming units. The lower unit is a two-to-three meter thick reddish
76 channel sandstone with prominent vertebrate burrows filled in with white sandstone (Figure 3).
77 The second, higher ledge-forming unit is a channel-fill coquina deposit with numerous vertebrate
78 (including phytosaur) remains throughout. MNA Loc. 1776, "Rocky Mountain Oysters," is
79 located in a drainage on the north side of the bowl, below the first ledge-forming unit. The fine-
80 grained red sandstone is a match for the lithology of the lower unit but not the coquina (which
81 was represented by abundant debris at the site) nor the overlying Wingate Sandstone (which has

82 larger grain sizes and a more orange hue). The presence of mud cracks on MNA V10984, while
83 not conclusive, conforms with the presence of mud cracks on several overhanging surfaces on
84 the lower ledge forming unit. As a result, and due to the presence of likely vertebrate burrows
85 within the lower unit, we conclude that these two slabs originated from the lower ledge forming
86 unit.

87

88 **Specimens**

89 MNA V10984, a single slab containing one right pes impression referable to *Grallator*.
90 MNA V10985, a single slab containing two manus and at least one pes impressions referable to
91 *Brachychirotherium*.

92

93 **Description of Specimens**

94 MNA V10984 is a mostly complete, probable *Grallator* right pes preserved in a
95 mudcracked surface (Figure 4). The total length from heel to tip of digit III is 13.3 cm while the
96 length of digit IV is 8.0 cm. Damage to digit II occurred during collection when the block broke
97 across DII and the majority of it flaked away. Nonetheless we have measured the angle of
98 divarication between digits II and IV on MNA V10984 at ~90 degrees.

99 MNA V10984 exhibits the classic tridactyl arrangement seen in the pedal morphology of
100 many theropod dinosaurs. Although digit II was damaged during removal from the field, and the
101 highly bioturbated undertrack surface obscures clear toe pad impressions, several key features
102 point to a probably *Grallator* identification. The angle of divarication of digits II-IV at ~90cm,
103 digit III exhibiting longest measurable length, and lack of metatarsal impressions are all classic
104 *Grallator* features that align with synapomorphies of Dinosauromorpha (Brusatte et al., 2010)
105 and with *Grallator* measurements with wider-than-average angles of DII-DIV divarication
106 (Williams et al., 2006). We acknowledge the difficulty in assigning footprint ichnotaxa to
107 specific clades, especially given the preservation of MNA V10984, though here we use
108 synapomorphies as a reliable method of attributing pedal morphology to track morphology
109 (Olson, 1995, Carrano and Wilson, 2001, Brusatte et al., 2010).

110 MNA V10985 consists of two manus impressions, both moderately well preserved, not in
111 association with any pes impression. There is also one well-preserved right pes impression,
112 though the individual digit pads cannot be discerned within the impression and digit I is
113 faint/incomplete. A second, possible pes impression (side indeterminate) is also present that
114 preserves impressions of digit II and digit III (Figure 5) with a total preserved length of ~8.2 cm
115 as measured along the longest preserved digit. Manus 1, a probable right manus, measures 2.47
116 cm in length along the longest digit and 3.4 cm in width (Figure 6), while manus 2, a possible
117 right manus, is 3.1 cm in length along the longest digit and 4.0 cm wide (Figure 7). Pes 1
118 includes a solid metatarsal impression and measures 10.65 cm from the posterior end of the
119 metatarsal to the tip of the longest digit, digit III, and a maximum width across the digits (tip of
120 DI to tip of DV) of 7.5 cm (Figure 8). P2 is difficult to measure, owing to its incomplete
121 preservation and faint impression. These indicate that it may be an undertrack from a surface
122 “above” the track surface exposed on the block.

123 Overall both P1 and M1 compare very favorably to those figured as *Brachychirotherium*
124 by Heckert et al. (2010), though they are roughly 50% smaller (Figure 9, 10) and generally
125 conform to the morphology of known *Brachychirotherium* tracks in that the pes has five digits
126 with DI being set posterior to DII-V and DIII being the longest of the five pedal digits. It is
127 worth noting that MNA V10985 also possesses features characteristics of manual and pedal
128 morphology seen in basal dinosauromorphs, such as a straight posterior margin of the manus and
129 parallel digits (Brusatte et al., 2010).

130

131 Discussion

132 While both MNA V10984 and V10985 are clearly referable to the ichnogenera
133 *Brachychirotherium* and *Grallator*, respectively, there are noticeable differences between the
134 Comb Ridge specimens and those reported elsewhere. MNA V10985 represents a smaller and
135 more gracile version of *Brachychirotherium* compared to similar tracks seen elsewhere in
136 Triassic rocks of Utah (Hamblin et al. 2000; Sprinkel et al. 2011; Martz et al. 2014; Irmis et al.
137 2015). We hypothesize that these two differences are likely related. A smaller, more gracile
138 animal would have less weight to impress on each digit, reducing the disturbance to the
139 substrate.

140 MNA V10984 is likewise different from other *Grallator* tracks reported elsewhere in the
141 state of Utah. The LDS tracksite (Williams et al., 2006) *Grallator* tracks have angles of
142 divarication between 62 and 108 degrees between DII and DIV, which is generally larger than
143 most *Grallator* specimens. Hitchcock's *Grallator* specimens have DII-DIV divarication angles
144 of 26 to 46 degrees (Hitchcock, 1858, Lull, 1953). Williams et al. (2006) conclude that the wide
145 variation in the angle of divarication between digits II and IV seen in many specimens of
146 *Grallator* are due to the interactions between the animal's foot and the substrate, as proposed by
147 other authors (Gatesy et al., 1999, Milan and Bromley, 2005, Milan, 2006). This may explain the
148 relatively wide spread of DII-DIV in MNA V10984. This seems likely as the mud cracks present
149 in the slab also cross the track surface (Figure 10), indicating that the track was made while the
150 surface was saturated.

151 Both MNA V10984 and V10985 are significant because they are likely to have been
152 made by taxa that are not represented by body fossils thus far at Comb Ridge. Although there has
153 been recent acknowledgement of similarities between basal suchian and dinosaurian pedal
154 morphology and - potentially - their corresponding tracks (Farlow et al., 2014), traditionally
155 *Grallator* is considered to have been made by a gracile theropod dinosaur (Lull, 1953; Olsen et
156 al., 1998; Gatesy et al., 1999; Milner et al., 2006; Lepore, 2007; Milner et al., 2009). The wide
157 angle of digit II to digit IV divarication in MNA V10984 rules out a basal suchian trackmaker,
158 for which forms like *Poposaurus* fall around 25 degrees (Farlow et al., 2014). Given the wide
159 DII-DIV angle of divarication and the length of digit III, both of which compare favorably to
160 *Grallator* measurements (Lull, 1953, Williams et al., 2006), we refer to this specimen as
161 probable *Grallator*. Yet, unambiguous body fossils of theropod dinosaurs, dinosauromorphs, or
162 basal suchians - all plausible grallatoroid track makers - are currently unknown from Comb

163 Ridge. Additionally no remains firmly assigned to Aetosauria - a plausible *Brachychirotherium*
164 track maker (Heckert et al., 2010, Lucas and Hunt, 2011) - have been found at Comb Ridge.

165 Although these two track blocks do not provide evidence of novel ichnotaxa, they do
166 nonetheless expand the Chinle fauna at Comb Ridge. These tracks are notable given the presence
167 of an exceptionally rich microvertebrate site close (<2 km) to MNA Loc. 1776 (Gay et al., 2016).
168 Further exploration of these ledge-forming units in the Church Rock Member of the Chinle
169 Formation around the Bears Ears area will doubtless lead to additional trace fossil localities
170 being discovered.

171

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177 assistance with permitting, Dave and Janet Gillette at the Museum of Northern Arizona for
178 repository assistance and access to specimens under their care, and Julia McHugh for her
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180 logistical support for fieldwork in the Bears Ears area in 2016.

181

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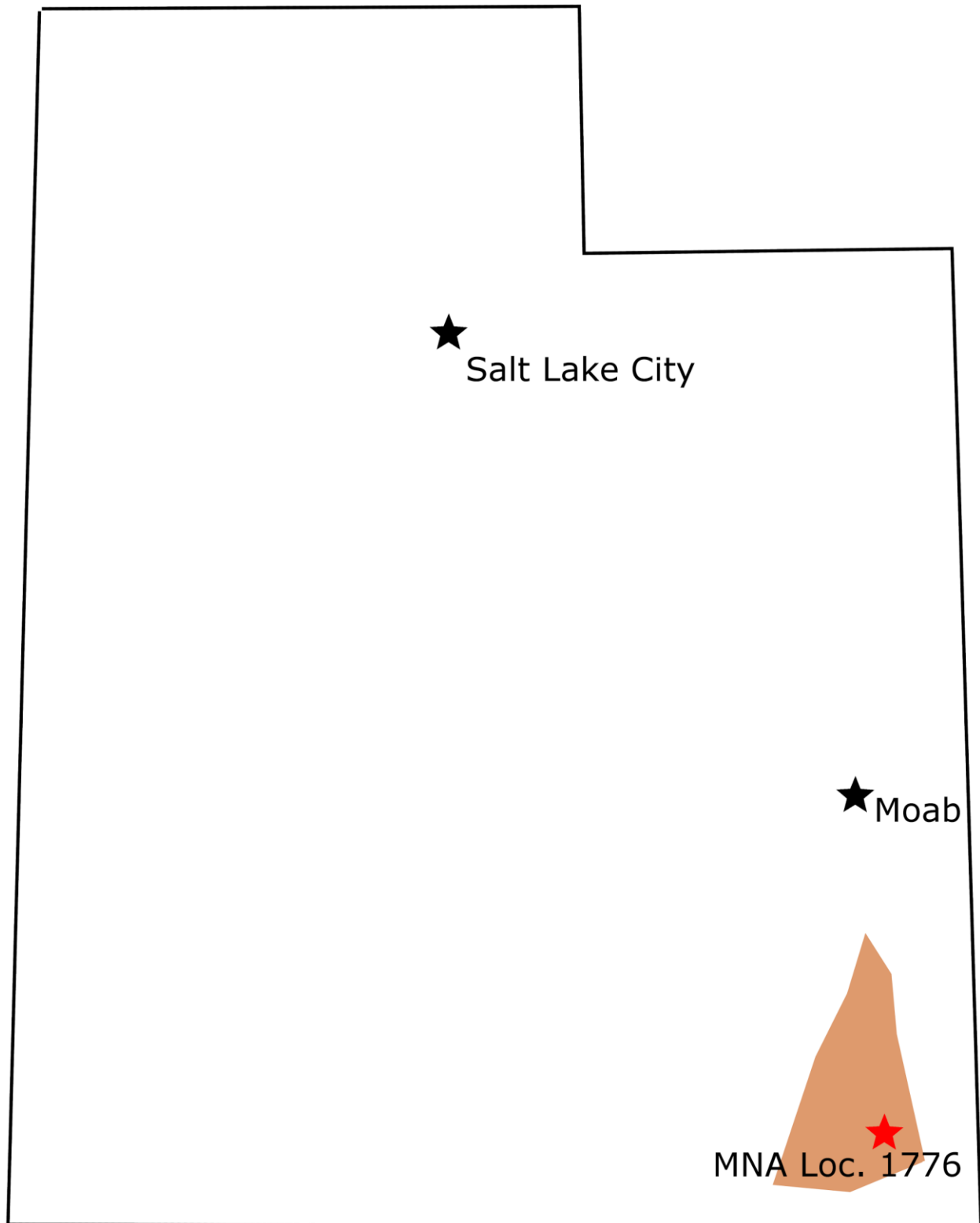
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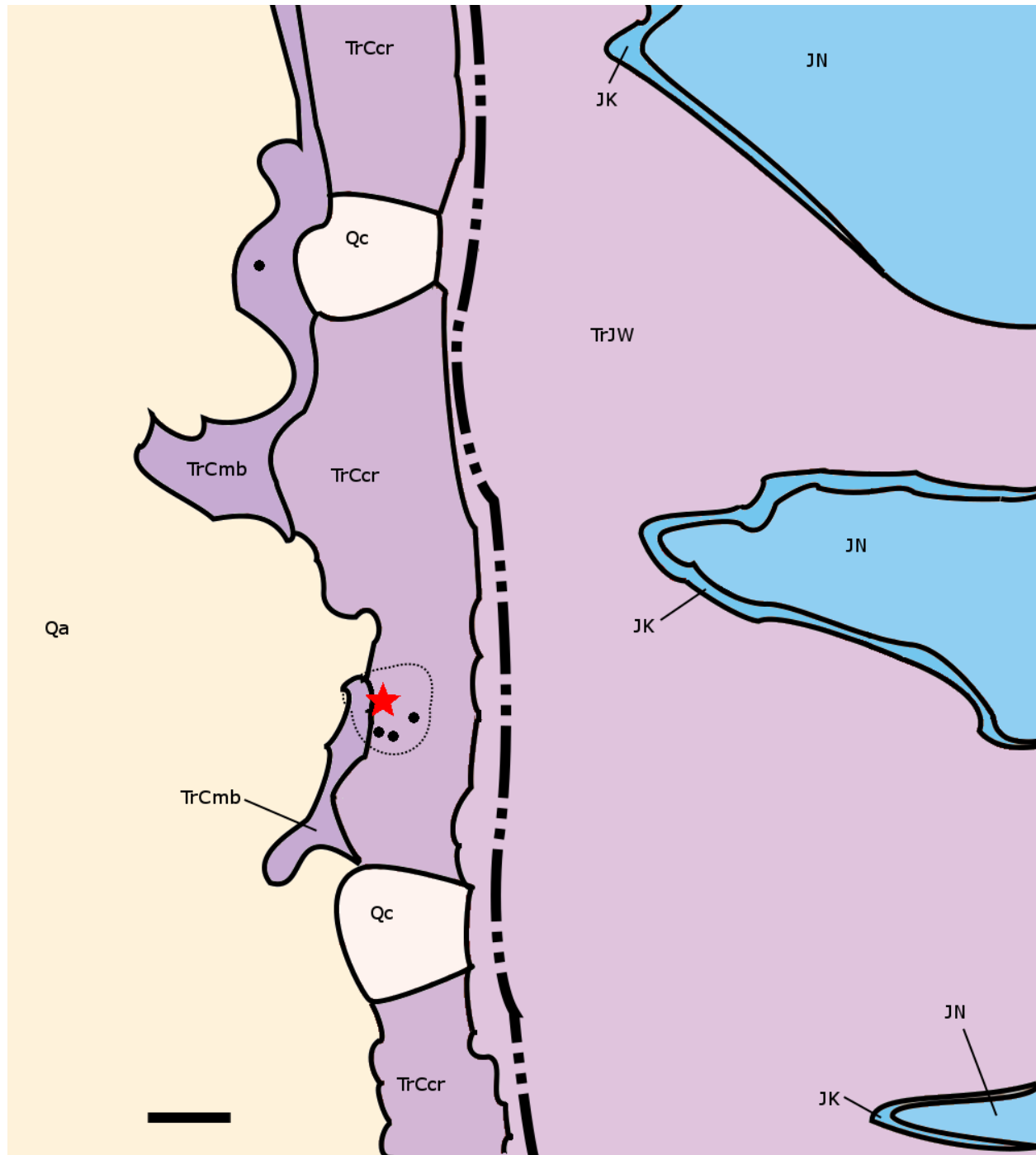
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Figure 1: Location of MNA Loc. 1776 in the State of Utah. Tan area indicates Bears Ears region.



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294 Figure 2: Generalized geologic map of MNA Loc. 1776 (red star) in relation to the Bread Bowl

295 area (small dashed line). Dashed and dotted line indicates the ridgeline of Comb Ridge. TrCmb,

296 Monitor Butte Member, Chinle Formation; TrCcr, Church Rock Member, Chinle Formation;

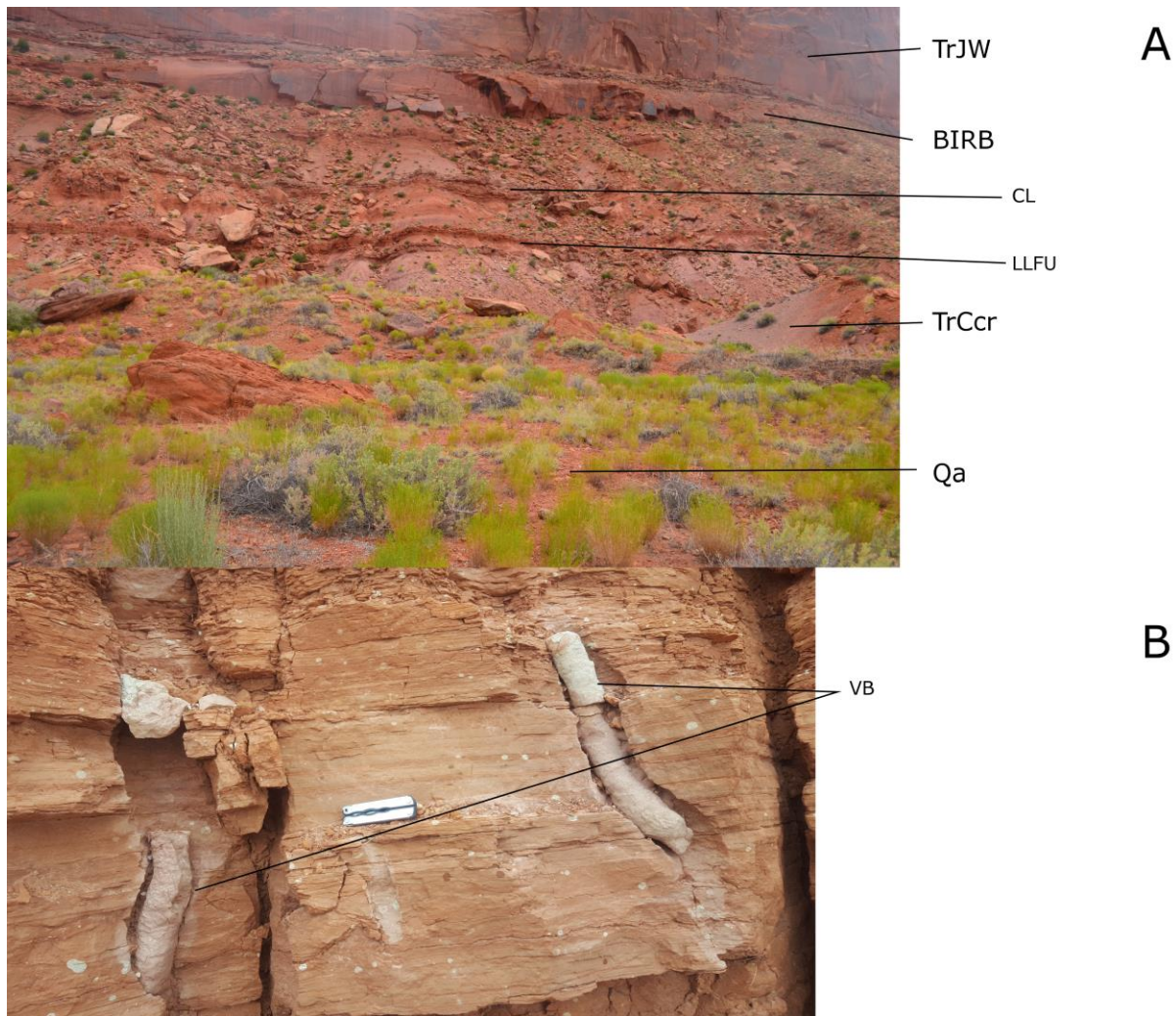
297 TrJW, Wingate Sandstone; JK, Kayenta Formation; JN, Navajo Sandstone; Qa; Alluvium; Qc;

298 Colluvium. Scale bar = 0.1 km, north is to top of image.

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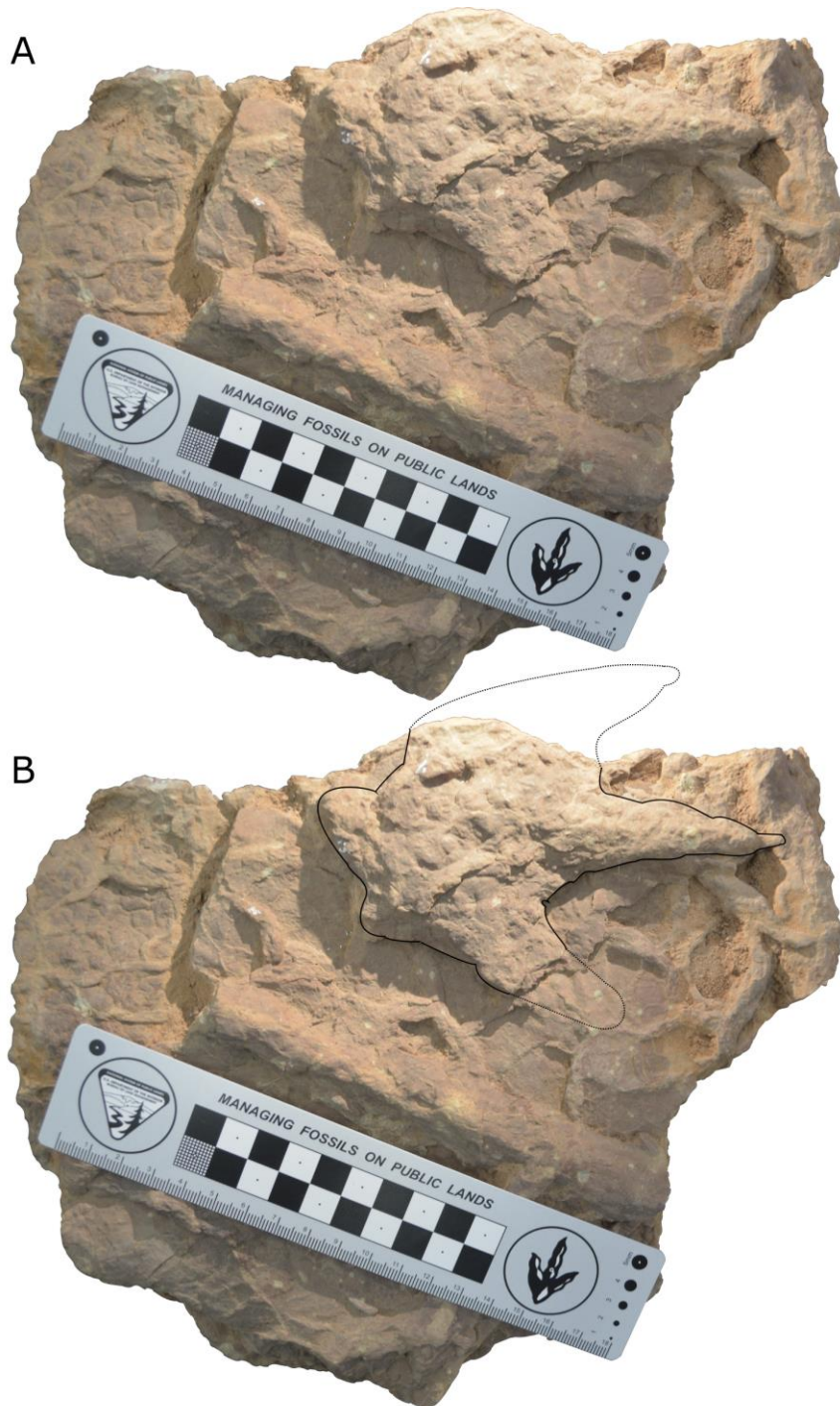
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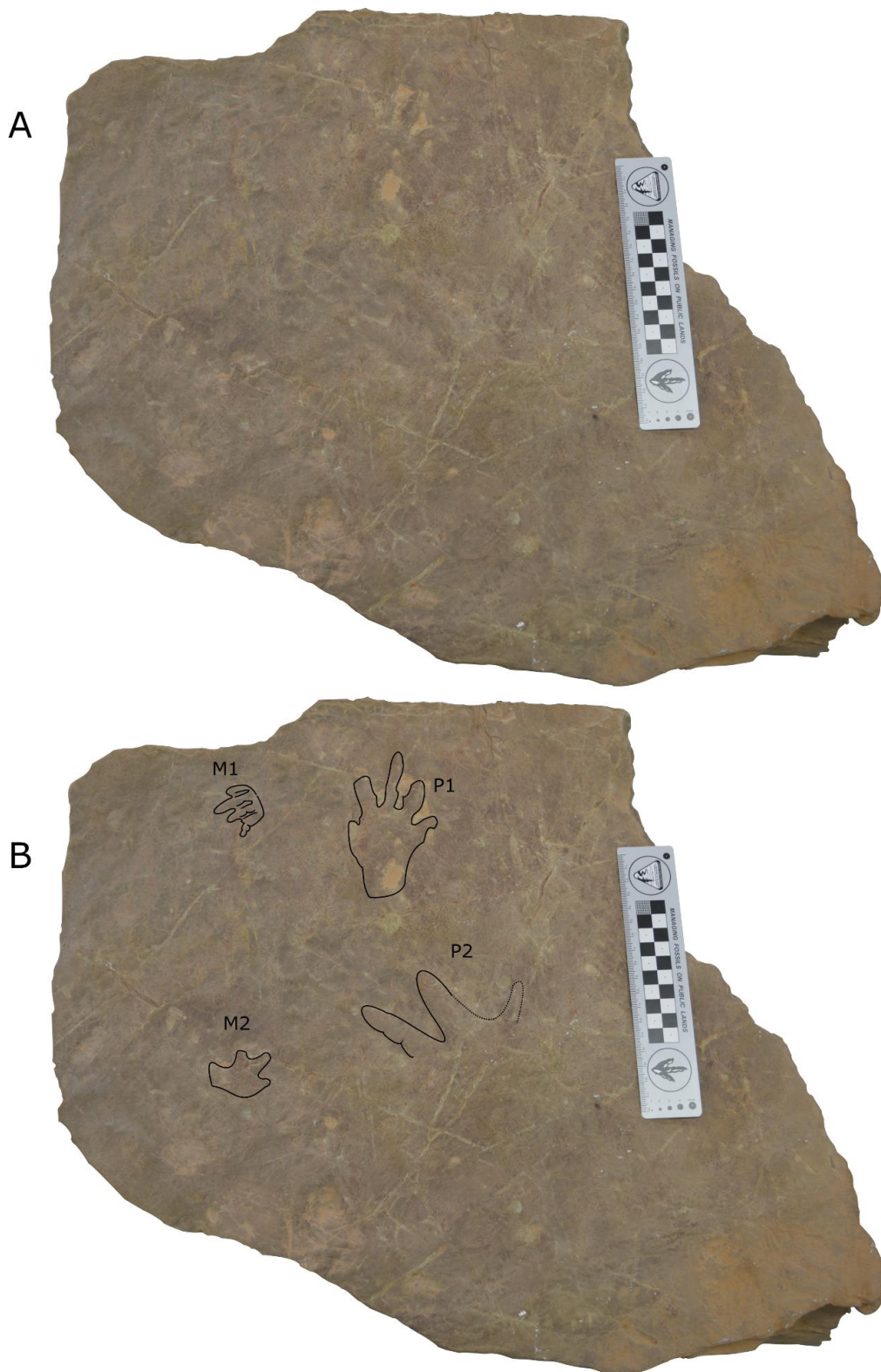
302 Figure 3: A) Photograph of Bread Bowl area with ledge forming units visible. BIRB; “Big Indian
303 Rock beds”; CL; coquina layer; LLFU; lower ledge-forming unit; TrCcr, Church Rock Member,
304 Chinle Formation; TrJW, Wingate Sandstone; Qa; Alluvium. B) Vertebrate burrows in the lower
305 ledge forming unit.

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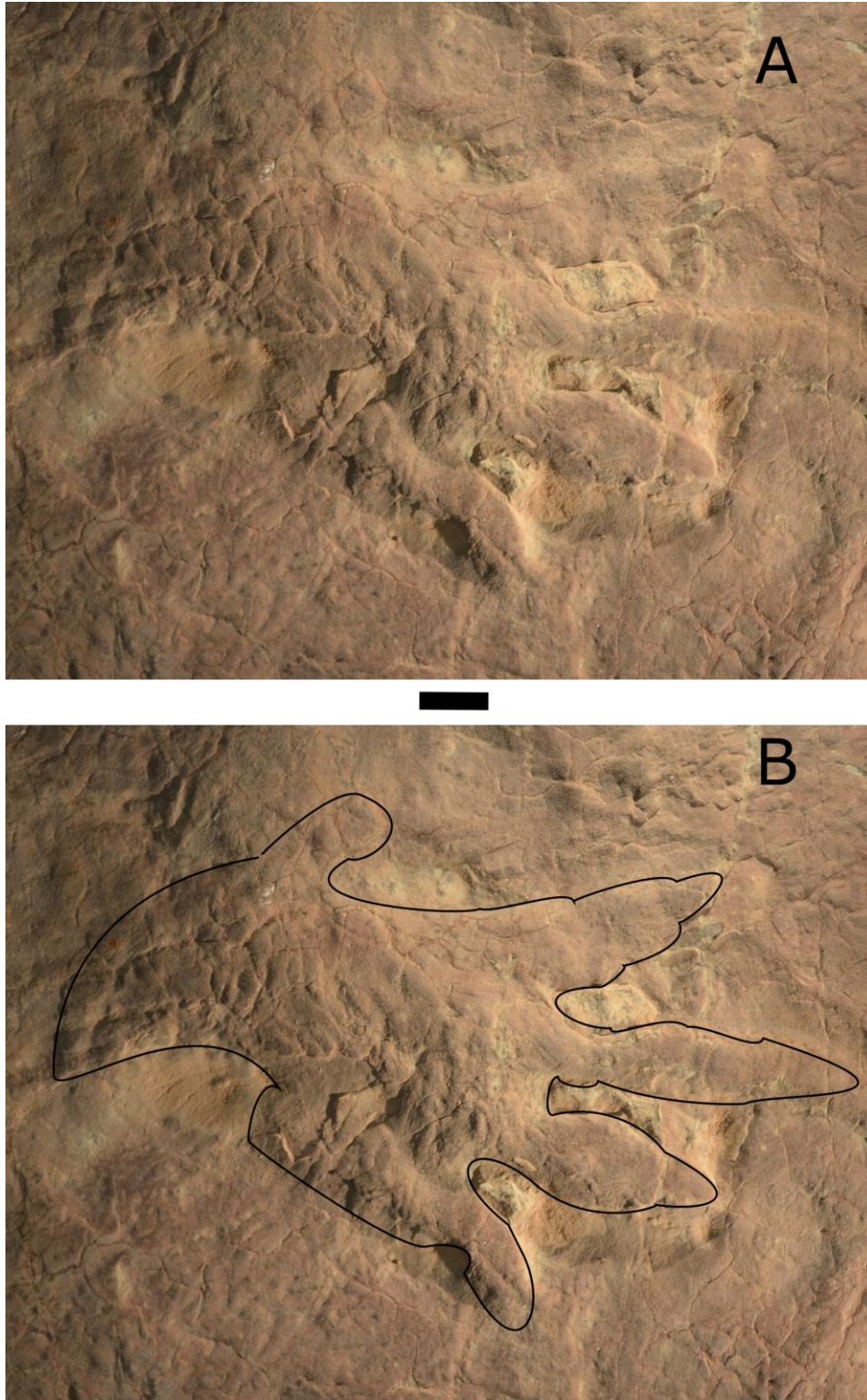


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Figure 4: A) MNA V10984, *Grallator* trace and mudcracks. B) MNA V10984, *Grallator* trace (outlined) with mudcracks. Dashed lines indicates where DII was present when discovered and the approximate presumed extent of DIV.

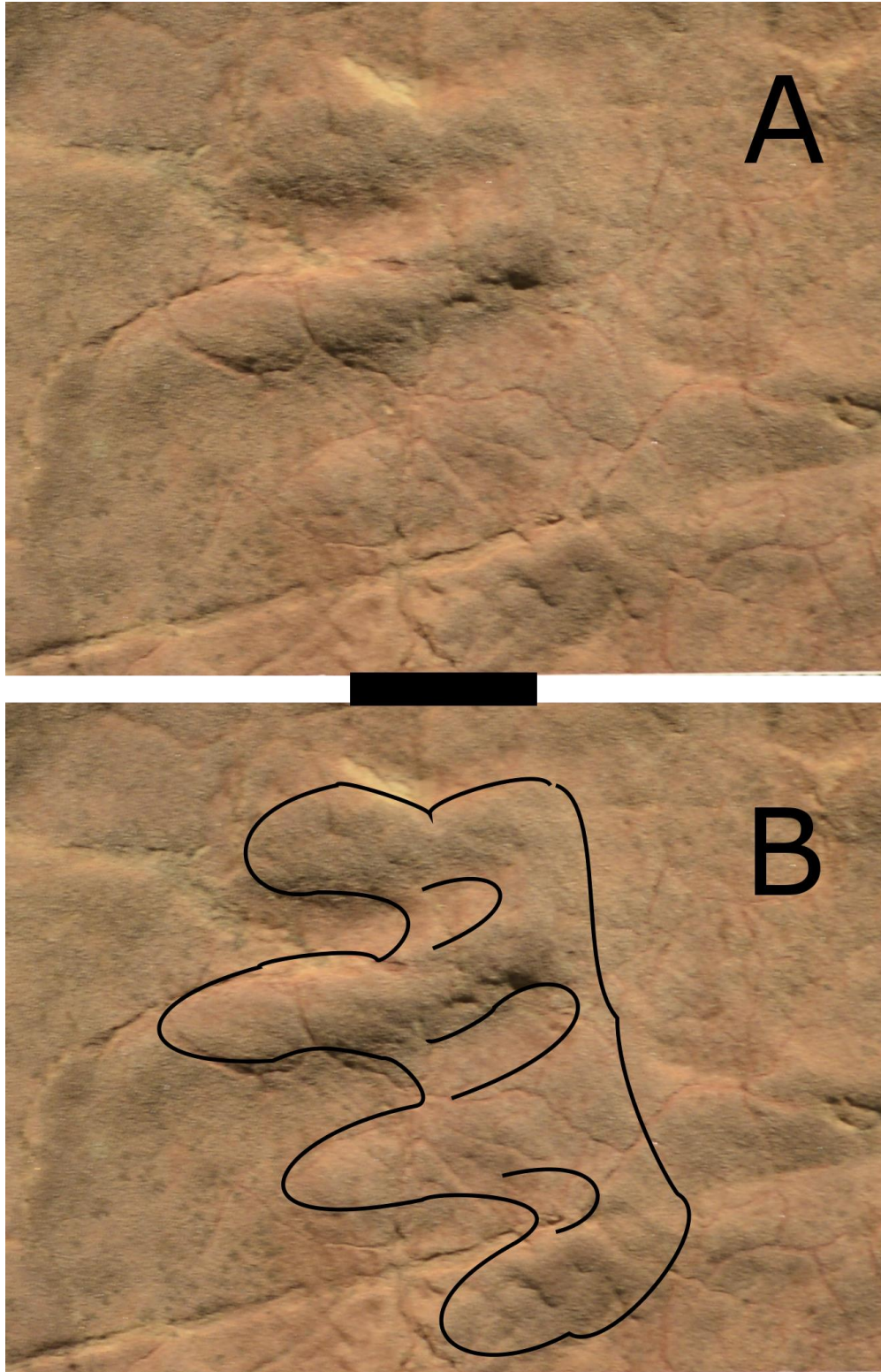


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314 Figure 5: A) MNA V10985. B) MNA V10985 with tracks outlined. M1, manus print 1; M2,
315 manus print 2; P1, pes print 1; P2, pes print 2.



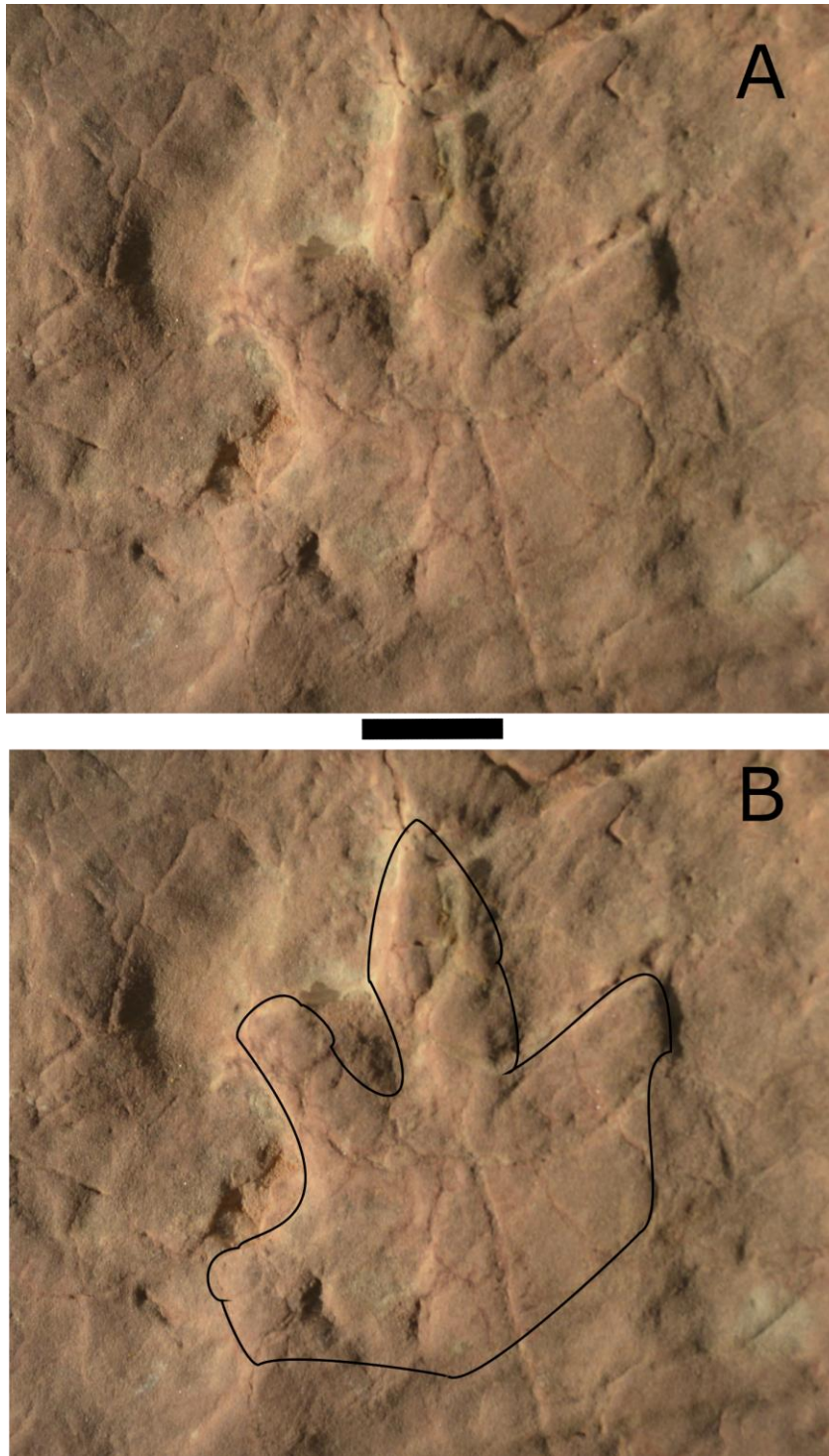
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Figure 6: A) Close-up of P1, MNA V10985. B) Close-up of P1, MNA V10985 with the trace outlined. Scale bar = 1 cm.

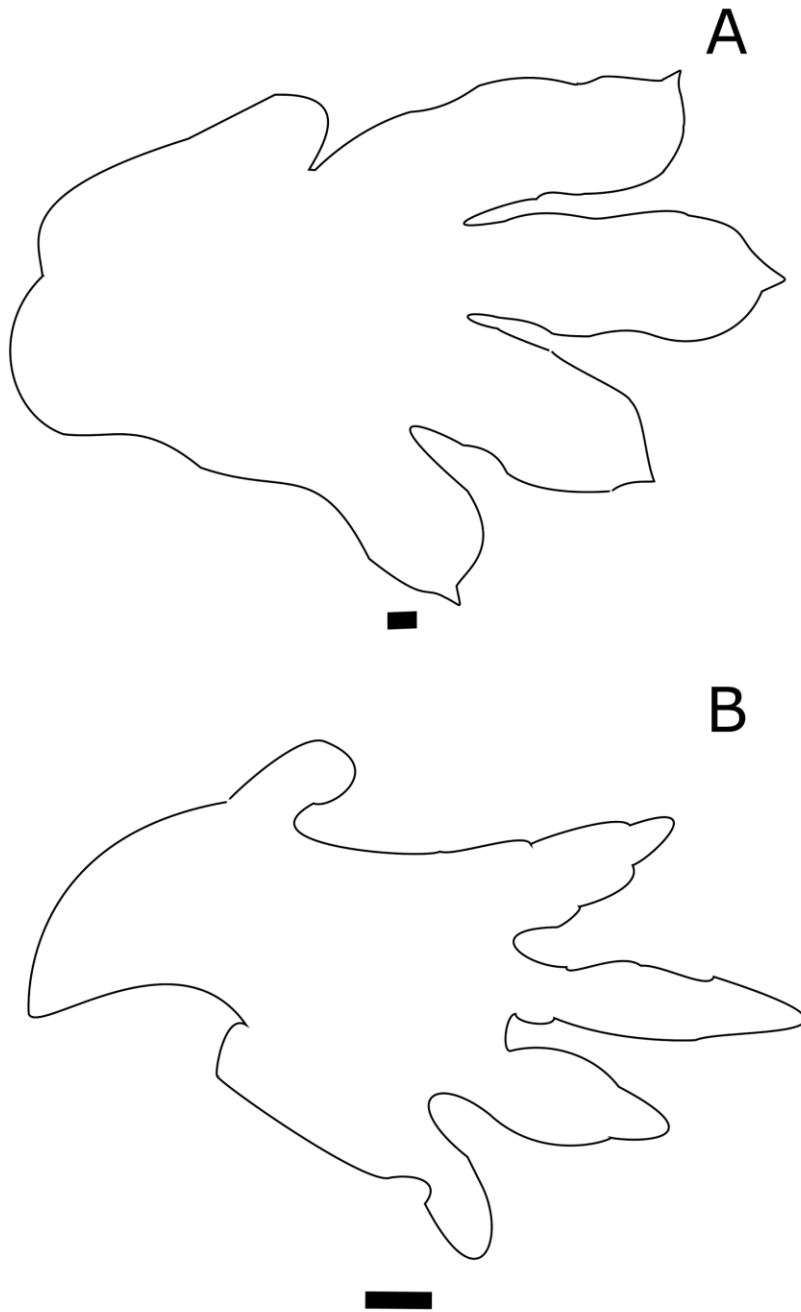


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Figure 7: A) Close-up of M1, MNA V10985. B) Close up of M1 with the track and features outlined, MNA V10985. Scale bar = 1 cm.



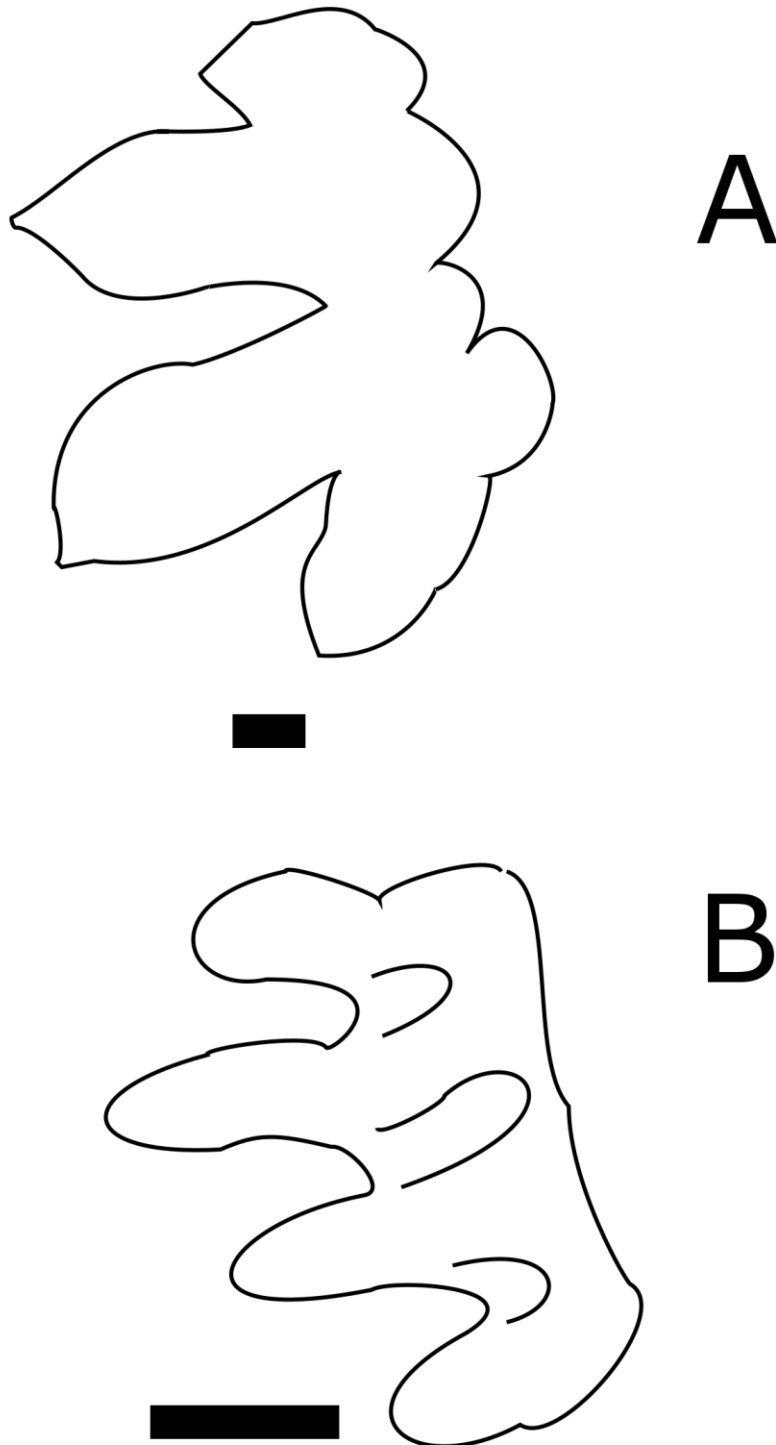
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325 Figure 8: A) Close up of M2, MNA V10985. B) Close of M2 with track outlined, MNA V10985.
326 Scale bar = 1 cm.



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328 Figure 9: A comparison between an aetosaur/*Brachychirotherium* pes track (modified from

329 Heckert et al., 2010) (A) and P1 of MNA V10985 (B). Scale bar 1 = cm for each track.



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Figure 10: A comparison between an aetosaur/*Brachychirotherium* manus track (modified from Heckert et al., 2010) (A) and M1 of MNA V10985 (B). Scale bar 1 = cm for each track.