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TURTLE TRACKS IN THE JUDITH RIVER FORMATION (UPPER CRETACEOUS) OF SOUTH-CENTRAL MONTANA

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ABSTRACT

A trackway, probably made by a large terrestrial turtle, is reported from Hidden Valley Quarry, Judith River Formation, Golden Valley County, south-central Montana. These fossil tracks are compared to modern tracks of Galapagos tortoises (*Geochelone elephantopus*) in captivity on substrates with variable moisture content. The fossil tracks were made on fine-grained substrate saturated with water. Further, in conjunction with traces of burrows likely produced by worm-like orangisms, these turtle tracks suggest a feeding behavior analogous to modern wood turtles (*Clemmys insculpta*). After detecting the underground movements of worms, wood turtles have been shown to alter their movements in such a manner that has been referred to as a stomp. A similar behavior may have occurred in the Cretaceous turtle track maker.

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INTRODUCTION

The purpose of this report is to document the occurrence of turtle tracks in the Judith River Formation of south-central Montana in the Hidden Valley Quarry (Figure 1). In 1981, an avocational fossil collector discovered dinosaur bones from what is now known as Careless Creek Quarry (Fiorillo 1991), Wheatland County, Montana. This discovery led to a series of excavations from 1984 to 1991, and again from 1994 to 1995, throughout Wheatland and Golden Valley Counties (Figure 2). These quarry excavations have provided important paleontological insights into dinosaur phylogeny (Dodson 1986; Dodson and Currie 1990), behavior, and taphonomy. For example, Careless Creek Quarry produced an abundance of juvenile hadrosaurian dinosaurs that suggest these dinosaurs nested in a coastal lowland environment (Fiorillo 1987a) in contrast to previous hypotheses. With respect to taphonomic issues, nearly one-third of the yield from Antelope Head Quarry contained bones with shallow, subparallel sets of scratch marks on the

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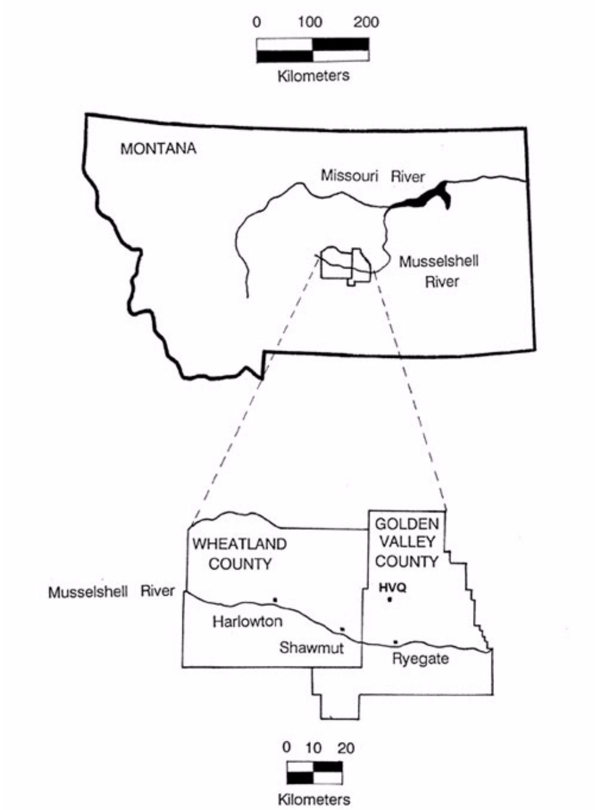

Figure 1. Location of Hidden Valley Quarry (HVQ), Golden Valley County, Montana.

marks on the bone surface, a feature attributable to trampling activity (Fiorillo 1987b). Blob and Fiorillo (1996) illustrated the important role that fossil size and shape can play in the composition of a microvertebrate assemblage. In this contribution, trace fossils are used to infer the presence and behavior of turtles. The tracks of modern tortoises were examined in order to verify that the Judith River tracks were in fact made by turtles. This paper reports the results of those observations and describes the tracksite as the first record of turtle footprints in the Judith River Formation.

GEOLOGIC BACKGROUND

The Judith River Formation yielded the first documented dinosaur remains from North America (Leidy 1856). It occurs throughout much of Montana and southern Canada. Based on a major sedimentological change traceable over a large geographic area in southern Alberta, Saskatchewan, and northern Montana (Eberth and Hamblin 1993), this rock unit has been elevated to group status. However, the change has not yet been identified in south-central Montana. In Montana, much of the stratigraphic and paleontologic work on this rock unit has occurred in the central or

Figure 2. View of Hidden Valley Quarry with field party excavating the tracksite.

north-central part of the state (e.g., Leidy 1856, Hayden 1871, Stanton and Hatcher 1905, Sahni 1972, Case 1978), areas that continue to prove fruitful in their scientific yield (e.g., Rogers 1993, 1994; Montellano 1992; Goodwin and Deino 1989).

In central Wheatland County to eastern Golden Valley County, the Judith River Formation varies in thickness from 70 m to more than 120 m (Fiorillo 1989a, 1991, 1997). The vertebrate-bearing interval consists largely of clastic nonmarine sediments (Fiorillo 1991) and nearshore sediments. Underlying the Judith River Formation in south-central Montana is the marine Claggett Formation. Overlying the Judith River is the marine Bearpaw Formation.

This region has yielded a diverse vertebrate fauna consisting of various fishes, salamanders, lizards, turtles, champsosaurs, crocodiles, pterosaurs, large and small theropods, hypsilophodontids, lambeosaurine and hadrosaurine hadrosaurs, centrosaurine and chasmosaurine ceratopsians, pachycephalosaurs, ankylosaurs, and various mammals (e.g., Dodson 1986, Dodson and Currie 1990, Fiorillo 1987, 1989, 1991, Fiorillo and Currie 1994, Gao and Fox 1996). Hidden Valley Quarry produced approximately 250 fossil bones and teeth representing 11 vertebrate taxa (Table 1).

The stratigraphic position of Hidden Valley Quarry was determined by measuring directly from the lower formational boundary (Figure 3). The lower boundary was taken as the base of a thick sandstone body that overlies the marine Claggett Formation. The top of the formation was taken as the uppermost extensive oyster beds (following Bowen 1915) or at the top of a laterally inconsistent sandstone body that contains sedimentary structures similar to those in the basal sandstone. In some sections this sandstone is capped with extensive oyster beds. Rogers (1993) suggested

Table 1. Faunal list of fossil vertebrates from Hidden Valley Quarry, based on fossil bones or teeth. Data from Fiorillo (1989) and Fiorillo and Currie (1994).

Order Acipenseriformes		
	Family Acipenseridae	
		Acipenser sp.
Order Elopiformes		
	Family Phyllodontidae	
		Paralbula sp.
Order Chelonia		
	Baenid, indeterminate	
Order Pterosauria		
	Family Azhdarchidae	
Order Saurischia		
	Family Ornithomimidae	
	Family Dromaeosauridae	
		Dromaeosaurus albertensis
		Saurornitholestes langstoni
	Family Troodontidae	
		Troodon formosus
	Family incertae sedis	
		Richardoestesia gilmorei
		Theropod "A"
Order Ornithischia		
	Family Hadrosauridae	
		Hadrosaurine, indeterminate

the sandstone in a similar stratigraphic position in north-central Montana was a tidally influenced, fluvial channel.

MODERN TURTLE TRACKS

Several specimens of large chelonid Galapagos tortoises (*Geochelone elephantopus*) were made available by the Philadelphia Zoo (Figures 4, 5). These animals were in an outdoor pen with broad regions of sandy substrate or fine silty substrate. The moisture level in the substrate varied from dry to saturated. The tortoises were near adult proportions, weighing approximately 130–175 kg and had a range in carapace length from approximately 0.75–0.84 m and widths ranging from 0.50 to 0.60 m.

Sections of substrate were cleaned of previous tracks with a broom. Tortoises were encouraged to walk across the cleaned surfaces and the resulting tracks were photographed. Tortoises were also encouraged to change gait from a normal walk to a brisk walk by a gentle tapping of a broom handle on the carapace. Such tapping typically increased the pace of the turtles' walk several fold.

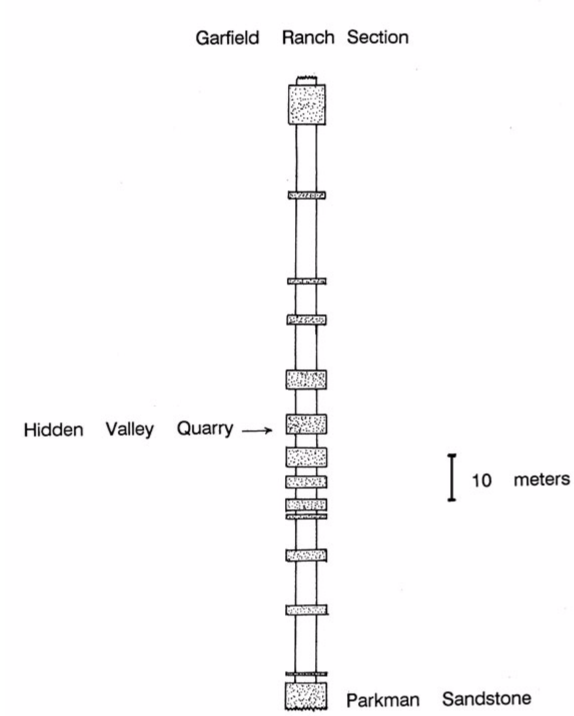

Figure 3. Generalized Judith River Formation section for Wheatland and Golden Valley counties showing the relative stratigraphic position of Hidden Valley Quarry (HVQ).

Track morphology of the footprints left by the tortoises varied significantly. The variation was largely controlled by the speed of the turtle and to a lesser extent by the substrate composition.

Sandy Substrate Tracks

Tracks in the drier sandy substrate were largely indistinct, slight depressions in the sand. No claw marks were observed in the tracks made by tortoises walking a normal pace across this substrate. When the pace of the tortoise increased several fold, the tracks became widely spaced and

Figure 4. Tortoises used in study. Note the graviportal nature of the feet.

Figure 5. Normal posture of tortoise while walking.

were distinct as sets of long grooves made by the claws of each foot of the turtle sweeping across the sand (Figure 6). When walking across a wet sandy substrate, the tracks were well defined, circular to elliptical in shape, and often had a raised lip around the edge (Figure 7). Claw impressions were often seen in these wet sandy tracks, but the

Figure 6. Widely spaced sets of scratch marks left by tortoise moving at an accelerated pace across a dry sandy substrate. Unit on tape measure is inches.

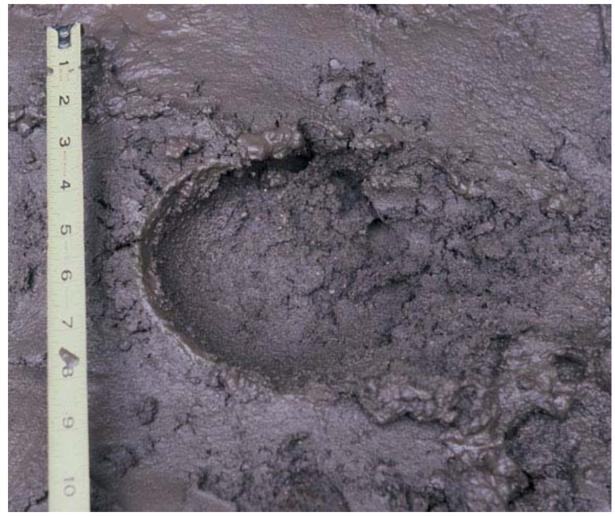

Figure 7. Single track left in a wet, sandy substrate. Note the narrow raised lip around the edge of the track. Also note that claw marks are only present for three of the digits. Unit on tape measure is inches.

claw marks were commonly subtle in definition and typically not all claws left impressions (Figure 7).

Muddy Substrate Tracks

No tracks were observed on a dry silty substrate. Tracks made by tortoises walking at a normal gait on a wet silty substrate were well-defined circular to elliptical depressions 10 to 20 mm deep (Figure 8). As with the tracks made in a sandy substrate, these tracks also exhibited a raised lip. The lips observed on these tracks made on the fine-grained substrate, however, were much wider and rounded in comparison to those tracks observed in

Figure 8. Tracks left in a saturated, muddy substrate. Note the broader raised lip around the tracks compared to the track shown in Figure 7. Unit on tape measure is inches.

Figure 9. Sets of scratch marks and individual tracks left by tortoise moving at an accelerated pace across a wet, muddy substrate. Unit on tape measure is inches.

a sandy substrate. Claw marks were sometimes evident on these tracks. As the pace of the tortoise increased, the tracks became widely spaced with sets of long grooves made by the claws of each foot sweeping across the mud (Figure 9).

JUDITH RIVER TRACKSITE DESCRIPTION

A set of 71 circular to elliptical depressions (Figures 10-13) occurs on a single bedding plane (Figures 14, 15) approximately 60 m above the base of the Judith River Formation (Fiorillo and

Figure 10. Isolated track located above camera lens cap. Note the presence of a broad, raised lip, most prominent on the right side of the track. Lens cap is 60 mm in diameter.

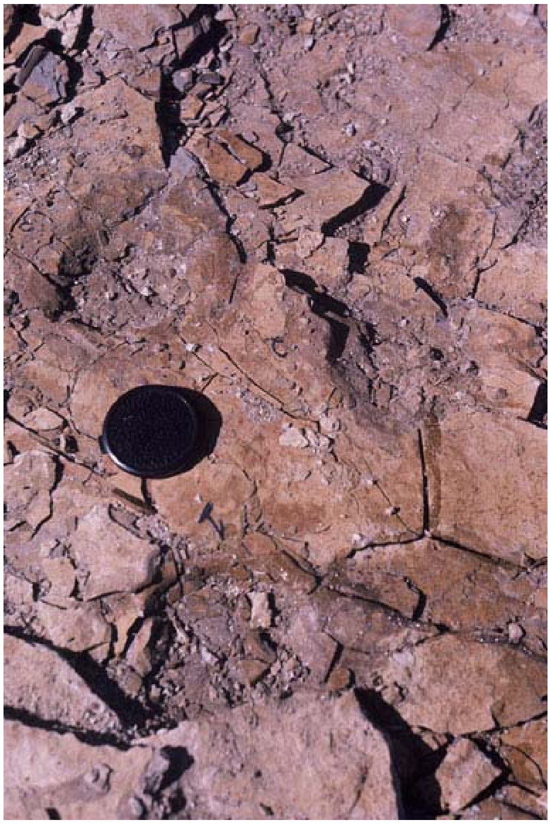

Figure 11. Cluster of three tracks around camera lens cap. Lens cap is 60 mm in diameter.

Currie 1994). Based on comparisons with footprints made by modern *Geochelone elephantopus,* these Cretaceous depressions are turtle tracks.

The tracks are preserved in a finely laminated dark gray siltstone that is prone to cracking and flaking as it dries. The bed containing the tracks is approximately 20 to 30 mm thick and occurs within a sequence of alternating light to medium gray, fine- to medium-grained sandstones and dark gray siltstones (Figures 15, 16). Beneath this unit is a layer of densely packed macerated, carbonized plant material. This package of alternating units is approximately 3.75 m thick. The sandstone-siltstone ratio is approximately 60:40. The alternating thin beds of sandstones and siltstones likely represent a levee deposit. Burrows likely produced by worm-like orangisms (Hasiotis 2002) are locally abundant in the track-bearing bed (Figure 17).

The tracks occur as slight depressions (Figures 10-13), generally elliptical or circular in shape and only a centimeter in depth (Figure 18). None of the tracks preserved any indication of claw marks or scratches the result of claws. Approximately one third of the tracks had a slightly raised and rounded ridge or lip. These lips were variable in extent, typically encircling the track but often extending only along one side of the track. Most tracks are

Figure 12. Cluster of four tracks around camera lens cap. Lens cap is 60 mm in diameter.

Figure 13. Positive of same tracks shown in Figure 6. Note the distinct morphology of the individual tracks. Lens cap is 60 mm in diameter.

between 80 and 100 mm in diameter or along the major axis of each ellipse (Figure 19). The two anomalously large diameters represent overprinting of tracks upon each other. These two large tracks are shown in the lower right corner of the trackway map (Figure 14) and are explained below with the behavioral interpretation. The tight, unimo-

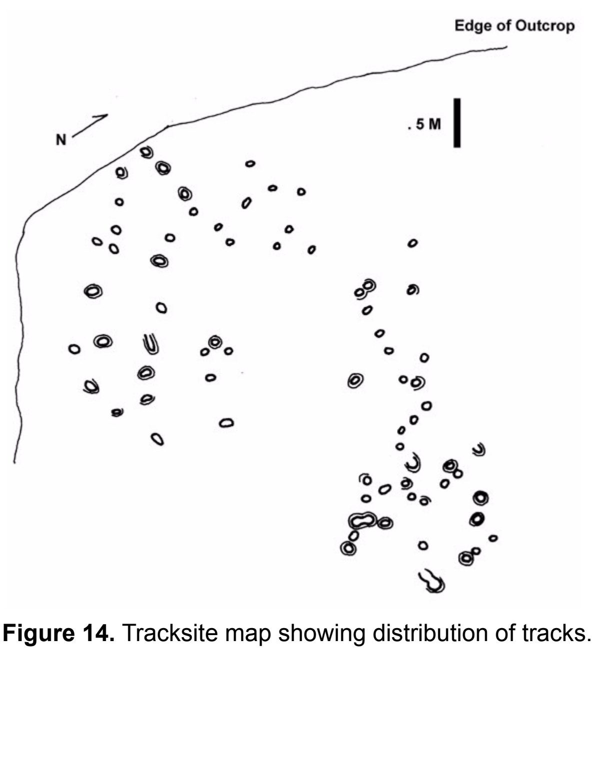

Figure 14. Tracksite map showing distribution of tracks.

Figure 15. Photograph of section containing tracksite.

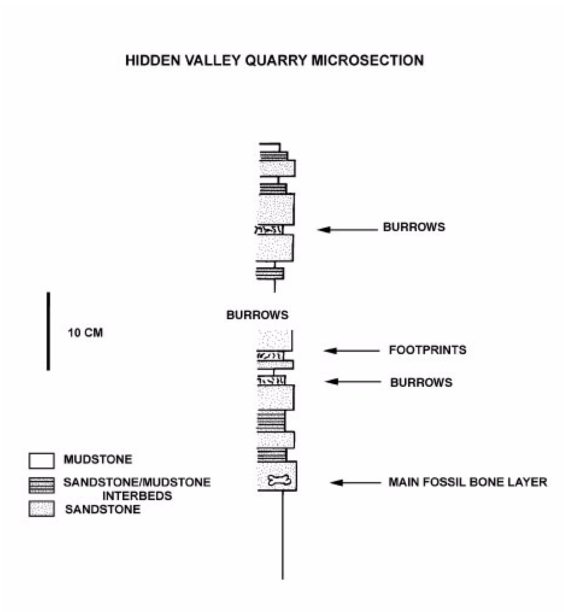

Figure 16. Detailed stratigraphic section containing tracksite horizon and horizons containing burrows likely produced by worm-like organisms.

dal peak in the distribution of track sizes shown in Figure 18 is evidence for a biogenic origin for these features rather than an abiogenic origin.

A wide trackway is a diagnostic feature for a walking turtle (Walker 1971), yet there are no clear trackways within this set of tracks. Therefore, definitive direction of movement is unclear. The circular to elliptical shape of these tracks suggests that they were made by a graviportal animal. Further, comparison to modern turtle tracks suggests that the lack of well-defined individual tracks indicates foraging behavior. Given that turtles tend to live in proximity to one another, it is perhaps more reasonable to suggest that multiple turtles may have been responsible for these tracks.

Although the only turtle remains from the Hidden Valley Quarry are of a baenid, neighboring quarries have produced other turtles (Fiorillo 1989) including *Basilemys*, a turtle with a carapace length of approximately 0.75 m, thus having the appropriate dimensions to have made tracks such as these. *Aspideretes* also approaches the appropriate size, although it is not graviportal. Moreover, the movements by modern soft-shelled turtles suggest that drag marks from the plastron would be expected. The track maker for the Hidden Valley Quarry tracks is most likely *Basilemys*.

DISCUSSION AND CONCLUSIONS

There are a limited number of fossil turtle footprint reports in the literature and fossil tracks have never been closely compared with modern turtle tracks. Foster et al. (1999) attributed a series of 29

Figure 17. Lithologic sample containing fossil burrows likely produced by worm-like orangisms, compare with Hasiotis (2002). Lens cap is 60 mm in diameter.

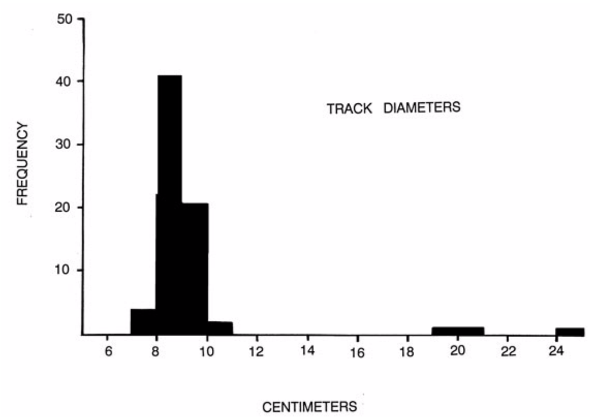

Figure 18. Histogram showing the frequency of class sizes of tracks. Measurements made along the long axis of tracks and depressions.

small (20 to30 mm) tracks found in the Jurassic Morrison Formation to an unidentified vertebrate, most likely a turtle. Those tracks were preserved in a sandstone unit as a series of scratch marks, with the individual scratches attributed to the digits of each manus or pes. Individual claw marks, defined as nearly point-like depressions, are not preserved in any of the 29 tracks described and illustrated by Foster et al. (1999). The scrapes left by the Morrison turtles are very similar to the tracks made by the Galapagos tortoises at the Philadelphia Zoo walking across a relatively dry, sandy substrate. The zoo tracks confirm the suggestion by Foster et al. (1999) that the Morrison tracks were indeed made by a turtle.

Wright and Lockley (2001) described a series of short, wide tracks with well-defined claw marks from the Cretaceous Laramie Formation of Colorado. These tracks were attributed to a turtle, and emphasis was placed on the presence of claw marks providing a means to investigate the interaction between the animal and the substrate. They further suggested that the animal was partially buoyed by water as it walked across the substrate. Although the claws of the tracks in the Laramie Formation are prominent, the illustrated tracks by Wright and Lockley (2001) are a reasonable extrapolation of the clawed tracks left by the zoo turtles examined during this work.

Based on the work by Wright and Lockley (2001), well-defined claw marks would seem to be appropriate indicators of turtle tracks. The lack of claw marks on the Hidden Valley Quarry tracks is not problematic, however, because not all zoo tortoise tracks exhibited claw marks. Furthermore, not all of the digits left claw marks in the substrate in some examples of the modern tracks. Presumably this is the result of the graviportal nature of the tor-

Figure 19. Track in cross-section showing downward distortion of bedding. Lens cap is 60 mm in diameter.

toise foot as opposed to the more characteristically clawed foot of other turtles such as trionychids.

The Hidden Valley Quarry sample of seemingly random tracks and overprinting of tracks upon tracks in the context of other trace fossils invites speculation regarding possible behavior. Layers immediately below these tracks, as well as others several centimeters above the tracks have dense concentrations of burrows likely produced by worm-like orangisms (Hasiotis 2002). After detecting underground movements by worms, wood turtles (*Clemmys insculpta*) have been shown to alter their movements during feeding in a manner that has been referred to as a stomp (Kaufman 1989). During this behavior, a wood turtle stomps its foot such that the vibrations generated drive the worms to the surface. The juxtaposition of a bioturbated horizon made by worms below the turtle trackway and the seemingly random distribution of tracks at the Hidden Valley Quarry is consistent with a similar feeding strategy to that of wood turtles.

In conclusion, comparisons between fossil tracks and those made by Galapagos tortoises (*Geochelone elephantopus*) suggest that the substrate of the imprinted surface was saturated with water. The tracksite includes 71 prints made by a turtle, but given that turtles generally live in proximity to one another, the tracks may have been made by more than one individual. The distribution of tracks suggests a possible feeding strategy similar to that exhibited by modern wood turtles (*Clemmys insculpta*). These fossil footprints represent the first report of turtle ichnofossils from this rock unit.

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REFERENCES

Blob, R.W. and Fiorillo, A.R. 1996. The significance of vertebrate microfossil size and shape distributions for faunal abundance reconstructions: a Late Cretaceous example. *Paleobiology*, 22:422-435.

Bowen, C.F. 1915. The stratigraphy of the Montana Group with special reference to the position and age of the Judith River Formation in north-central Montana. *United States Geological Survey Professional Paper*, 90:93-153.

Case, G.R. 1978. A new selachian fauna from the Judith River Formation (Campanian) of Montana. *Palaeontolographica, A*, 160:176-205.

Dodson, P. 1986. *Avaceratops lammersi*: a new ceratopsid from the Judith River Formation of Montana. *Academy of Natural Sciences of Philadelphia Proceedings*, 138:305-317.

Dodson, P. and Currie, P.J. 1990. Neoceratopsia, p. 593-618. In Weishampel, D.B., Dodson, P., and Osmolska, H. (eds.), *The Dinosauria*. University of California Press, Berkeley.

Eberth, D.A. and Hamblin, A.P. 1993. Tectonic, stratigraphic, and sedimentologic significance of a regional discontinuity in the upper Judith River Group (Belly River Wedge) of southern Alberta, Saskatchewan, and northern Montana. *Canadian Journal of Earth Sciences*, 30:174-200.

Fiorillo, A.R. 1987. Significance of juvenile dinosaurs from Careless Creek Quarry (Judith River Formation), Wheatland County, Montana, p. 88-95. In Currie, P.M. and Koster, E.H. (eds.), *Fourth Symposium on Mesozoic Terrestrial Ecosystems*. Royal Tyrrell Museum of Palaeontology, Drumheller.

Fiorillo, A.R. 1989. The vertebrate fauna from the Judith River Formation (Upper Cretaceous) of Wheatland and Golden Valley Counties, Montana. *The Mosasaur*, 4:127-142.

Fiorillo, A.R. 1991. Taphonomy and depositional setting of Careless Creek Quarry (Judith River Formation), Wheatland County, Montana, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 81:281-311.

Fiorillo, A.R. 1997. Stratigraphic distribution of fossil vertebrates in the Judith River Formation (Upper Cretaceous) of Wheatland and Golden Valley Counties, south-central Montana. *Northwest Geology.* 27:1-12.

Fiorillo, A.R. and Currie, P.J. 1994. Theropod teeth from the Judith River Formation (Upper Cretaceous) of south-central Montana. *Journal of Vertebrate Paleontology*, 14:74-80.

Foster, J.R., Lockley, M.G., and Brockett, J. 1999. Possible turtle tracks from the Morrison Formation of southern Utah, p. 185-191. In Gillette, D.D. (ed.), *Vertebrate Paleontology in Utah*. Utah Geological Survey, Miscellaneous Publication 99-1.

Gao, K. and Fox, R.C. 1996. Taxonomy and evolution of Late Cretaceous lizards (Reptilia: Squamata) from western Canada. *Bulletin of the Carnegie Museum of Natural History*, 33:1-107.

Goodwin, M. and Deino, A. 1989. The first radiometric-ages from the Judith River Formation (Upper Cretaceous), Hill County, Montana. *Canadian Journal of Earth Sciences*, 26:1384-1391.

Hayden, F.V. 1871. Preliminary report of the United States Geological Survey of Wyoming and portions of contiguous territories (being a second annual report in progress). Washington, D.C.: Government Printing Office, 511 p.

Kaufman, J.H. 1989. The Wood Turtle stomp. *Natural History*, 8:8-13.

Leidy, J. 1856. Notices of the remains of extinct reptiles and fishes discovered by Dr. F.V. Hayden in the badlands of the Judith River, Nebraska Territory. *Academy of Natural Sciences of Philadelphia Proceedings*, 8:72-73.

Montellano, M. 1992. Mammalian fauna of the Judith River Formation (Late Cretaceous, Judithian), north-central Montana. *University of California Publications in Geological Sciences*, 136:1-115.

Rogers, R.R. 1993. Marine facies of the Judith River Formation in the type area (Campanian, north-central Montana), p. 61-69. In Vern Hunter, L.D. (ed.), *Energy and Mineral Resources of Central Montana*. Montana Geological Society Field Conference Guidebook.

Rogers, R.R. 1994. Nature and origin of through-going discontinuities in nonmarine foreland basin strata, Upper Cretaceous, Montana: implications for sequence analysis. *Geology*, 22:1119-1122.

Sahni, A. 1972. The vertebrate fauna of the Judith River Formation, Montana. *American Museum of Natural History Bulletin*, 147:321-412.

Stanton, T.W. and Hatcher, J.B. 1905. Geology and paleontology of the Judith River beds. *United States Geological Survey Bulletin*, 257:1-128.

Walker, W.F. 1971. A structural and functional analysis of walking in the turtle, *Chrysemys picta marginata*. *Journal of Morphology*, 134:195-214.

Wright, J. and Lockley, M. 2001. Dinosaur and turtle tracks from the Laramie/Arapahoe formations (Upper Cretaceous), near Denver, Colorado, USA. *Cretaceous Research*, 22:365-376.