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DINOSAUR STATE PARK, CONNECTICUT, USA: HISTORY, FOOTPRINTS, TRACKWAYS, EXHIBITS*

PETER M. GALTON[1]
JAMES O. FARLOW[2]

RESUMEN

La mayor parte de los rastros de Dinosaurio y sus calcos, de la Formación Berlín Este (Jurásico inferior) del Parque Estatal de Dinosaurios, Rocky Hill, Connecticut, se encuentran a techo de los estratos. Las huellas pertenecen al icnogénero *Eubrontes* y,o a grandes *Anchisauripus*, y probablemente fueron hechas por dinosaurios terópodos. No hay ninguna indicación de que las rastrilladas sigan direcciones preferentes. Dichas rastrilladas están marcadas por dinosaurios que marchaban solos o en pequeños grupos y que probablemente pasaron por el lugar durante un intervalo de tiempo de mes o más. Este periodo de tiempo es el que se considera necesario para que el nivel del lago bajase unos 2 m, profundidad estimada por la presencia de secuencias cortas de huellas interpretadas como rastros de "natación". En estas huellas solo se imprimen las garras que forman tres estrías estrechas y subparalelas con barro empujado hacia su terminación posterior. Sin embargo, estas extrañas características pueden ser resultado de la interacción del pie con el sustrato, durante las tres fases de contacto, en un sustrato firme emergido. Si fuese así, todos los rastros se habrían podido marcar en un solo día. Las exposiciones del Parque, que incluyen plantas fósiles, peces y otras huellas así como dioramas a tamaño natural, explican la geología, historia y paleontología del Valle de Connecticut y del Parque.

Palabras clave: Dinosauria, Theropoda, *Eubrontes*, Jurásico inferior, huellas, Connecticut USA.

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[1] College of Naturopathic Medicine, University of Bridgeport, Bridgeport, Connecticut 06601 USA.

[2] Department of Geosciences, Indiana-Purdue University at Fort Wayne, Indiana 46805 USA.

ABSTRACT

Dinosaur trackways in the East Berlin Formation (Lower Jurassic, Hettangian, ~205 mya) at Dinosaur State Park, Rocky Hill, Connecticut mostly occur on the main surface and as corresponding under tracks. The prints belong to the ichnogenera Eubrontes *and/or large* Anchisauropus, *and were probably made by theropod dinosaurs. There is no obvious preferred orientation of trackways, which may have been made by animals, either alone or in small groups, over a month or more. This time would be needed for the lake level to go down by about 2 m, the depth indicated by short sequences of prints interpreted as "swimmer" tracks. In these footprints, only the claws imprint to form three narrow sub-parallel grooves with mud pushed up at the posterior ends. However, these strange characteristics could have resulted from foot-substrate interactions during the three phases of contact on an emergent firm substrate. Thus, all the trackways may actually have been made over a day or so at the most. The associated exhibits at the Park, which include fossil plants, fish and other foot prints plus life size dioramas, explain the geology, history and paleontology of the Connecticut Valley and of the Park.*

Key words: Dinosauria, Theropoda, Eubrontes, *Lower Jurassic, Footprints, Connecticut USA.*

"There is no branch of science so important and so neglected as the art of tracing footprints."

Arthur Conan Doyle, 1891, Study in Scarlet (quoted in exhibit at Dinosaur State Park).

0. INTRODUCTION

The Connecticut Valley region of southern New England consists of broad, elongate lowlands extending over 160 km from northern Massachusetts to Long Island Sound (Fig. 1A). Such early Mesozoic rift valleys or basins extend for over 1900 km along the eastern margin of North America from Nova Scotia to South Carolina. These basins were formed by upwelling lithospheric extensions in the Late Triassic and Early Jurassic, associated with the continental rifting episode that started the breakup of Pangaea, and which ultimately created the Atlantic Ocean. The resulting Newark Supergroup, a sequence of non-marine sedimentary rocks, includes numerous sills and dikes, formed from diabase intrusives within the sedimentary rocks, and several major basaltic extrusives or lava flows that spread out over the surface of the underlying rocks. Over time the originally horizontal beds tilted, with a 15-25° dip towards the east and, after erosion of the softer brownstones to form fertile valleys, the basalt flows now form traprock ridges wherever the western end juts out of the ground.

The red color of the soil of the Connecticut Valley is very unusual for a northern region with a temperate climate. However, it is characteristic of tropical and subtropical climates that probably prevailed when the source rocks for the present soil, the underlying "red-beds", were deposited. Occasionally, the brownstone layers are interspersed with dark shales deposited in lakes. However, the brownstones also include mudcracks, evidence of dry lake beds that are typical of a dry, hot climate. The climate when the footprints were made was probably subtropical and monsoonal with alternating episodes of high precipitation and aridity (Krinine, 1950).

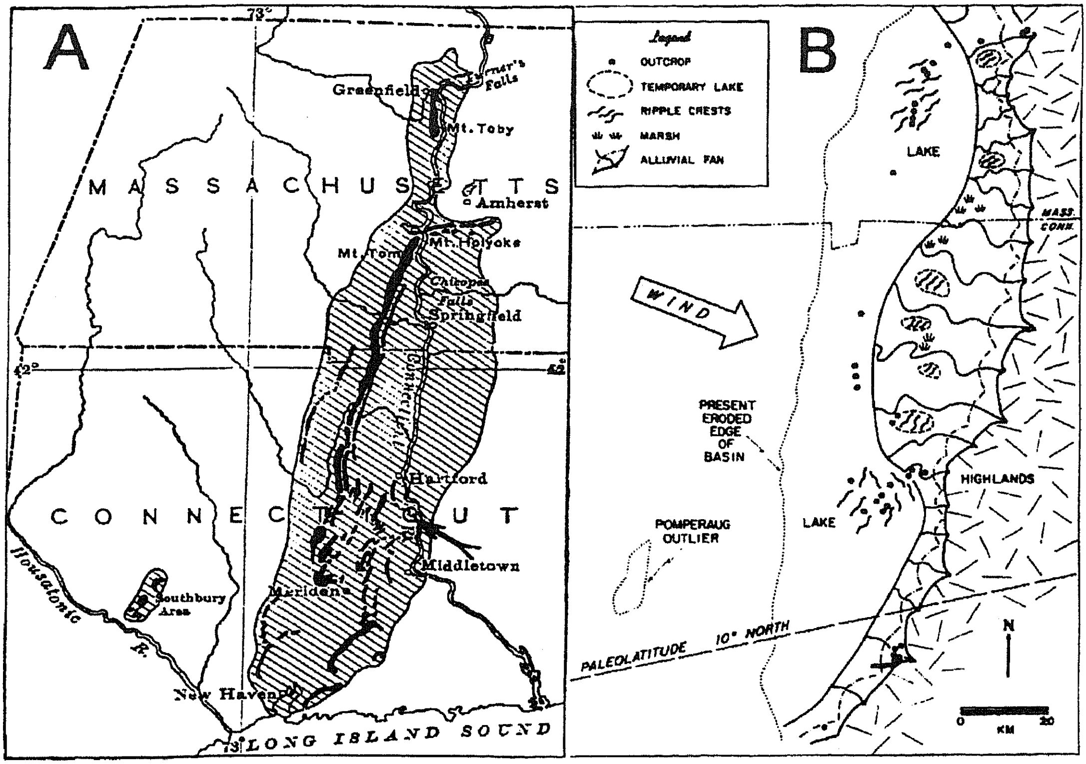

FIGURE 1. ***A*, Upper Triassic and Lower Jurassic continental deposits (ruled areas) and igneous rocks (solid black) of the Connecticut Valley (from Colbert, 1963) - arrow indicates approximate position of Dinosaur State Park, Rocky Hill. *B*, paleogeography of the region with outcrops of the East Berlin Formation (Lower Jurassic) at the time of a relatively large perennial lake. At its maximum size, the lake extended eastwards to encroach locally on the alluvial fans (from Hubert** et al, ***1978).***

The Connecticut Valley has been, and continues to be, an important source of footprints from the Lower Jurassic since the pioneering work of Hitchcock (1836, 1841, 1858, 1865). Accounts of the history of the discovery of footprints in the Connecticut Valley are given by Lull (1953), Steinbock (1989), Galton (2002) and Galton and Rainforth (in prep.); the history of the discovery of skeletal remains is reviewed by Lull (1953), Galton (1976) and Galton and Rainforth (in prep.); and the life of the Connecticut Valley during the Lower Jurassic is reviewed by Lull (1953), Colbert (1973), Olsen (1980), and McDonald (1995). Dinosaur State Park at Rocky Hill, Connecticut, was discovered in 1966. Popular articles on Dinosaur State Park and its footprints include Anonymous (1986), Krueger (1986), Dunnigan (1988) and Galton (2002). Galton worked on the original large exposure prior to its burial in 1970, and on the smaller exhibit area in the early 1980's. Farlow later became interested in the exhibit area as part of a larger study of morphological variability in foot and footprint shapes within and across taxa of bipedal dinosaurs and ground-living birds. We therefore pooled our efforts in a joint study of the Rocky Hill site. In this paper, details are given on the history of the trackway site, along with details on footprints and trackways of interest, and the associated exhibits. The present paper, which reports our preliminary findings, is partly adapted from Galton (2002) and Farlow and Galton (in press); a more detailed report will be given elsewhere.

Museum abbreviations: AM, Amherst College, Amherst, Massachusetts; DSP, Dinosaur State Park, Rocky Hill, Connecticut; WU, formerly in collection of Wesleyan University, Middletown, Connecticut; YPM, Peabody Museum of Natural History, Yale University, New Haven, Connecticut.

1. HISTORY

McDonald (1996: 227) lists two old references under "tracks, Rocky Hill". Footprints were reported (but not described) by Hitchcock (1837), only one year after his historic 1836 paper on "Ornithichthnology", and Wickersham (1848) described (but did not illustrate) tracks and a mollusc shell, so the species involved in each case are indeterminate (Lull, 1953). However, this old "Rocky Hill" locality is in present day southwest Hartford (locality 32 of Lull, 1915, 1953), about 9 km northwest of the town of Rocky Hill, with the town of Wethersfield in between. Hitchcock (1858) listed 38 localities for footprints in the Connecticut Valley and, of the very few localities discovered since that time (Lull, 1953), Dinosaur State Park is the most important one.

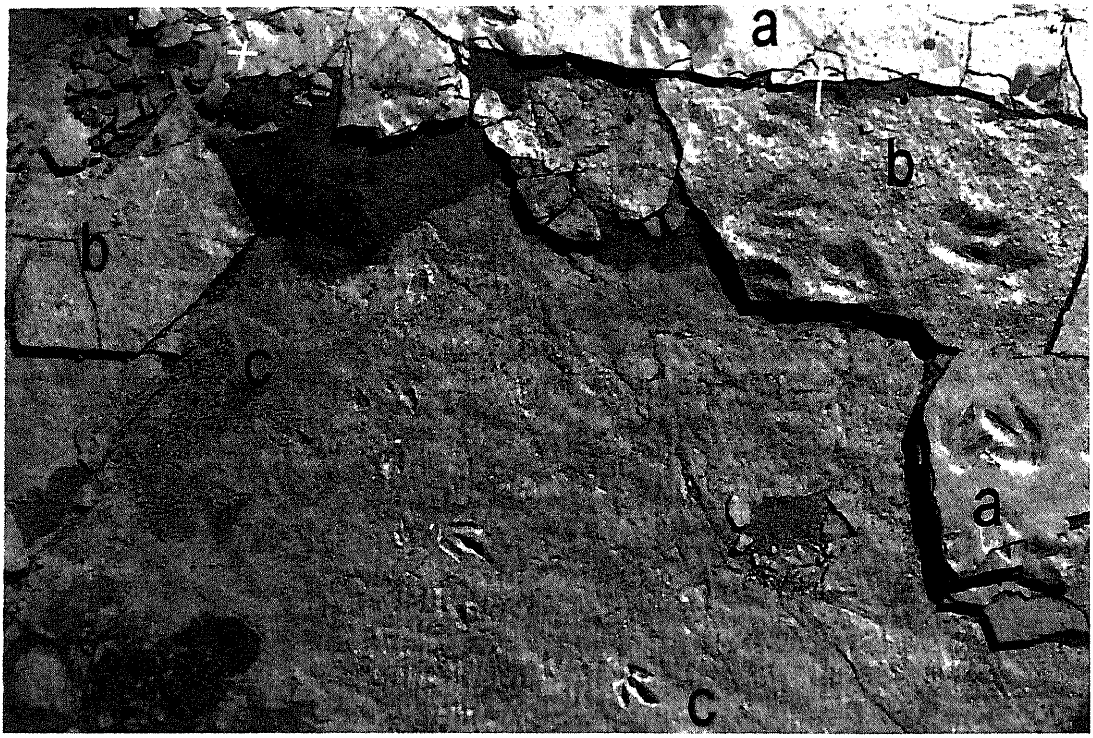

FIGURE 2. ***Main footprint layer (a) with under track layer (b) and a third level (c) that shows a moment in time at Rocky Hill (1970 photograph, area since eroded away). The water's edge is indicated by the ripple marks that end parallel to the left edge (for more details see text). Tape crosses 3 m apart, aligned west-east.***

On August 24, 1966, Edward McCarthy was operating a bulldozer to excavate the foundation and basement for a new testing laboratory for the Connecticut State Highway Department at Rocky Hill (Fig. 1A). He noticed six prints, which were unearthed about 3.7 m below the natural level of the ground, so he stopped the machine and reported the discovery to the engineer and architect at the site. Staff at the Peabody Museum of Natural History of Yale University in New Haven, the University of Connecticut at Storrs, and the State Geological and Natural History Survey at Middletown were consulted about the significance of the find, that was also reported to the press. The latter was unfortunate because that evening many people descended on the site to collect specimens, as did others from local educational institutions the next day, on the assumption that the area would soon be covered with concrete. Work on the site was stopped the evening of the 25th and security precautions were taken, viz., the erection of a temporary fence and a 24 hour guard by the State Police. Various actions at different governmental levels ultimately resulted in the announcement on September 13, 1966 by Governor John Demsey that founded the Dinosaur State Park, a remarkably quick turn of events for a bureaucracy. Peoples (1967) provides a very detailed history of the early events at Rocky Hill as regards the proceedings of meetings and correspondence (summary of main events in Ostrom, 1967), along with subsequent updates (Peoples, 1969, 1971).

Excavation by student volunteers under the direction of Grant Meyer (Peabody Museum of Natural History; see Peoples, 1967: Pls. 2, 3) continued until the end of October, by which time a large area with about 1,500 footprints was exposed and covered with a plastic sealing material. Sump pumps were installed at the lowest points in the excavation area to lower the water table and, in an attempt to protect the area from the weather during the winter, it was temporarily covered with black vinyl sheeting, electric heating cables, sand, sawdust, and more black vinyl sheeting with old car tires on top.

A panoramic view looking up slope from the south to show all of the fully excavated larger trackway exposure is given by Ostrom (1967: Fig. 2, lower photo; central part of the photograph of track exposure in Peoples, 1967: Pl. 3; Ostrom and Quarrier, 1968: Fig. 1; Colbert, 1970: Fig. 13; McDonald, 1996: Fig. 11; earlier stage of excavation in Weishampel and Young, 1996: Fig. 9.7; oblique aerial view of the Park site looking south in Peoples, 1967: Pl. 1). The other panoramic photograph in Ostrom (1967: Fig. 2, upper photo, same width) purports to show the site before excavation but, given that it was taken by John Howard of the Peabody Museum of Natural History rather than the Connecticut State Highway Department, it must have been taken after the discovery of footprints at the site. The figure caption notes that it is from a different angle but, even taking this into account, no sections of the "before" photo correspond with the underlying sections of the "after" photo. Comparisons of these panoramic photos with the aerial view in Peoples (1967: Pl. 1) explain why this is the case: the "after" photo includes only the larger excavation site whereas the "before" photo includes most of the width of the Park (so "after" photo shows only about a third of the width of the "before" photo, a fact not mentioned in the figure caption). In addition, the decreased height of the "before" photo means that any excavations already present were hidden by undulations of the ground.

A small area on the northeast edge (Fig. 2), which shows the water's margin with *Anchisauripus* trackways on a slightly lower level than the main layers, is discussed by Ostrom (1967: Fig. 1; also in Peoples, 1967: Pl. 4; Ostrom and Quarrier,

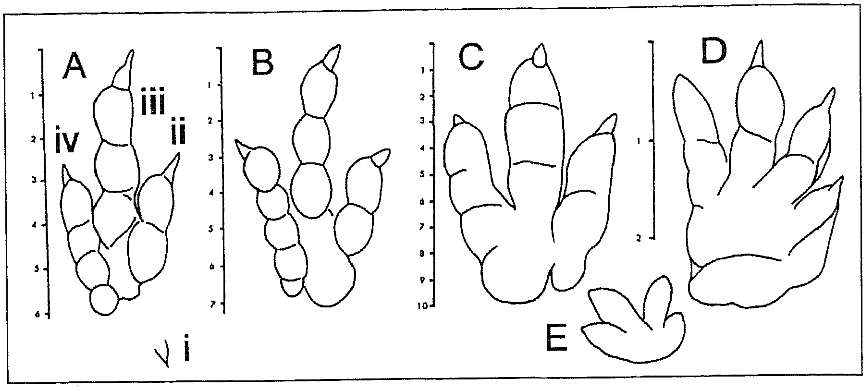

FIGURE 3. ***Comparison of the four kinds of footprints at Rocky Hill as identified by Ostrom and Quarrier (1968): all as left pes drawn to the same unit length with a scale in inches (1 in = 2.4 cm) to indicate actual sizes. A,*** **Anchisauripus*****; B,*** **Grallator*****; C,*** **Eubrontes*****; C-D,*** **Batrachopus*****: C, pes; D, manus. i-iv, digits I to IV. From Ostrom and Quarrier (1968) but after Lull (1953), not based on specimens found at Rocky Hill (Ostrom, pers. comm.).***

1968: Fig. 4), as well as in many geological textbooks. Ostrom and Quarrier (1968) identified four genera of reptilian tracks at the Park, viz., *Eubrontes*, *Anchisauripus*, *Batrachopus* and possibly *Grallator*, but the drawings given (Fig. 3) were scaled from Lull (1953), rather than taken from actual footprints (Ostrom, pers. comm.).

A smaller area, that is probably on the same bedding plane but is exposed about 10 m to the west of the larger main area, was excavated in 1967 from June into the fall, under the direction of Sidney Quarrier, a geologist with the state (Fig. 4A). This work resulted in an exposure of about 500 new footprints. During 1968 a temporary inflatable exhibit building was erected over the small area (Fig. 5; see Peoples, 1969: Pls. 1, 2, drawings of site and inside of building to show potential site development; Pl. 3, photo taken Feb. 1969 from east across snow covered large trackway area towards building; Pl. 5, Quarrier and *Coelophysis* model at lowest part of small area; for scale plan of Park, see Peoples, 1971: Fig. 1; building from large trackway in October, 1970 in Galton, 2002: Fig. 12). The official opening of Dinosaur State Park was held on October 17, 1968, at which time the National Park Service presented a bronze plaque designating the site as a Registered Natural Landmark, one that "possesses exceptional value in illustrating the natural history of the United States" (see Peoples, 1969: Pl. 4).

The large area was left uncovered during the summers until the fall of 1970 (not 1969 as stated by Peoples, 1971: 6), when it was covered again, and then it was left uncovered after the spring of 1973. However, because the surface layers flaked due to expansion and contraction on wetting and drying, not the freezing and thawing originally tested for, it was buried for protection in 1975. The large area of trackways is underneath the extensive sloped grassed over area between the exhibits building and the parking lot (corners are approximately indicated by concrete markers). However, Lessem (1999) is incorrect in stating that the area under the grass is still "unexcavated". It is hoped to eventually display the large area

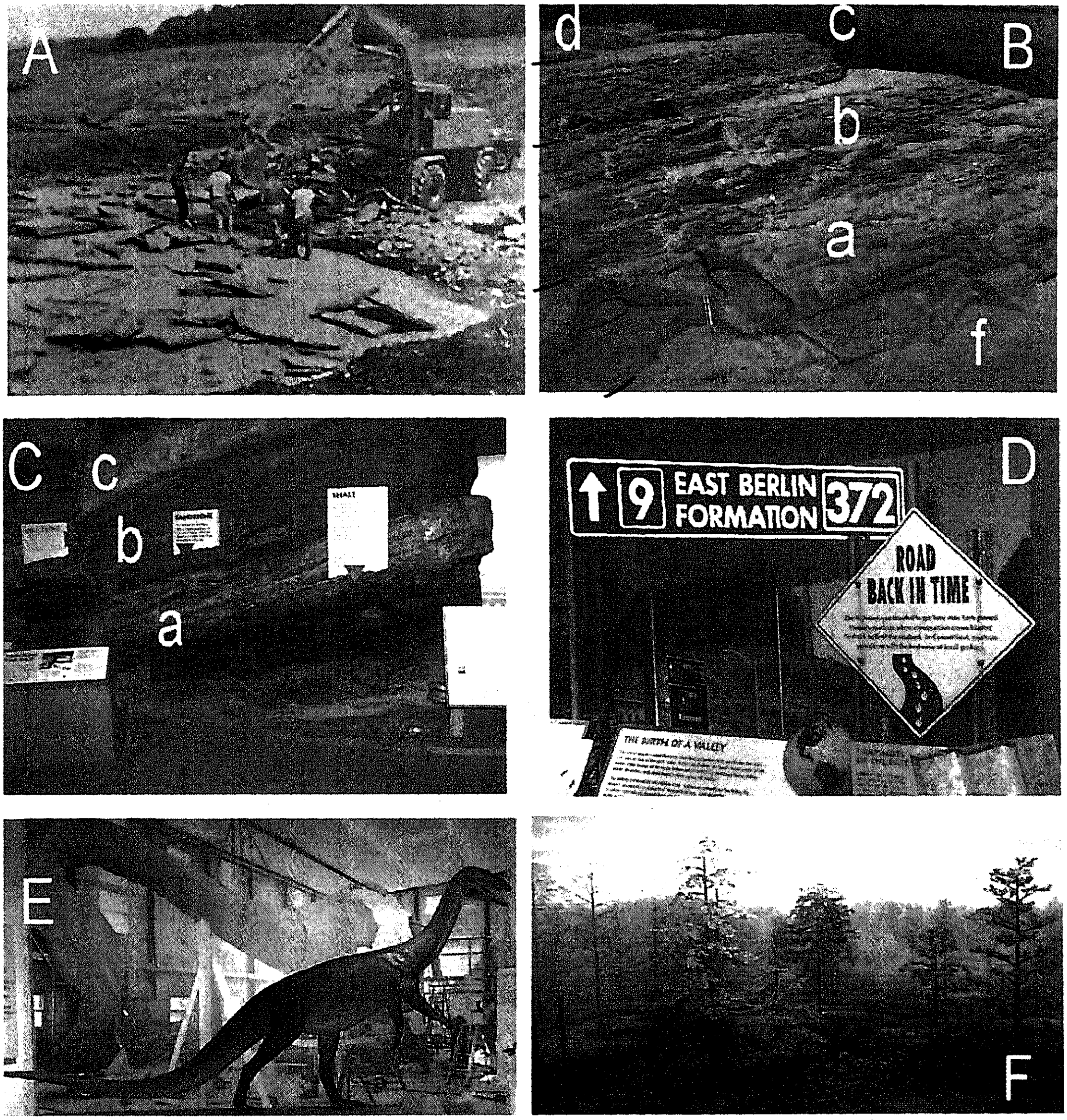

FIGURE 4. ***Dinosaur State Park. A, backhoe being used in excavation of small exhibit trackway area in the late summer of 1967 under the supervision of a shirtless Sid Quarrier - view towards southeast (from exhibit photograph at Dinosaur State Park). B, cliff at southwest corner of exhibit area (Figs. 5B, 18G) (f, main footprint layer; see text for details on a-d), upright ruler standing on trackway surface is 15 cm. C-F, peripheral exhibits: C, life size replica of road cut through part of East Berlin Formation at exit ramp for Routes 9 and 372 connector near Rocky Hill in Cromwell. The beds are labeled (a, shale; b, sandstone; c, basalt) and a small door can be opened to reveal a sample and information about each rock type. D, lead in to C with fictional road signs and photographs of the intersection. E, first life sized dinosaur model at Park,*** Coelophysis ***(Fig. 5B), now displayed against a background photograph which shows the Louis Paul Jonas Studio in the process of making the life size reconstruction of*** Brontosaurus ***(now*** Apatosaurus***) for the World Fair in New York in 1964. F, a x1/12 diorama showing the flora and fauna of the Upper Triassic (left half) and Lower Jurassic (right half) of the Connecticut Valley.***

under some sort of permanent protective structure. Peoples (1971: Fig. 2) published a greatly reduced copy of a photo-mosaic of most of the large area and Ostrom (1972: Fig. 4), who used information from the original mosaic, produced a rose diagram for the orientations of the trackways and isolated footprints at Rocky Hill (Fig. 6C). The apparent maze of trackways going in all directions is in marked contrast to the situation at other sites, including that at Mt. Tom to the north of Holyoke, Massachusetts (Figs. 6A, B), that he interpreted as indicating gregarious habits for dinosaurs (also Ostrom, 1986).

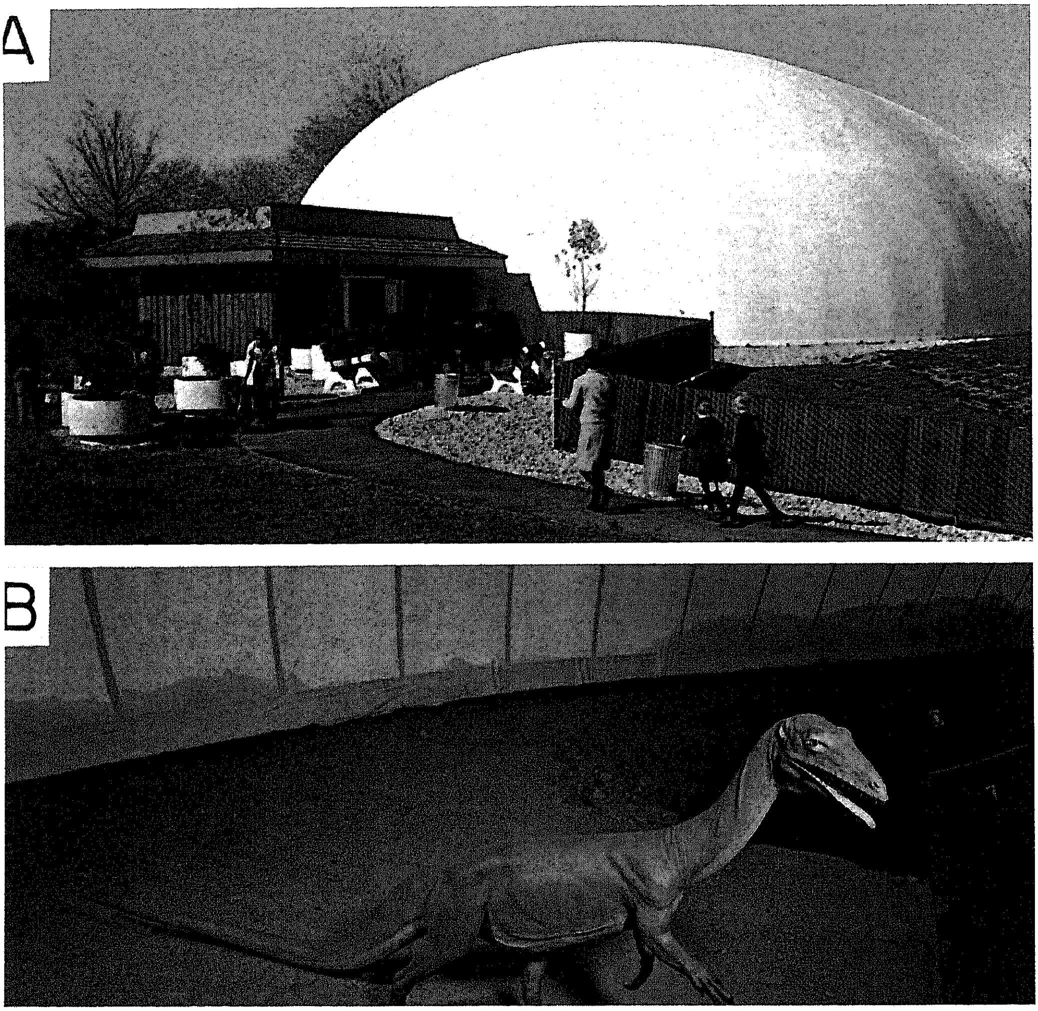

FIGURE 5. ***Dinosaur State Park - the early days (1968-1976) with the temporary pressurized dome over the exhibit tracks. A, view of southern aspect with entrance building and grass covered area between trackway areas - large area to right of picture is now covered with grass. B, inside dome to show an early exhibit (purchased by 1969), a life size model of the small theropod dinosaur*** **Coelophysis** ***on the cliff on southwest side of area (with four layers indicated on right side) that is still exposed in the current building (Figs. 4B, 18G; see Peoples, 1969: Pl. 5 for photo of*** **Coelophysis** ***and Sid Quarrier at foot of cliff). Copies of postcards purchased in late 1960's.***

The inflatable exhibit building collapsed for the last time on January 14th 1976, due to a severe storm that, along with being left on the ground for several months, caused irreparable damage to the fabric. The park remained closed until August 1978, during which time a permanent building was built over the original exhibit trackway area, not a new excavation as stated by Coombs (1980: 1198). The new 13 m high building is covered by a 37 m diameter aluminum Temcore Geodesic Dome, the first large geodesic structure in New England (Figs. 7, 8A, for comparable view in 1985 without landscaping, see photo in Anon., 1986: 11; for view from north from the road, see Weishampel and Young, 1996: Fig. 9.10; Galton, 2002: Fig. 13A). However, the geodesic dome was not without its problems for many years, with large but light pieces of roof insulation occasionally crashing down onto the footprint area from two different ceilings (both attached to underside of roof; the

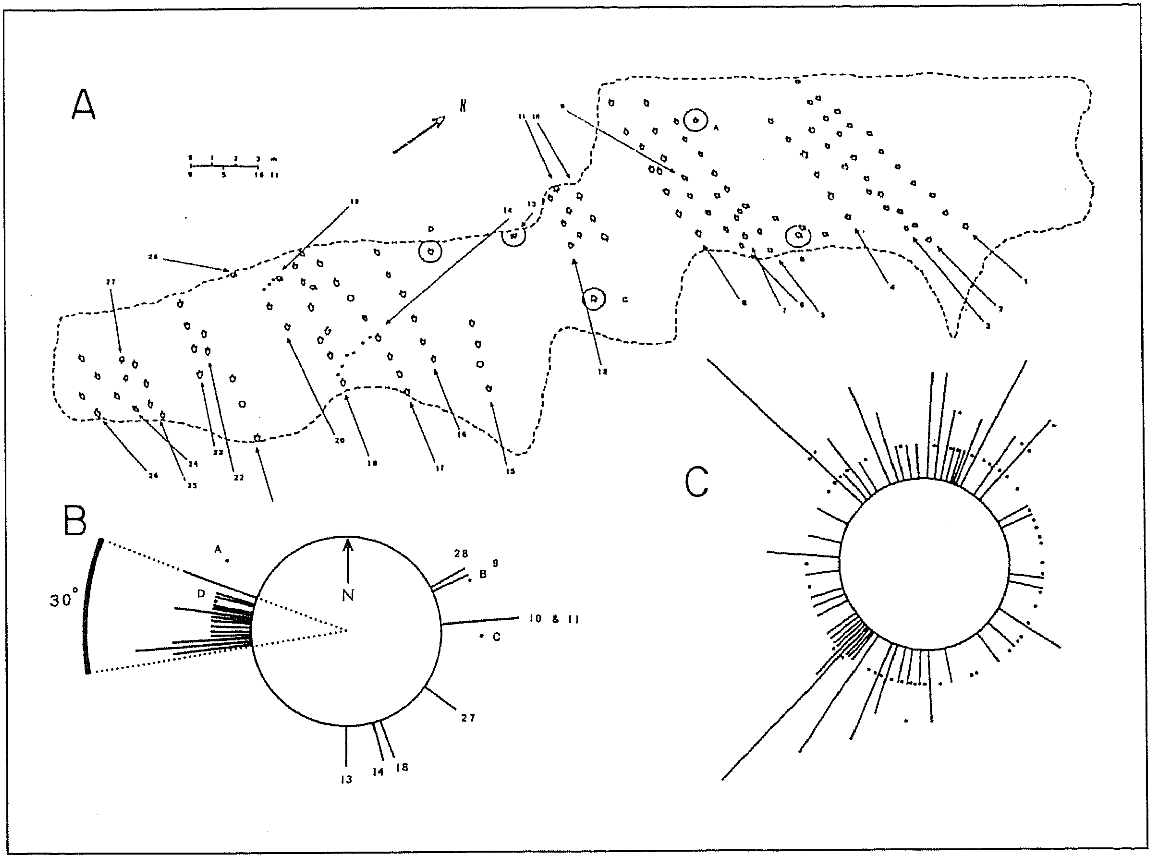

FIGURE 6. ***A-B: Mt. Tom trackway site on west bank of Connecticut River 1.6 km north of Holyoke, Massachusetts (map in Ostrom, 1972, Fig. 1). A, map of Mt. Tom trackways, small open circles indicate destroyed footprints, arrows indicate the general trends (a new larger exposure 69 m above this one at Mt. Tom has a similar orientation of the trackways, Smith and Smith, 1996); B-C, Mt. Tom (B) and larger area at Rocky Hill (C, north approximately vertical): rose diagram plots of the trackways (solid lines) and solitary footprint (dots); lengths of solid lines are proportional to the number of trackways with that bearing (maximum of three in B, six in C) (track and print numbers in B as in A). Dot positions along radii correspond to the number of solitary footprints with that approximate orientation (from Ostrom, 1972).***

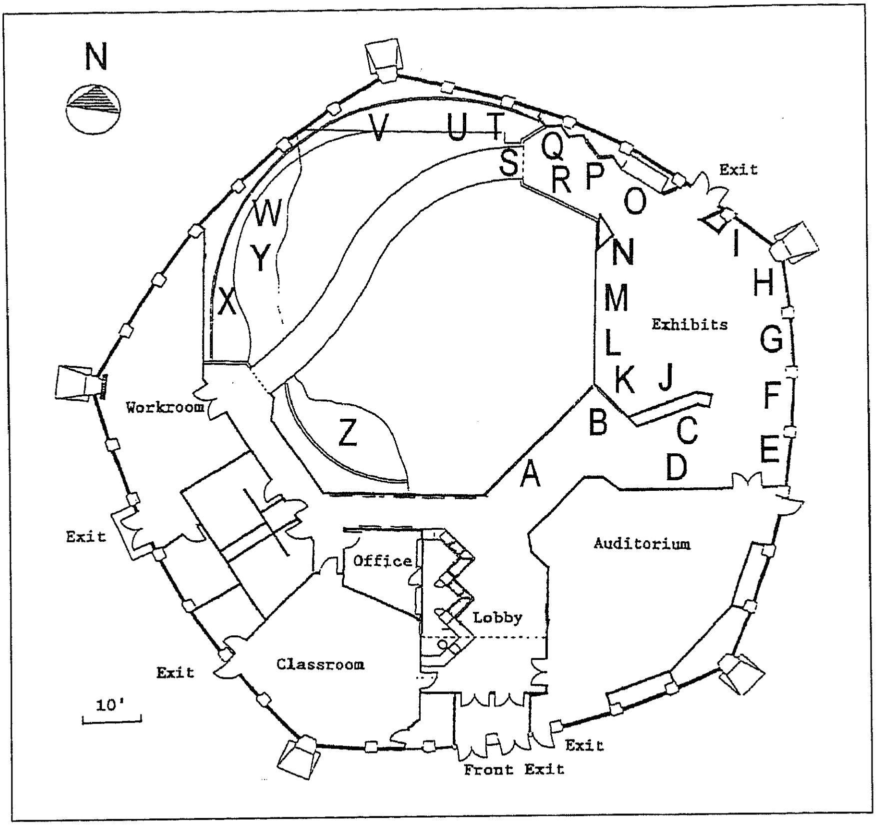

FIGURE 7. ***Floor plan of exhibit building of Dinosaur State Park. Letters A-Z indicate approximate positions of exhibits and dioramas (for details see text, section 10). Scale line 10' or 3m.***

third and current suspended ceiling is a black mesh that was installed in 1995). Richard Krueger announced that schools and other groups were welcome to the surplus natural casts left over from the original excavations of 1966-67, not from additional excavation for the new building as stated by Waters (1981). This led to the second "Great Dinosaur Rush" at the Park, with numerous people accepting the offer, but the enthusiasm of some was a little dampened when they realized that the average slab weighed about 18,000 kg.

Because of the park's location near major urban areas, the dinosaur footprints were originally seen by over 100,000 park visitors each year. The Park still attracts over 80,000 visitors a year, with the reduction possibly being due to less advertizing by the State and a small entrance fee, and it is still a particularly popular destination for school parties. As the result of a petition by the fourth grade class at Center School in Old Lyme, a bill designating *Eubrontes* as the state fossil was passed by both houses of the Connecticut legislature and signed into law on May 8,

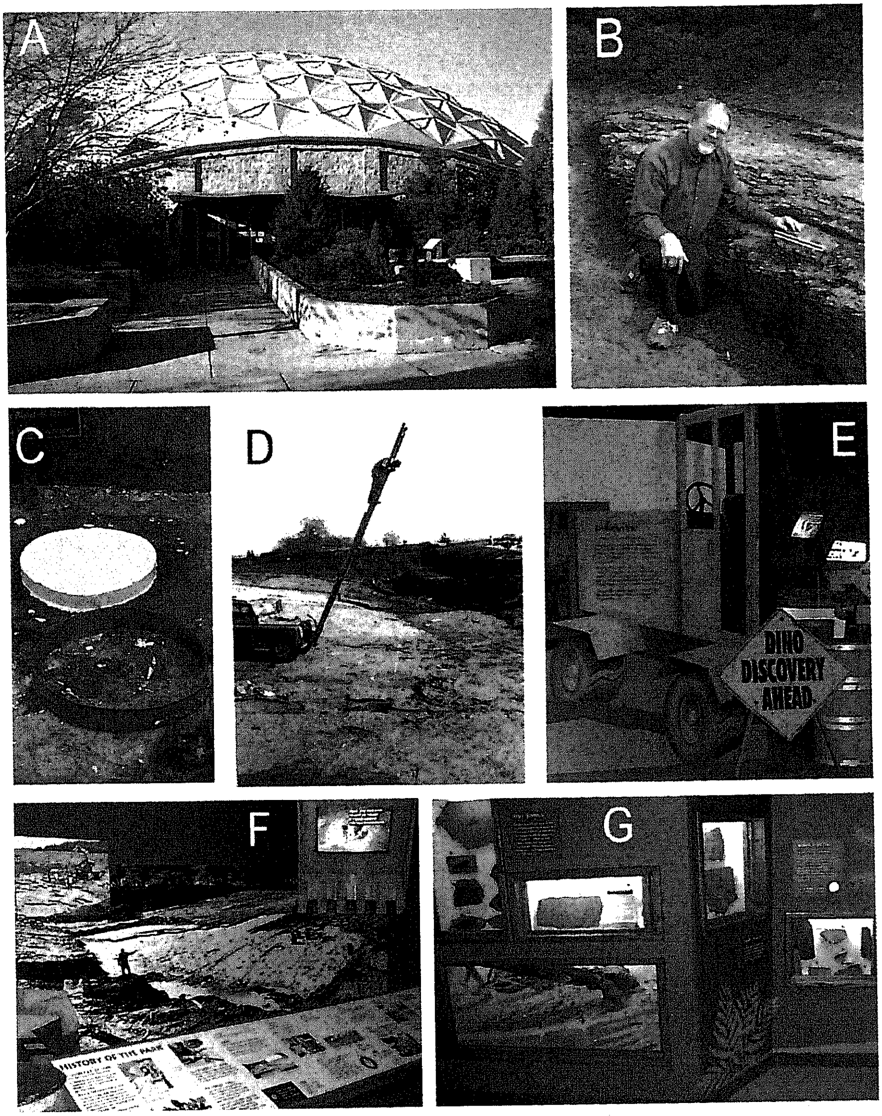

FIGURE 8. *Dinosaur State Park. A, southern front entrance of permanent building over the exhibit trackway in November 2001. B, outside "cliff" just south of the fault with a 5.5 m upward displacement so flat platform with footprints and ripple marks is equivalent to the under track level of the adjacent large footprint area. Rich Krueger shown in 2001 on the raised under print layer holding a 30 cm ruler at the horizon where he discovered* Batrachopus *footprints in 1971 (Fig. 19C). C, casting your own footprint. The metal ring has just been released and removed from the setting plaster that will then be carefully levered off the rock surface, providing enough cooking oil was used! D, large trackway exposure (now buried) in October 1970. Sid Quarrier, shown atop a home made cherry picker mounted on his Land Rover, is photographing 3 m squares, the corners of which are marked out on the rock surface with white tape X's. The photographs were mounted to give a photomosaic (Fig. 13). View towards east to show most of larger area - straight chalk line is alongside trackway with manus imprints (Fig. 12A). E-G, some of the peripheral exhibits: E, entrance to peripheral exhibit area with a model back hoe and a large oil drum; F, display beyond oil drum with history of Park in foreground, photographs of excavation of small area on left (Fig. 4A) and of large area in background, and on right a TV monitor in the bucket of the back hoe that shows a video of the excavation. G, exhibit cases with Connecticut Valley fish remains, an underwater diorama, and fossil plant remains.*

1991 by Governor Lowell P. Weicker, Jr.; on a less official basis, *Eubrontes* has been Massachusetts' state fossil since 1981.

From the smaller exhibit area, Coombs (1980; summary account in Wright, 1997a, see also Mossman and Sarjeant, 1983: 77; Anon., 1980a) described several unusual trackways, the prints of which consist of tridactyl toe-tip impressions, and he identified large (*Eubrontes* sp.) and small (*Anchisauripus* sp.) prints. He suggested that these trackways were made by a partly submerged carnivorous theropod dinosaur that was kicking along the muddy bottom with the tips of its toes. He restored the large trackways being made by a large carnivorous theropod like *Megalosaurus* (isolated bones, Middle Jurassic, England), with a total body length of about 6-7 m. However, Richard Krueger suggested (in McDonald, 1982) that a better match for *Eubrontes* was the large theropod *Dilophosaurus*, known from a complete skeleton from the Lower Jurassic of Arizona (Welles, 1984).

Ishigaki and Fujisaki (1989) used moiré topography to obtain computer generated three dimensional representations of a dinosaur footprint. To do this they used a plaster cast made from a positive of a Rocky Hill *Eubrontes* footprint set up for casting by visitors to the Park (Fig. 8C; see also Weishampel and Young, 1996: Fig. 9.9 for photograph with Richard Krueger, director of the Park since 1970).

2. GEOLOGY

Summary accounts of aspects of the geology of the Connecticut Valley are given by Lull (1953), Colbert (1970), Wright (1997b), McDonald (1995), and Olsen *et al.* (1998). The geology and paleontology of the Park were discussed in detail by Byrnes (1972), and a summary account was given by Ostrom and Quarrier (1968) and Anonymous (1986). The dinosaur footprints occur in the East Berlin Formation (Fig. 9; Lower Jurassic, Hettangian, about 205 mya), in sediments that accumulated under subaerial and shallow-water lacustrine conditions (Olsen *et al.*, 1989) (Fig. 1B). The track-bearing units are the gray arkoses, siltstones and mudstones in the upper portion of an East Berlin lacustrine cycle (Figs. 4A, B, 9). The rocks display abundant ripple marks (Fig. 2), raindrop impressions, mud cracks (Fig. 10H), and cross bedding indicative of shallow water deposition, exposure to the air, and desiccation. Cornet and Traverse (1975: 30) noted that the palynoflorule comprises more than 90 % *Corollina* pollen from conifers that lived abundantly on sandy areas of the alluvial fans and highlands. The rarity of xeromorphic cuticular adaptations in the flora (including large-leaf forms of *Clathropteris*), and the many kinds of cryptogams (based on spore diversity), suggest a humid savanna climate with a short dry season. The palynoflorule is found in the lacustrine gray mudstone and black shale and records recurring periods of relatively high rainfall that coincided with the existence of a large perennial lake (Fig. 1B). Hubert *et al.* (1976, 1978) estimated that the size of this lake ranged from a minimum of 2160 km^2 to a maximum of at least 5000 km^2, with a central minimum depth of at least 20 m to as much as 80 m.

The tracks are best preserved in the well developed bedding planes of the arkosic units. At the Park these strike N 85° E and dip 7-10° S. The exposed rocks are on the south flank of a broad anticlinal structure, which gently slopes towards the border fault, and the joints in the rock are a result of this folding (Figs. 13, 15). At the base of the large footprint area, a small fault was exposed that strikes ENE with an apparent vertical displacement upwards of 5.5 m on the south side and an

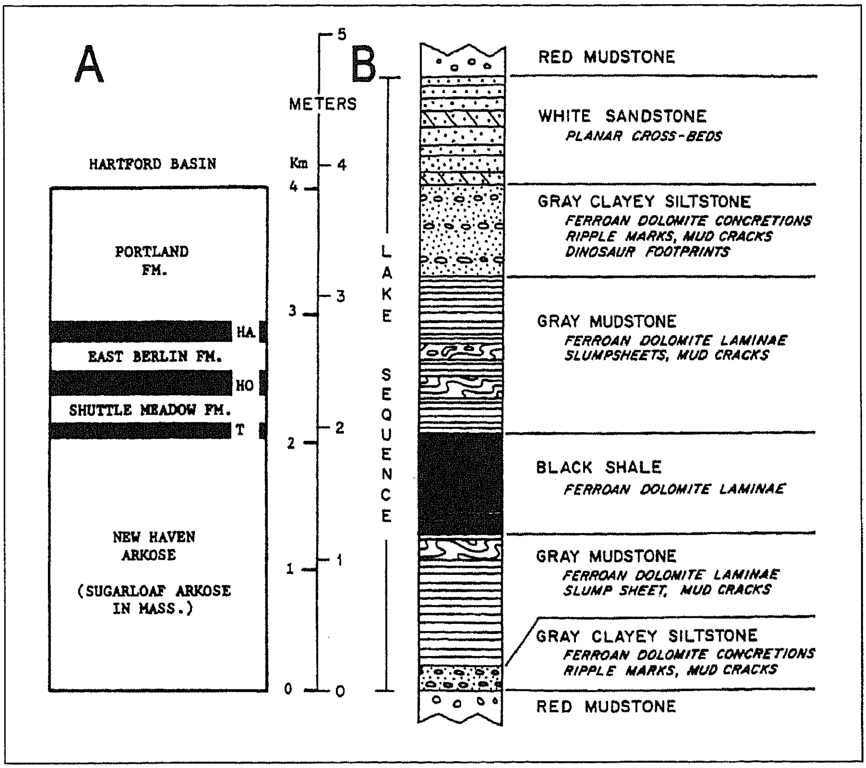

FIGURE 9. ***A*, stratigraphic nomenclature in Connecticut, solid black represents the basaltic formations: *HA*, Hampden Basalt; *HO*, Holyoke Basalt; *T*, Talcott Basalt. *B*, one of the cycles of a perennial lake sequence in the East Berlin Formation near Rocky Hill at Cromwell, Connecticut. Fish fossils, spores and pollen occur in the black shale and gray mudstone (A, B from Hubert** et al, ***1978*).**

unknown horizontal displacement; the sheared zone of this fault was well shown (Byrnes, 1972: Figs. 34, 35) but the area was filled in (under observation platform next to raised under track area with footprints, Fig. 8B). The strata at the Park are located approximately 20 m below the Hampden Basalt (Fig. 9A), which forms the southern ridge of the Park area. Byrnes (1972) correlated these strata with the stratigraphically highest lacustrine cycle, immediately below the Hampden Basalt, at the section exposed in the road cut for the Route 9 and Interstate 91 Interchange, Cromwell (for details see Klein, 1968: 9-14; Hubert *et al.*, 1976, 1978: 77-109; summary in McDonald, 1982: 161-162). At least eight bedding surfaces, containing dinosaur tracks, were encountered in the gray sandstones. The horizons exposed were chosen because the overlying strata separated from them most easily and, in addition, these horizons contained a greater number of better preserved prints (Byrnes, 1972).

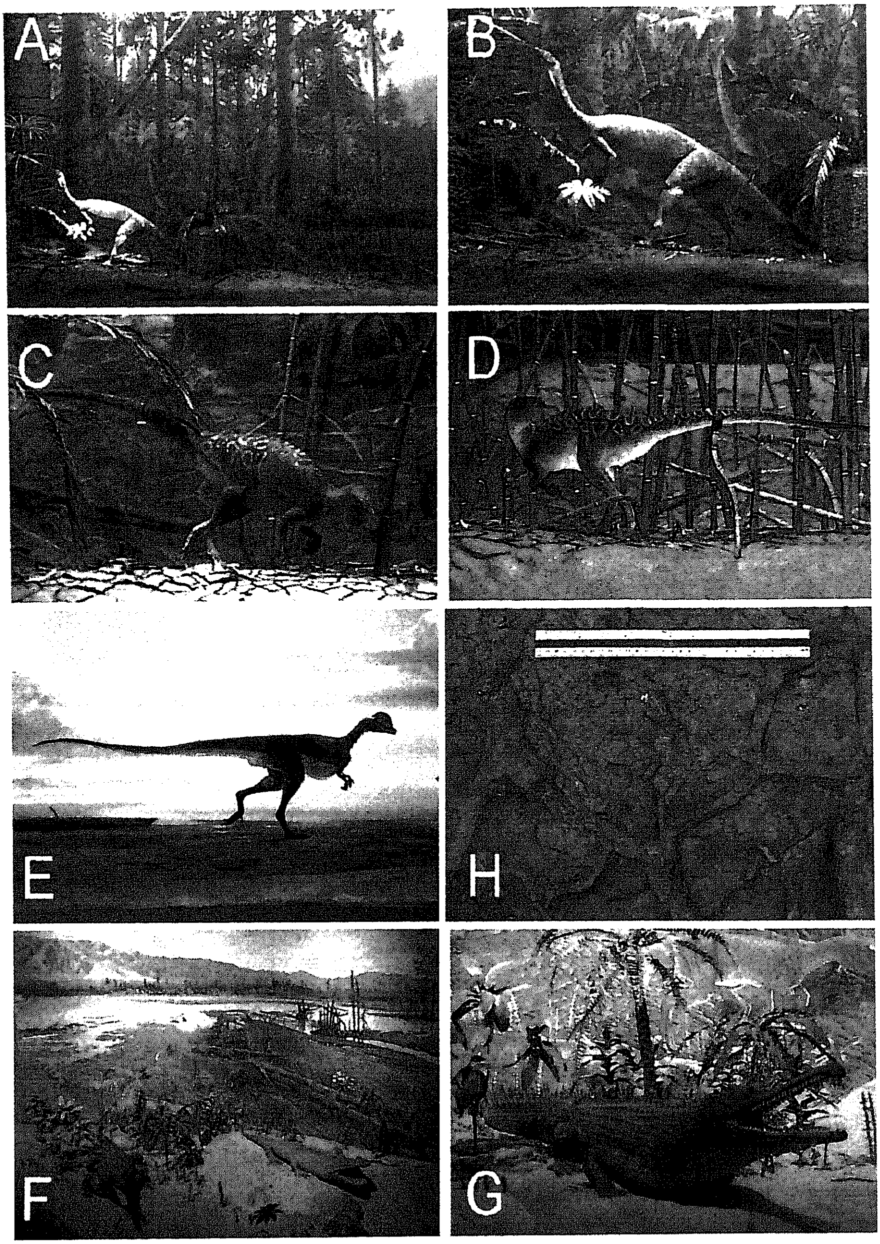

FIGURE 10. *A-G, dioramas adjacent to exhibit tracks: A-E, Lower Jurassic diorama: A-B, extreme left end (Fig. 18G) to show the prosauropod* Anchisaurus. *C-D, next part to show small ornithischian dinosaurs, similar to* Lesothosaurus *from the Lower Jurassic of South Africa, the presumed makers of the footprints of* Anomoepus. *E, painting of* Dilophosaurus *(Fig. 18A). F-G, Upper Triassic diorama, based mainly on the fossils of the New Haven Arkose: F, overall view and G, detail to show the crocodilian-like parasuchian (phytosaurian) archosaurian reptile* Rutiodon. *H, surface view to show mudcracks infilled with sandstone in shales just above level for* Batrachopus *footprints on outside "cliff" just south of large track area (Fig. 8B). 30 cm ruler.*

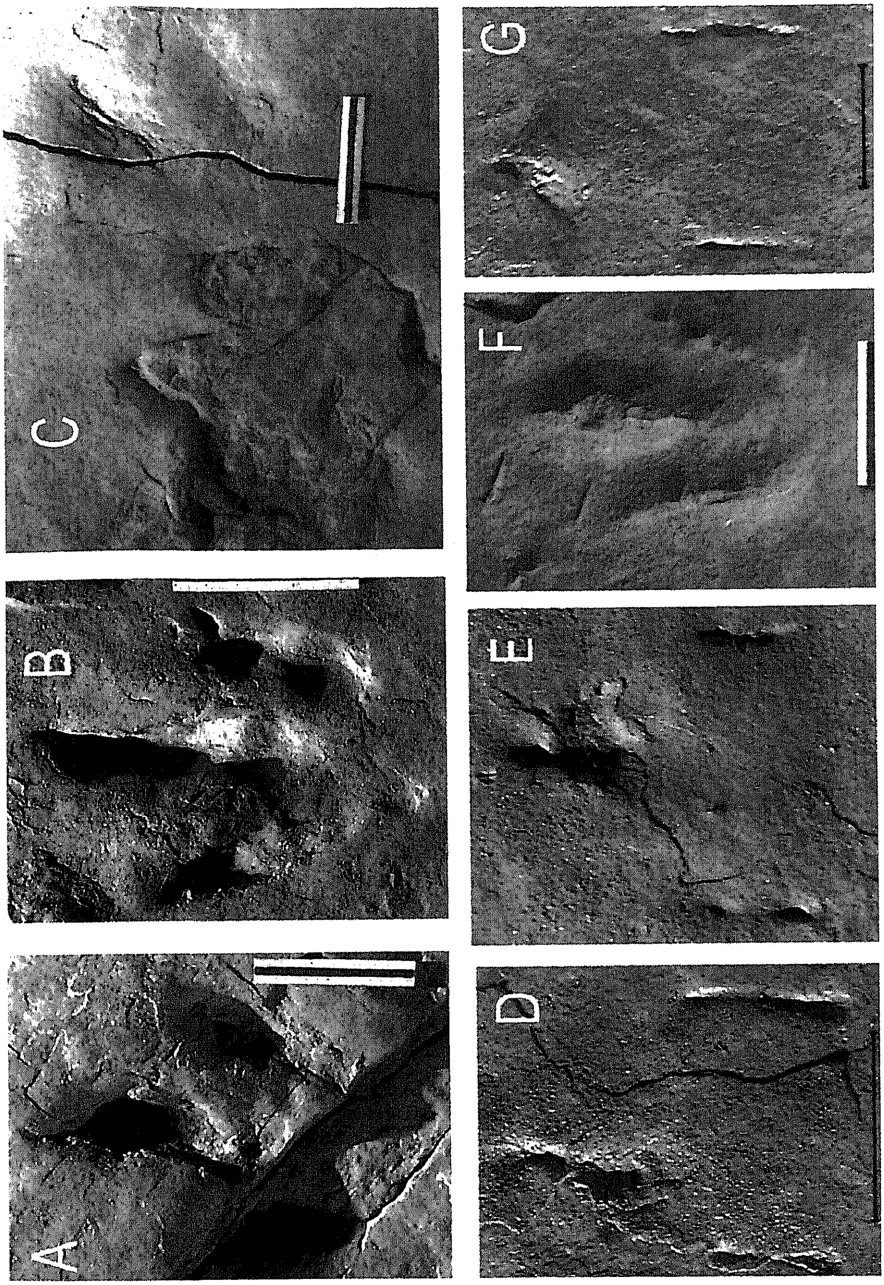

FIGURE 11. ***Footprints from the main level of exhibit trackways: A-E,*** Eubrontes***: A, "split-level" right left footprint with lower left part as an under track on a level 2-3 cm below. B, normal print. C, deep right print from which the overlaying rock has failed to separate. It partly overprints a faint left print that was made earlier when the substrate was much firmer. D-E, two of "swimmer" footprints of*** Eubrontes ***described by Coombs (1980). F-G, "swimmer" footprint of*** Anchisauripus***, one next to a shallow*** Eubrontes ***footprint (F). Rulers 15 cm (A-C, F), scale lines 5 cm (D, E).***

3. OCCURENCE OF FOOTPRINTS

Most of the dinosaur footprints at the park occur in two layers, one 2-3 cm below the other (a, b, Fig. 2). The lower layer is exposed at the northern end of the current exhibit area under the dome (Figs. 14, 15) and it has prominent ripple markings that are not present on the upper layer. Many trails in the upper layer can be traced northward beyond the edge of the upper layer to where they continue in the lower layer. In some cases, the northern edge of the upper layer terminates in the middle of a footprint, and the print is exposed in both the upper and lower track-bearing layers (Fig. 11A). Consequently most, if not all, of the prints in the lower layer are under tracks (subtraces or ghost prints). Footprints in the lower layer are fainter and have less distinct margins.

The quality of preservation of footprints in the upper, track-bearing surface is variable (Figs. 11A-C, F). Some prints are deeply impressed and show sharp, clear margins. Others are shallow and faint, with less distinct margins. Digital pad impressions are faint at best in most footprints, and the boundaries between claws and digital pads are generally not clear. The better-preserved footprints were probably made by dinosaurs walking on the footprint-bearing surface itself. The possibility exists that the fainter prints on the upper track surface, like those on the lower layer, are under tracks. However, in several cases these faint footprints are themselves overprinted by the well-preserved footprints (Fig. 11C). Thus the differences in preservation of tracks in the upper, print-bearing surface are probably due to differences in substrate conditions when the various footprints were made. The "swimmer" tracks (Figs. 11D-G) of Coombs (1980) are discussed below (section 9).

4. METHODS

Just prior to the cover up in October 1970, Galton and Sidney Quarrier chalked in the outlines of the footprints on the large area, by pacing them out on the bedding plane and connecting as many of them together as possible to form trackways. Unfortunately, the persistent occurrence of rain showers meant that the lines had to be replaced and, in the end, only a few trackways were so indicated (Fig. 12). The larger area was marked out to form a grid of 3 m squares, with the vertical lines oriented north-south, the corners marked with tape crosses, and each square was photographed at an angle of about 90° from the top of a home made cherry picker, a 6.7 m ladder attached to the front bumper of Quarrier's Land Rover (Fig. 8D; for photo in opposite direction with inflatable building in background, see Galton, 2002: Fig. 12). The printed squares (corrected if necessary by adjusting the angle of the enlarger base) were then cut out and mounted to form a photomosaic (Fig. 13), the starting point for a map that is currently being prepared. A linear series of photographs were also taken of a few trackways of particular interest and, in these cases, a scale line was marked in chalk parallel to the trackway (Fig. 12). In the summer of 1981, Galton and Jeffrey Shepherd worked on the smaller exhibit area that, because of the dome, could not be photographed from above. Instead translucent plastic sheeting was stretched across a 1.5 m wooden frame that was laid over a quarter of a marked out 3 m square. The footprints were traced using a washable marking pen, the sheet was photographed, the tracing washed off, and the process repeated many times. The photographs of the 1.5 m squares were mounted and used as the starting point for a map of the smaller area (Fig. 14). Recently, Olsen and Rainforth (pers. comm.) pointed out that Byrnes

(1972: Fig. 23) published a photograph of this area taken at an oblique angle by James F. Chipps, Jr. (Connecticut State Highway Department) before it was covered by the exhibit building. This would have been sometime between early fall 1967 and before the summer of 1968 when construction started on the foundations for the pressurized building (Fig. 5A). When scanned at high resolution, the photograph shows little x's on the track surface (invisible on the photo at the original size) to show the grid at that time. Using the x's as guides (lines added) and keeping the blocks defined as squares, the photograph was digitally "undistorted" to

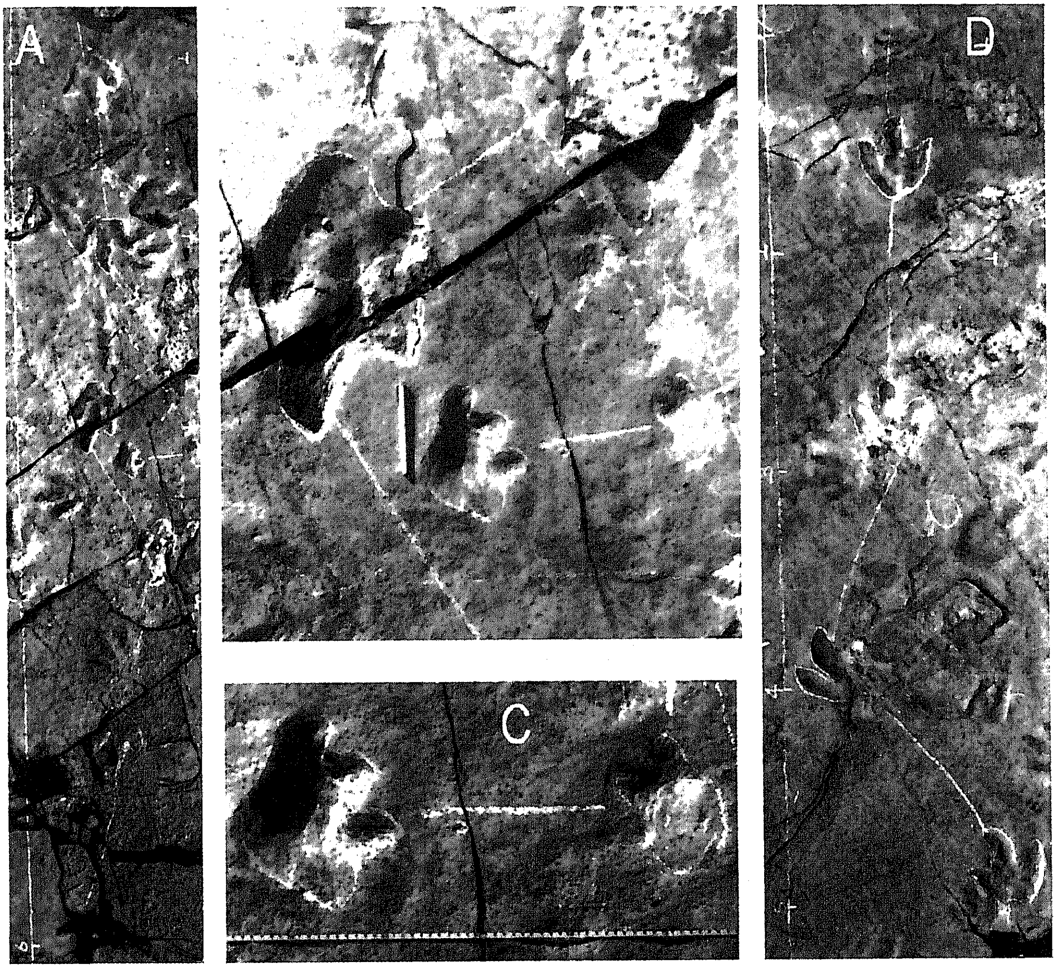

FIGURE 12. *Trackways of* Eubrontes *from large trackway area (now buried, Figs. 8D, 13). A-C, showing possible manus impressions: A, trackmaker entered at top of page while moving in typical dinosaurian fashion with a narrow gauge trackway. The animal abruptly shortened and widened its step, and then placed both forefeet on the substrate surface, directed inwards towards each other. The dinosaur then got up and resumed normal locomotion. B, detail of right pes and the manus impressions. C, close up of manus impressions. D, showing change of direction, trackmaker entered at bottom of page in process of turning to left, then turns towards right before resuming straight course. Chalk lines alongside trackways marked in meters (A, D), maximum width of largest manus print 21 cm (B, C).*

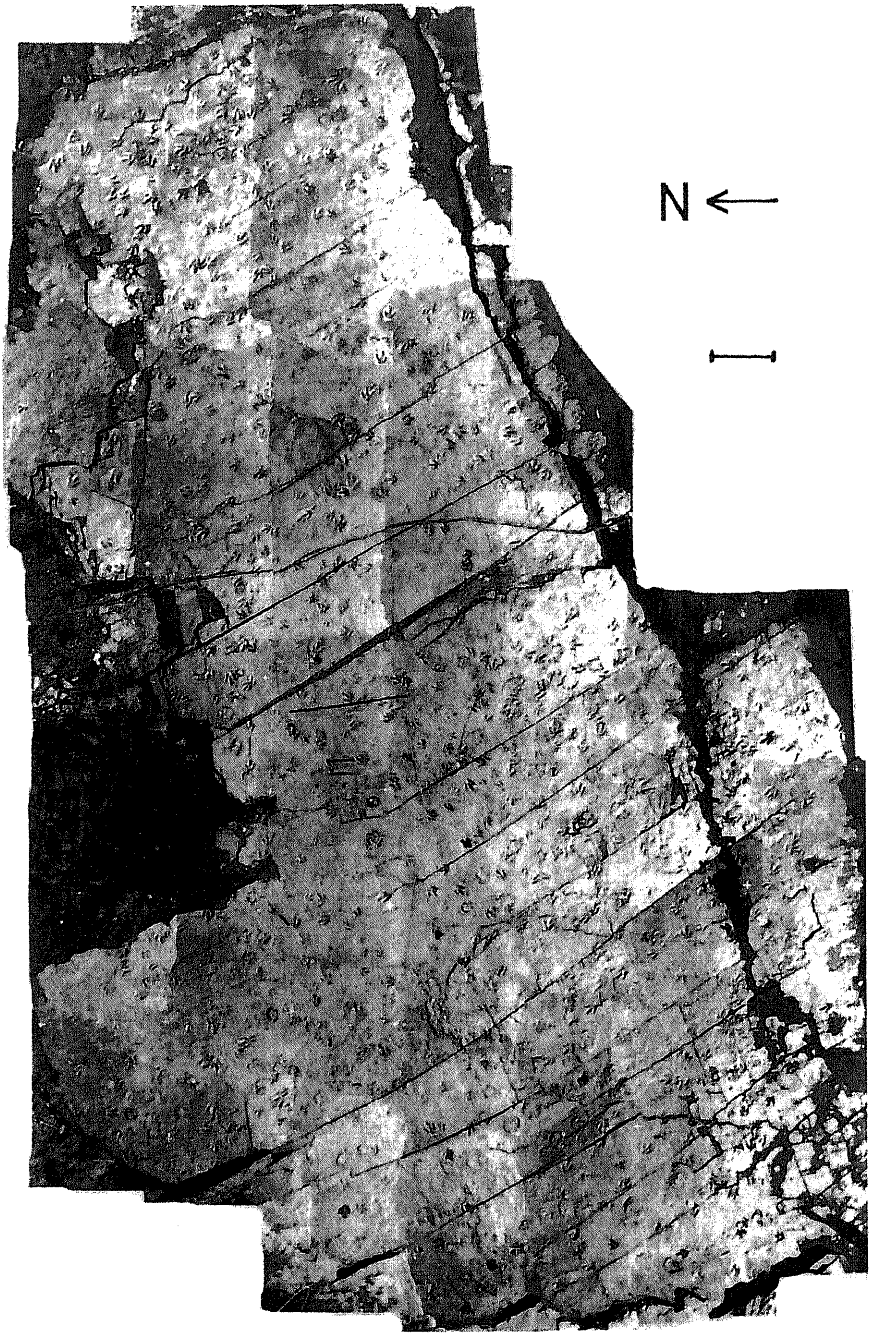

FIGURE 13. ***Photo-mosaic of the large track-bearing surface (now buried) at Dinosaur State Park. Scale line represents 3 m.***

get an "aerial photograph" of this exposure (Fig. 15, courtesy of Olsen and Rainforth, pers. comm.). Fortunately, there is a very close correspondence when Figures 14 and 15 are digitally superimposed.

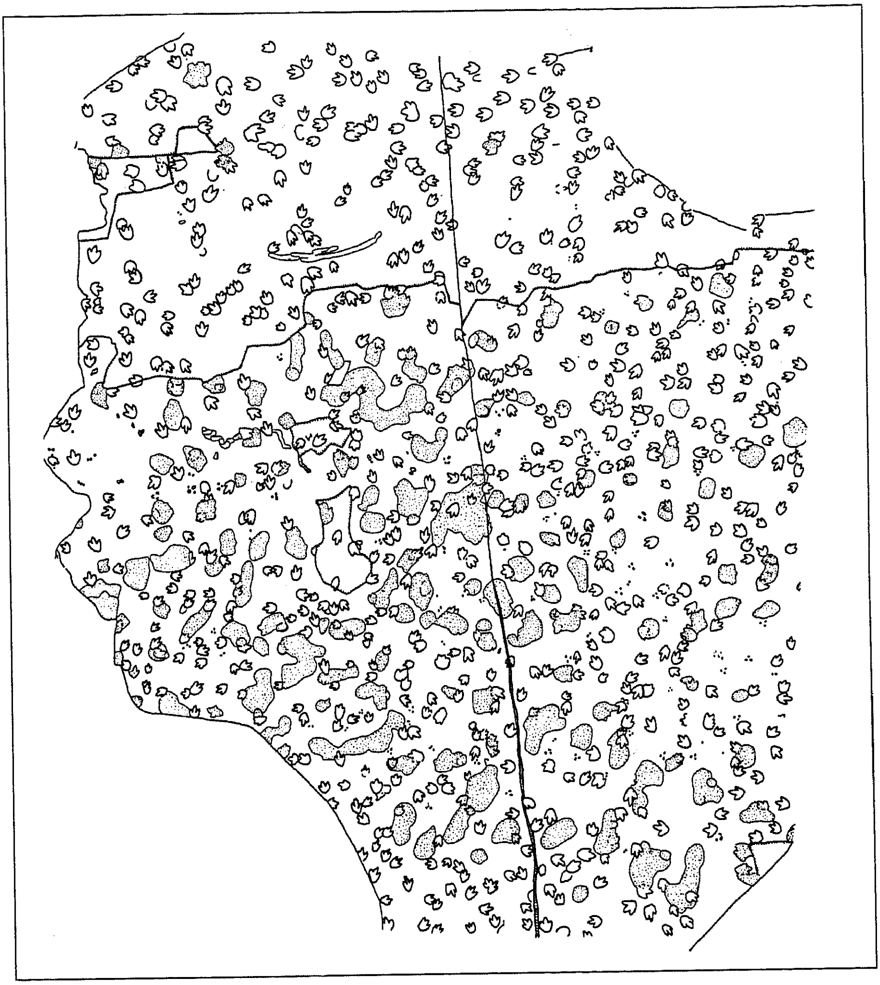

FIGURE 14. ***Map of dinosaur footprints in the exhibit area at Dinosaur State Park. Exposure with footprints is about 10 x 12 m. Stippling shows areas where overlying rock did not separate cleanly from the upper track-bearing layer (see Fig. 11C); here the presence of footprints beneath the covering layer can be inferred on the basis of trail patterns. Cross-hatched lines indicate the boundary between the upper and the under (lower) track bearing layers; cross-hatches are directed toward the lower layer. Groups of circles arranged in a triangular pattern show "swimmer" prints. Central fault line approx. north-south (cf. Fig. 15).***

In an attempt to determine the group(s) of dinosaurs responsible for the footprints at Dinosaur State Park, and the diversity of taxa within these groups, Farlow and Galton (2003) compare the Rocky Hill dinosaur footprints with data on dinosaur foot skeletal shapes (Farlow and Chapman, 1997) and the footprint shapes of modern ground birds. Detailed measurements have only been made on the footprints in the exhibit area. The parameters measured for each footprint mostly followed well established practices (see Leonardi, 1987; Weems, 1992; Pérez-Lorente, 2001), and these are given in Farlow and Galton (2003).

5. FOOTPRINT SIZE, SHAPE, TAXA REPRESENTED, AND POSSIBLE MAKERS

5.1. Introduction

Footprint lengths mostly fall within a rather narrow size range of 30 to 40 cm (and spaced about 105 to 135 cm apart), comparable to the lengths of named specimens of *Eubrontes* and larger representatives of *Anchisauripus* (nomenclature of Lull, 1953). There is a suggestion of polymodality in the size-frequency distribution; this could reflect the occurrence of different age classes and/or sexual dimorphism in a single species, and/or the presence of more than one species, of track maker (Farlow and Galton, in press: Fig. 4). The Dinosaur State Park footprints are similar in gross shape to *Eubrontes* and *Anchisauripus* and, on the basis of a modified Weems' plot for footprints from the exhibit area, most would fall within the fields of *Eubrontes giganteus* and *E.* (formerly *Anchisauripus*) *miniscul*us of Weems (1992).

Footprints of this general shape are usually attributed to theropod dinosaurs (cf. Farlow, 1987; Thulborn, 1990; Lockley, 1991; Smith and Farlow, 1996; Olsen *et al.*, 1998). In contrast, Weems (1987, 1992, 1996) has argued that many early Mesozoic footprints of this shape could have been made by functionally tridactyl plateosaurid prosauropods. Weems' argument was based partly on the presumably conservative structure of the foot in bipedal saurischians, but also on problems in behavioral and paleoecological interpretations if such abundant footprints are considered to have been made by carnivores rather than herbivores (cf. Coombs, 1980).

Wright (1997b) suggested several possible reasons for the abnormally strong bias in favor of carnivores in the Connecticut Valley. Firstly, the higher activity of theropods means that they moved around more and made more footprints. Secondly, theropods may have waited at strategic spots, such as watering holes, for their prey and therefore spent a longer time in areas where their footprints were more likely to be preserved. Thirdly, some of the footprints identified as theropod may not be theropod. Weems also noted Lull's (1953: 178) observation that the *Eubrontes*-makers were "definitely dinosaurian and probably Theropodous although not perhaps strictly carnivorous in their habits for they lack the trenchant, raptorial type of claws generally associated with beasts of prey."

Some of the exhibit area prints do show terminal toe ends that suggest the presence of fairly sharp claws (Figs. 11A, B). Furthermore, the claws of large ground birds like emus (*Dromaius novaehollandiae*) often become blunt by abrasion against the ground. The same could well have occurred with theropod feet, and so the lack of sharp claw marks in footprints may not be a compelling argument against theropods as the footprint-makers. A disproportionately large number of putative theropod trackways is often seen in later Mesozoic dinosaur tracksites

(Lockley, 1991; Schult and Farlow, 1992; Lockley and Hunt, 1995), unless one wants to argue that the makers of these trails, too, have been misidentified (admittedly not impossible). However, ecological and behavioral arguments should carry little weight in the identification of early Mesozoic trackmakers. It should also be noted that *Eubrontes*-like footprints continue into the Middle and Upper Jurassic, and then on to the Upper Cretaceous (Lockley and Hunt, 1995), as do theropod dinosaurs, but this is well beyond the last record of prosauropod bones in the Lower Jurassic (Galton, 1990).

Farlow and Chapman (1997; also see Schult and Farlow [1992], Farlow and Lockley [1993]) noted that theropods tend to have relatively shorter unguals (com-

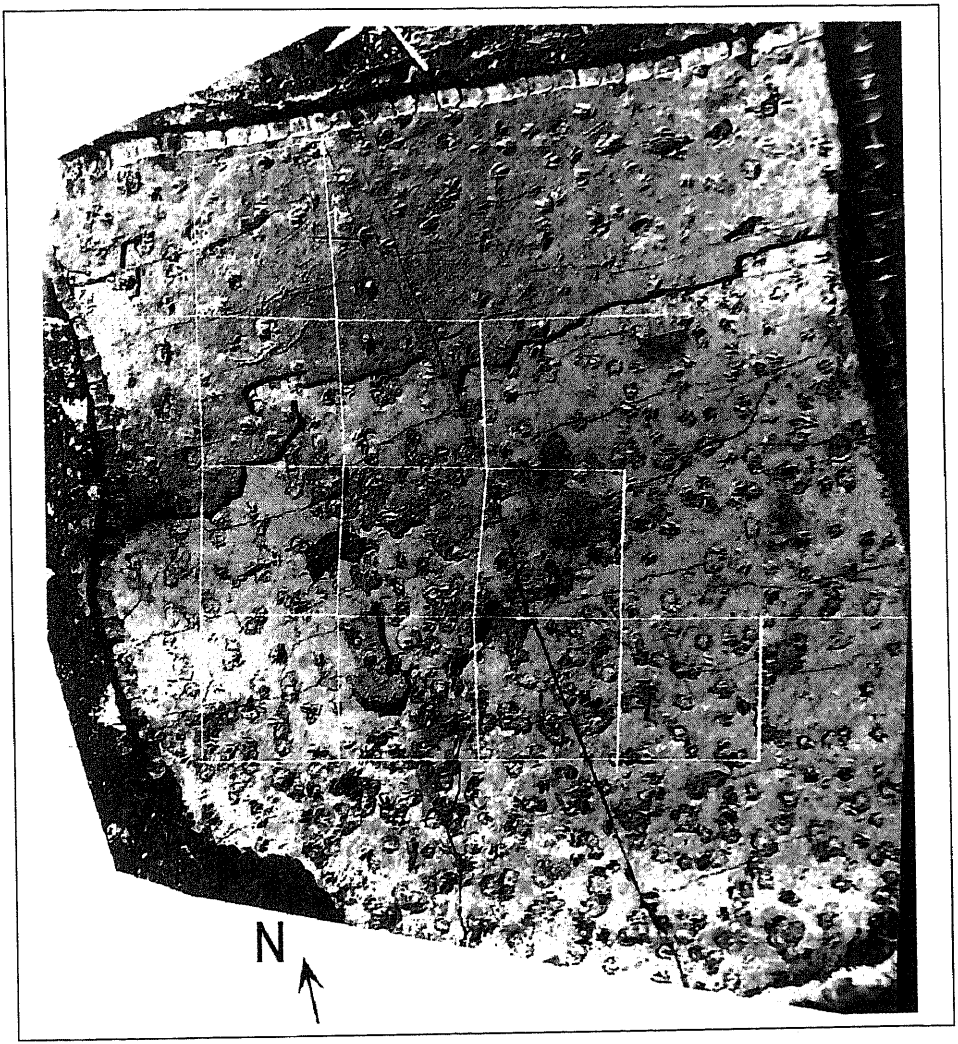

FIGURE 15. ***"Aerial" photograph (for details see text, 4. Methods) of the exhibit area taken sometime between Fall 1967 and Summer 1968, courtesy of Olsen and Rainforth (pers. comm.).***

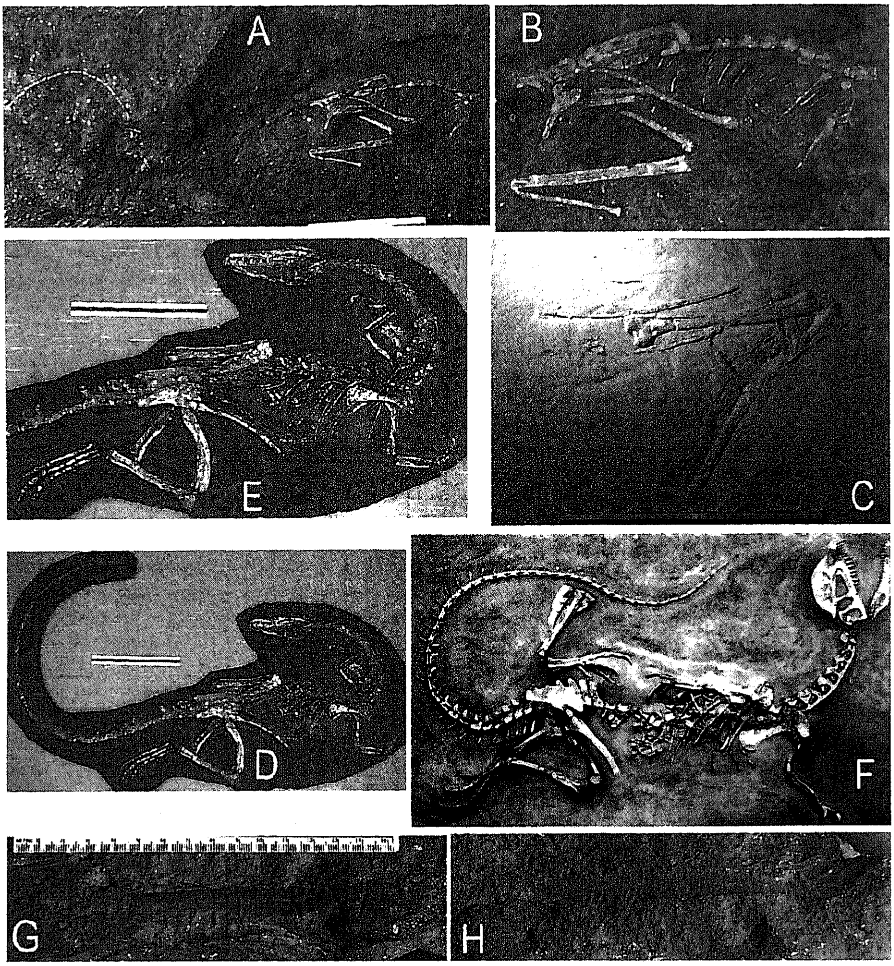

FIGURE 16. ***Skeletal remains that may have made the footprints of the dinosaurs*** **Anchisauripus** ***(A-E),*** **Eubrontes** ***(F), and the crocodile-like*** **Batrachopus** ***(G-H). A-B, plaster cast of holotype of*** **Podokesaurus holyokensis** ***Talbot, 1911, a partial skeleton in a Portland Formation boulder (Lower Jurassic) found on the campus of Mount Holyoke College, South Hadley, Massachusetts [Lull (1915, 1953), original destroyed by fire that burnt down Williston Hall of Mount Holyoke College in 1916; this cast is at Dinosaur State Park]: A, complete specimen and B, detail of anterior part (see Fig. 17B). C, natural cast of ribs, tibia and pubis of a larger individual than A, possibly*** **Podokesaurus** ***sp., from Portland Formation of Portland (on east side of Connecticut River near Middletown, Fig. 1A), Connecticut (this plaster cast YPM 3912). Plaster cast described as*** **Coelophysis** ***sp. by Colbert and Baird (1958), the original natural sandstone cast (specimen 13656) then being in "dead storage" in the collection of the Boston Society of Natural History. Guinness (1996) noted that this specimen was thrown out in 1961, when the Boston Science Museum moved to new facilities, but this is incorrect because it was located in a storage area in mid-2001 and it will be part of a new exhibit in 2002 (Baum, pers. comm.). D-E, cast of skeleton of*** **Coelophysis** ***from Upper Triassic of New Mexico, cast by American Museum of Natural History as YPM 5705: D, complete skeleton and E, detail of anterior two thirds. F, cast of mounted articulated skeleton of*** **Dilophosaurus wetherilli** ***from Lower Jurassic of Arizona [Fig. 17A; cast in California Academy of Sciences, San Francisco, original specimen in Museum of Paleontology, University of California, Berkeley, described by Welles (1984)]. G-H, natural mold of inside (G) and outside (H) of skull roof and dorsal armor plus partial limbs of holotype (AM 900) of*** **Stegomosuchus longipes** ***(Emerson and Loomis, 1904) (Fig. 17C). Rulers: A, G, 15 cm; C-E, 30 cm; scale line F, cm.***

pared with the rest of the toe) than do prosauropods and ornithischians. Although few of the Dinosaur State Park footprints have clear digital pads, from which the size of the clawmarks relative to impressions of the remainder of the toe could be determined, what indications there are do not suggest particularly long clawmarks (Figs. 11A-C). We therefore think it likely that the Park trackways were made by theropods, as opposed to prosauropods.

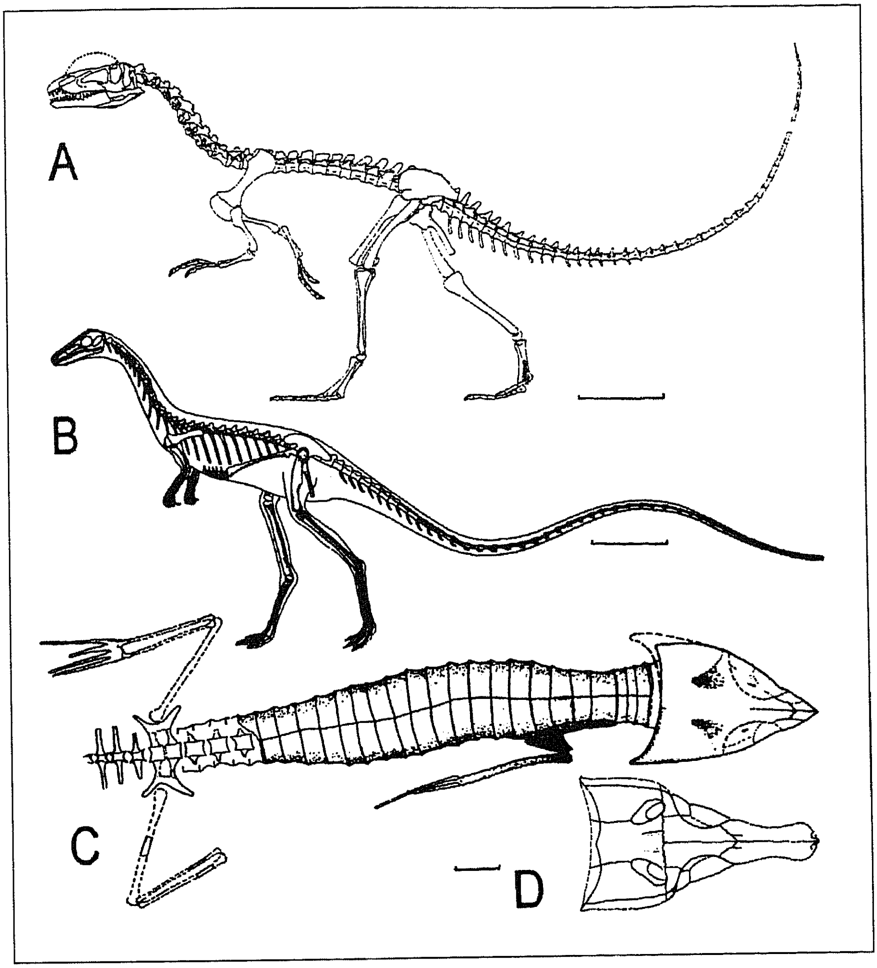

FIGURE 17. ***Skeletal reconstructions of possible makers of dinosaurian footprints*** **Eubrontes** ***(A) and*** **Anchisauripus** ***(B) and the crocodile-like*** **Batrachopus** ***(C-D): A,*** **Dilophosaurus wetherilli** ***(Fig. 16F), B,*** **Podokesaurus holyokensis** ***(Fig. 16A) and C-D,*** **Stegomosuchus longipes** ***in dorsal view: C, skeleton (Figs. 16G, H); D, reconstruction of skull. A from Welles (1984), B, C from Lull (1953), D, from Walker (1970). Scale line represents 50 cm (A), 10 cm (B) and 1 cm (C).***

Ostrom and Quarrier (1978) identified footprints (in decreasing frequency) of *Eubrontes giganteus, Anchisauripus sillimani, Batrachopus dispar*, and possibly *Grallator cuneatus* from Rocky Hill (Fig. 3).

5.2. *Eubrontes*

Using good non-Rocky Hill Connecticut Valley footprints, Smith and Farlow (1996) noted that the relationships between the phalanx measurements and the relationships between the digit measurements are both linear, and that theropods and non-theropods tend to separate nicely if these proportions are compared. *Grallator*, *Anchisauripus*, and *Eubrontes* tend to cluster well within the theropods on a plot of digit III/digit IV lengths versus digit III/digit II lengths. On a plot of phalanx III2/phalanx IV1 lengths versus ungual II3/phalanx II2 lengths, these ichnotaxa fall within the theropod cluster, with the first two plotting closer to *Coelophysis*. However, *Eubrontes* falls much closer to *Herrerasaurus* (Upper Triassic, Argentina) and *Liliensternus* (Upper Triassic, Germany) than to *Dilophosaurus*, which is usually considered to be the best skeletal match for *Eubrontes*. The large theropod *Dilophosaurus*, unknown from the Connecticut Valley or northeastern USA., is known from a complete skeleton from the Lower Jurassic of Arizona (Figs. 16F, 17A, 18C; Welles, 1984).

5.3. *Grallator*

The location of the possible *Grallator* prints was not mentioned by Ostrom and Quarrier (1968), but they were on the exhibit area (Ostrom, pers. comm.). However, apart from the small "swimmer" tracks referred to *Anchisauripus* by Coombs (1980) (see section 9), all of the tracks on the exhibit area seem to pertain to *Eubrontes*/large *Anchisauripus*. However, a possible *Grallator* footprint may be represented by an isolated positive that was found by Richard Krueger in the spoil heap material from the excavation of the trackway exposures (Fig. 19D).

5.4. *Anchisauripus*

Coombs (1980) identified the smaller "swimmer" tracks as *Anchisauripus* sp., and some of the normal looking trackways could be a large *Anchisauripus* sp. A good trackway of a smaller individual of *Anchisauripus* was exposed on the northern margin of the larger area, but at a third level, a few centimeters below the under print level (c, b, Fig. 2). The water's edge is indicated by the ripple marks that end parallel to the left edge of the photograph. A trackway of *Anchisauripus* passes diagonally across (c-c) - at the left the animal first stepped on firm mud on the banks of the lake, then on softer mud as it came to the edge of the water, and then on very soft bottom mud at the right. Tracks of a smaller individual, apparently another theropod, passed parallel to the water's edge, an even smaller individual passed in almost the opposite direction, and several indeterminate invertebrate trails are visible. This exposure, which differed markedly from the levels above in displaying clear fine water ripples (cf. less well preserved coarse ripples on parts of under track level) and much smaller prints, had crumbled to pieces and completely weathered away by 1975 (Krueger, pers. comm.). It was in a much softer,

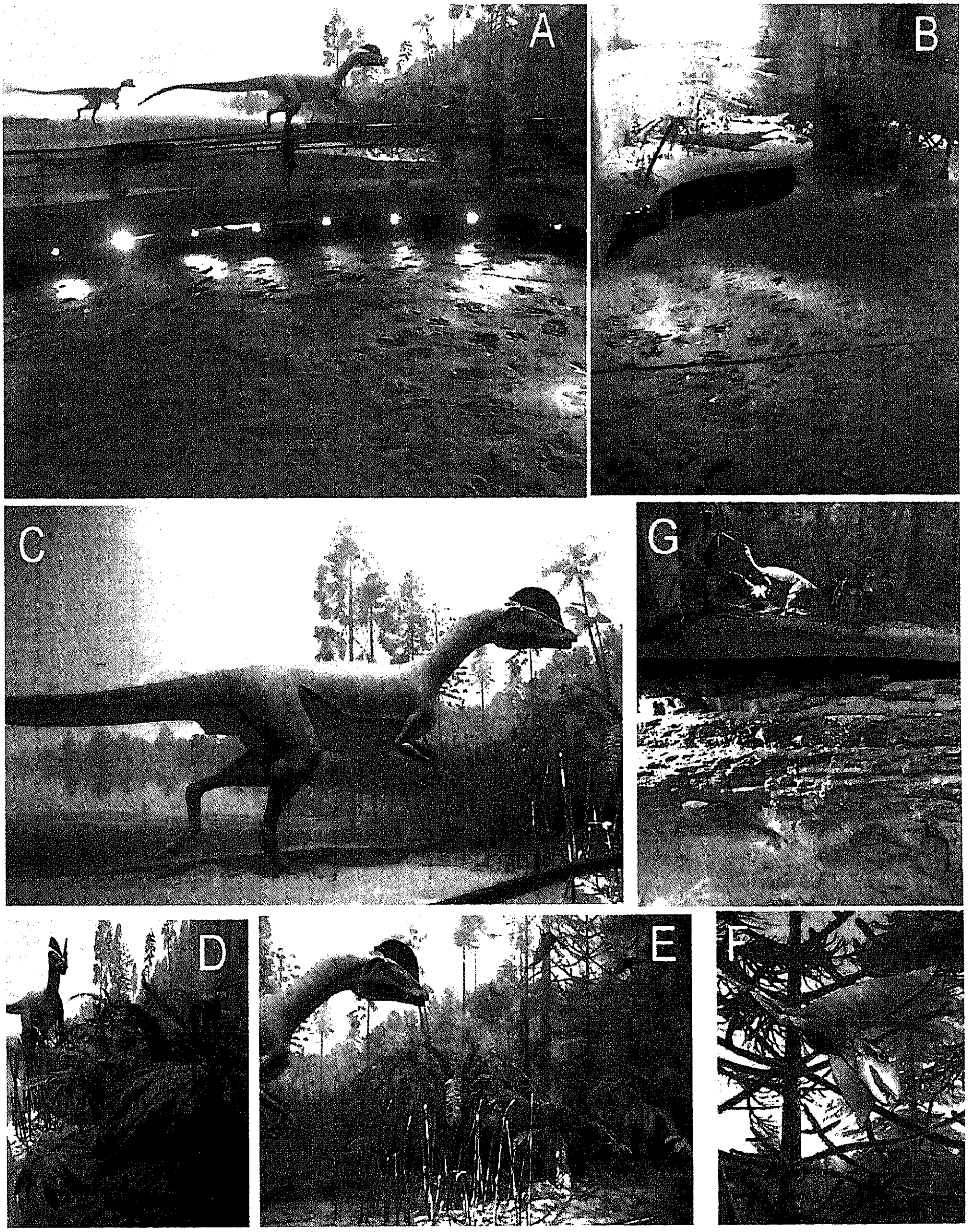

FIGURE 18. ***Exhibit trackways and adjacent dioramas. A-B, views looking across trackways: A, to right part of pedestrian walkway and Lower Jurassic diorama with two individuals of*** Dilophosaurus. ***B, perpendicular to A to Upper Triassic diorama and left end of walkway. C-D, life size model in side and head on views of*** Dilophosaurus ***(Figs. 16F, 17A), a possible maker for*** Eubrontes ***footprints. E, woods at right end with head of*** Dilophosaurus. ***F, detail of E to show model of long tailed flying reptile*** Dimorphodon ***(Lower Jurassic, England). G, the main track surface, small cliff (Figs. 4B, 5B), and the left end of the Lower Jurassic diorama with a model of the prosauropod*** Anchisaurus.

dark brownish black rock and, because it was never studied, photographs now provide the only available information (Fig. 2).

Anchisauripus footprints are usually attributed to the ceratosaurian theropod *Coelophysis*, many skeletons of which are known from the Chinle Formation (Upper Triassic) of Ghost Ranch, New Mexico (Figs. 16D, E; Colbert, 1989). A similar dinosaur is represented by a partial skeleton of an animal with an original total length of about 0.85 m from the Longmeadow Sandstone of South Hadley, Massachusetts (Fig. 17B; Lull, 1953: 129-141). It was described as *Podokesaurus holyokensis* Talbot, 1911 and, although only plaster casts now exist (Figs. 16A, B), it was regarded as a small individual of *Coelophysis* by Colbert (1964, as *C. holyokensis*). A natural sandstone cast of a more fragmentary specimen (Fig. 16C), representing a much larger individual of about 2.5 to 3 m from the Portland Formation of Portland, Connecticut, was described as *Coelophysis* sp. by Colbert and Baird (1958); it was referred to *C. holyokensis* by Colbert (1964). However, Colbert (1989: 29) noted that, given the incompleteness of the holotype of *Podokesaurus* and its subsequent destruction, it is probably best to let the genus stand, rather than regard it as a junior synonym of *Coelophysis*, a decision that is supported by the age difference for the two genera, Late Triassic versus Early Jurassic. Rowe (1989) described a similar ceratosaurian from the Kayenta Formation (Lower Jurassic) of Arizona as *Syntarsus kayentakatae*. *S. rhodesiensis* is well known from abundant material from the Lower Jurassic of southern Africa (Raath, 1977, 1990) and, because of its age, *Syntarsus* is a more likely maker of *Anchisauripus* prints than *Coelophysis*.

5.5. *Batrachopus*

The footprints of *Batrachopus dispar* were probably made by a small, quadrupedal crocodile-like animal like *Stegomosuchus longiceps*, a reasonably complete skeleton of which was discovered near Longmeadow, Massachusetts (Figs. 16G, H, 17C, D; Emerson and Loomis, 1904; Lull, 1953: 83-89). The *Batrachopus* footprints of Ostrom and Quarrier (1968), that were exposed in soft rocks that form a low "cliff" a few meters south of the fault next to the grass covered large footprint area (Fig. 8B), weathered away within a year of their discovery (Quarrier, pers. comm.). Unfortunately they were never studied or photographed and, as noted above, the drawings of *Batrachopus* (Figs. 3D, E) were scaled from those in Lull (1953: Fig. 106). However, a small block and its counterpart, with a few small isolated footprints of *Batrachopus* (Fig. 19C), were excavated from the same area by Krueger in 1971 in a sandstone layer within the dark shales. The horizon is about 50 cm above the under track footprint layer, that forms a flat area, covered with coarse ripple marks, adjacent to the observation platform (Fig. 8B).

6. TRACKWAY PARAMETERS

Most footprints in the exhibit area point directly ahead, or slightly outwards, with respect to the track makers' direction of travel (Figs. 12A, D). This is in contrast to the presumed theropod trackways from the Lower Cretaceous of Texas in which the prints commonly angle slightly inwards (Farlow, 1987).

Compared with dinosaur trackways from other ichnofaunas, step lengths of the Rocky Hill trackmakers are relatively short. Not surprisingly, the stride/footprint length ratio for these prints (most prints about 30 to 40 cm long and spaced about

105 to 135 cm apart) is comparable to that of dinosaur trails at the Mt. Tom site in Massachusetts (Fig. 6A; Ostrom, 1972) and named trackways of *Eubrontes* and of larger representatives of *Anchisauripus* from the Connecticut Valley. Relatively short step lengths for the Rocky Hill exhibit area trackmakers translate into fairly slow estimated speeds for these dinosaurs (Alexander, 1976): mostly between 5 and 8 km h^{-1}, with the fastest estimated speed being 12 km h^{-1}. Although within the range commonly reported for bipedal dinosaur trails (Thulborn, 1990), these speeds are a bit on the low side. It is not known whether this reflects differences in behavior or in the structure of the Rocky Hill trackmakers (e.g. relatively shorter legs, or less cursorial limb proportions [cf. Holtz, 1994], or a heavier body build). Values of the pace angulation of the Rocky Hill dinosaur trails (Farlow and Galton, in press: Fig. 13) are comparable to those observed in other trackways of large bipedal dinosaurs (e.g. Farlow, 1987).

7. *EUBRONTES* MANUS PRINTS

One of the *Eubrontes* trackways in the buried large area seems to record an individual that slowed down, with the usual narrow gauge trackway preceding and following a section with an increased track width, a wide gauge section (Fig. 12A). Most theropod trackways are narrow gauge but Day *et al.* (2002) describe a dual gauge trackway of a large theropod from the Middle Jurassic of England: in the wide gauge part it was walking whereas in the narrow gauge part it was running.

At the presumed stopping point there are impressions of the trackmaker's forefeet that are opposite each other and medially directed (Fig. 12B), as though it paused at least for a moment in a resting position; in trackways of archosaurs walking quadrupedally, the manus prints are staggered and the digits are directed anteriorly rather than medially. The better-preserved of the two poorly preserved possible manus prints (Fig. 12C) seems to show a four-fingered hand that does not closely match what one would expect to see in any of the plausible candidates for the *Eubrontes*-maker. The manus of a facultatively bipedal, non-dinosaurian, predaceous archosaur like *Postosuchus* should have five fingers (Chatterjee, 1985). The prosauropod hand (Galton, 1990) might leave a four-fingered imprint, but there should be a much stouter impression of the claw on digit I than seems to be indicated in the Rocky Hill print, more like that seen in the prosauropod trackway *Navahopus* from the Lower Jurassic of Arizona (Baird, 1980; Lockley and Hunt, 1995). Primitive ornithischians might make four-fingered manus impressions (Thulborn, 1990), but digits II and III should leave much longer marks than I and IV, unlike the Rocky Hill print. *Herrerasaurus* (Sereno, 1994), and most ceratosaurs (Welles, 1984; Colbert, 1989), would probably make a three-fingered manus print. The hand of *Ceratosaurus* (Gilmore, 1920) might fit the shape of the Rocky Hill manus impressions, but digits II and III of this dinosaur are excessively longer than I and IV. Unfortunately, the poor preservation of the manus prints (Fig. 12C) does not help much in settling the question of the nature of their maker. Furthermore, the preceding discussion assumes that the manus was impressed over its entire length in the formation of the print. If instead, only the proximal portion of the hand touched the ground, so it is only a palm print as may well be the case, then many of the key anatomical features of the manus would not have been recorded in the print. This would also be true in the less likely case that the track maker curled its fingers and touched down only on the dorsal surfaces (as a "knuckle walker").

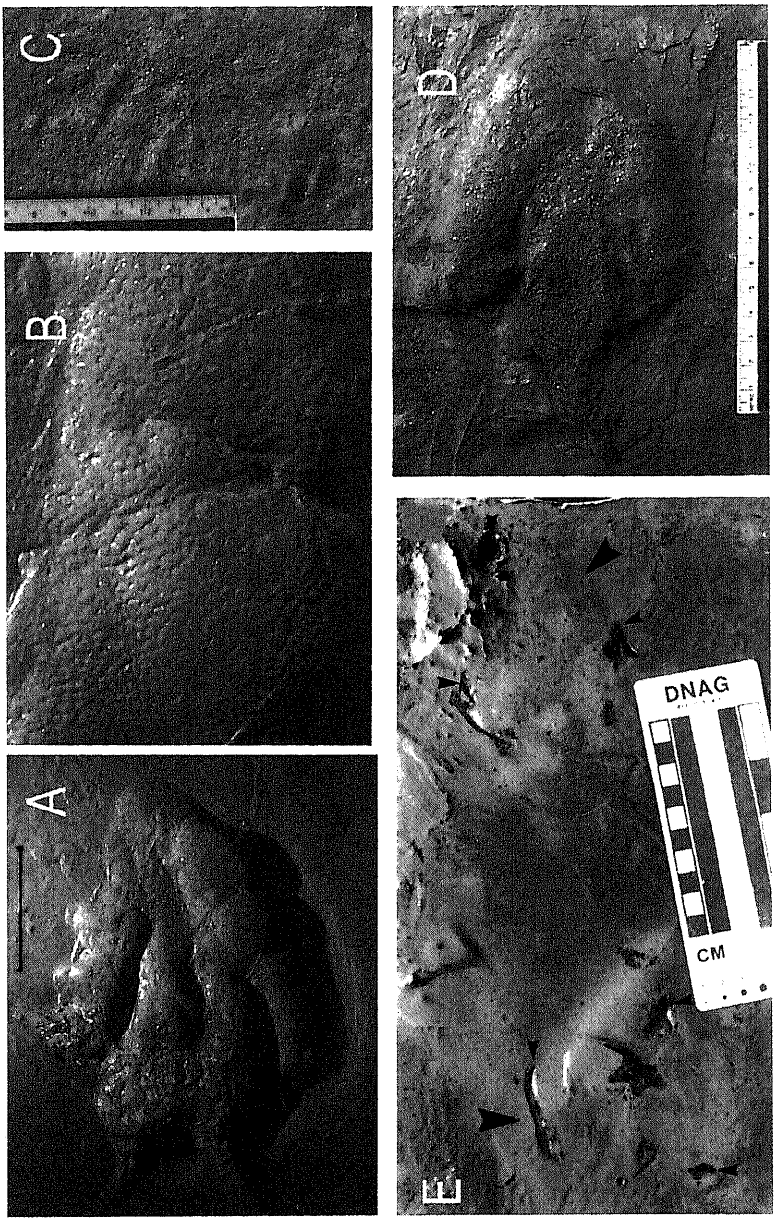

FIGURE 19. *A-B, right footprint on trackway of* Otozoum moodii *from Lower Jurassic (Portland Formation) of Portland, Connecticut (DSP WU 680): A, complete footprint and B, detail of middle part of left edge of print to show natural skin impression. C, footprints of* Batrachopus, *that were probably made by a small crocodilomorph reptile, found at Dinosaur State Park about 50 cm above main footprint layer (Fig. 4B). D, natural cast of incomplete right footprint of* ?Grallator *from Dinosaur State Park. E, sequence of two footprints (pace 23.2 cm) made by a lesser rhea (*Rhea pennata*) running over nearly hardened plaster of Paris at Mesker Park Zoo, Evansville, Indiana. Large arrow shows positions of two prints, small arrows indicate distal ends of claw-marks. Scale line A, 10 cm; rulers in C-E in cms.*

8. ORIENTATION OF TRACKWAYS

In contrast to the markedly unimodal or bimodal orientations seen at many dinosaur tracksites (cf. Figs. 6A, B; Ostrom, 1972; Farlow, 1987; Thulborn, 1990; Lockley, 1991; Lockley and Hunt, 1995), dinosaur trails in the exhibit area do not show any strongly preferred orientation (Fig. 20). Furthermore, in contrast with the straight-line, seemingly purposeful movements recorded at many dinosaur tracksites (cf. Figs. 6A, B; Ostrom, 1972, 1986; Lockley and Hunt, 1995), several of the trails show marked changes in direction over their course (Fig. 20). Trails in the pre-

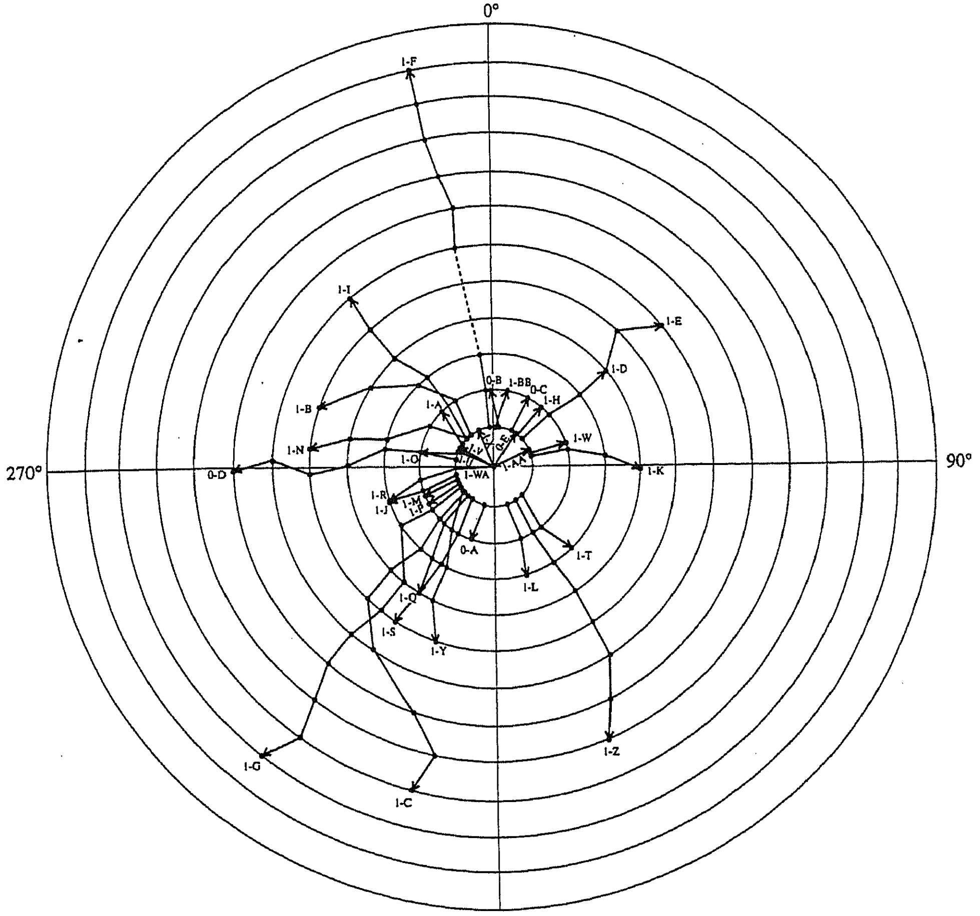

FIGURE 20. ***Dinosaur State Park, overall direction of trackmaker travel in the exhibit area. Note the rather rambling paths taken by some of the dinosaurs. For measurable trail segments, the dinosaur's overall direction of travel was plotted as a series of concentric circles, with 0° corresponding to magnetic north in May 1989. The first dinosaur heading was determined as the average bearing of the first two footprints, and plotted on the innermost circle. On the next circle outward were plotted the average bearing of the second and third footprints in the trail, and a line was drawn connecting the two average bearings. This was repeated for the average bearing of the third and fourth footprints on the next circle outward, and so on.***

sently buried large track surface (Fig. 13) are somewhat less rambling (but rambling ones do occur, Fig. 12D), and there are slightly more trackways heading in a northeasterly or easterly direction than in other directions (Fig. 6C).

There is no obvious indication that the Dinosaur State Park tracks were made by a large group of animals moving through the area together. Rather it was individual dinosaurs, or perhaps small groups of dinosaurs, passing across the site at different times as previously described by Ostrom (1972). As discussed in the next section, the footprint-bearing surfaces may have recorded tracks over either a day or so or perhaps a month or more, depending on the status of the "swimmer" tracks.

9. "SWIMMER" TRACKWAYS

Coombs (1980) described several unusual trackways from the exhibit area (Figs. 11D-G; short accounts in Anon., 1980a; Mossman and Sarjeant, 1983: 77; Wright, 1997a), identifying the more common larger prints as *Eubrontes* sp. and the less common smaller ones as possibly *Anchisauripus* sp. He observed 43 prints, with eight consecutive steps as the longest sequence made by a single individual, and noted that in some cases the prints are overstepped by normal *Eubrontes* footprints. He suggested that these trackways were made by nearly floating, swimming carnivorous theropod dinosaurs that were kicking along a muddy bottom with the tips of the toes (Fig. 21). If this interpretation is correct then, as he noted, traditional ideas on escape behavior of herbivorous dinosaurs and pursuit tactics of predatory theropods need to be revised. These prints are characterized by impressions only of the distal ends of the toes (Figs. 11D-G). In such footprints the dinosaur's

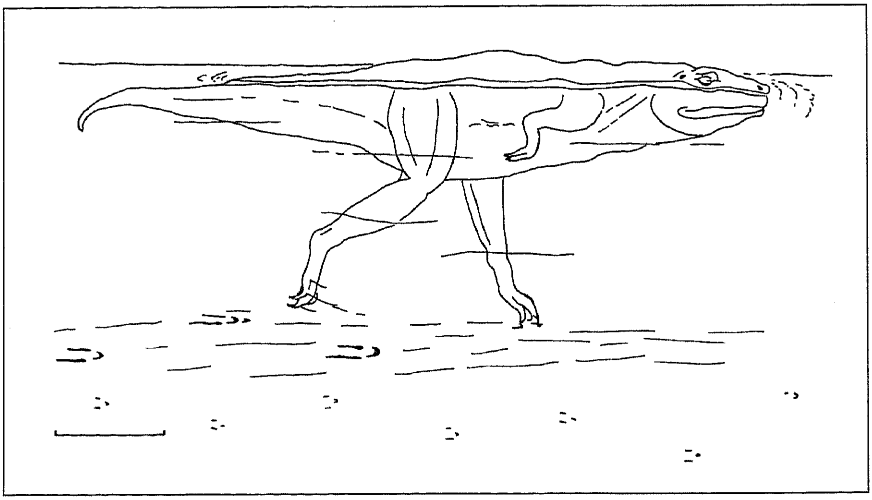

FIGURE 21. ***Reconstruction of the maker of the*** **Eubrontes** ***swimming tracks (Figs. 11D, E) after Coombs (1980), patterned on*** **Megalosaurus** ***and shown in the swimming posture. Below is a map of eight footprints (Figs. 11F, G) made by a smaller animal, possibly*** **Anchisauripus**. ***Scale line 1 m.***

claws made long grooves, often with small mounds of sediment at their posterior ends. The distal ends of the marks made by digits II and IV are subparallel, being closer to the footprint's midline than in typical prints (Fig. 11F), as though the digits were not spread out and bearing the animal's weight. Coombs argued that these print shapes were inconsistent with their formation as under tracks, or as imperfect impressions in a very firm substrate. He also noted that the sequences of footprints begin and end abruptly, and many are single, isolated footprints, as would be expected from the hypothesized mode of formation.

If Coombs' hypothesis of swimming dinosaurs is correct, then this also has implications for the hydrology of the ancient lake in whose sediments the prints were placed. Some of the allegedly swimming dinosaurs were large animals, estimated by Coombs to probably be comparable in size to the individuals responsible for the more typical footprints in the exhibit area, with a restored hip height of about 2 m (Fig. 21). To float animals of that size would probably require a water depth of a bit more than 2 m (Coombs, 1980). However, the same rock surface that contains the large "swimmer" footprints also has the smaller "swimmer" trackways (hip height about 1 m) and, in addition, the much more numerous prints of dinosaurs walking more normally on the exposed surface. In order for dinosaurs to be able to walk across a sediment surface, either before or after an interval during which the water was deep enough to float a large bipedal dinosaur, would require a lake water level rise or fall of at least 2 meters. Given that the lake in question may have had a surface area of at least 5000 km^2 (Hubert *et al.*, 1976, 1978), this would require a significant influx or loss of water from the lake. Modern Lake Chad (Tchad) in Chad, central North Africa, has a surface area that averages about 20,000 km^2, probably larger than the lake of at least 5,000 km^2 bordering Dinosaur State Park. Lake Chad's surface area fluctuates dramatically in the semi-arid climate, so lake levels can rise or fall by 1-3 meters over as little as a few months (Isiorho, 1993). Comparable rates of lake level change could well have occurred in the Early Jurassic lake at Rocky Hill under the tropical, seasonally dry climatic regime thought to have characterized that time (Cornet and Traverse, 1975; Hubert *et al.*, 1976). The question then becomes whether the rate of sedimentation during such changes would have been slow enough (if changes climate related), and the durability of the oldest footprints in the surface great enough, for footprints made at both the beginning, the middle and the end of the interval over which the lake level changed to be able to co-occur in the same bedding plane - a question that we cannot answer. However, Krueger (pers. comm.) notes that in a rift valley, tectonic activity could result in subsidence in one area that could shift bodies of water from adjacent areas to the area of subsidence. Thus a rapid change in lake level might possibly have occurred independent of climate.

The variable quality of preservation of footprints in the upper track-bearing layer might be explained by a long interval of a month or more, over which time the sediment surface was available to record tracks. If this was the case, then the exhibit surface bears footprints made when the surface was under water at depths of about 2 m (for larger "swimmer" prints) and then about 1 m (for smaller ones). Subsequently, the mud was exposed but still wet so looser, deeper prints were formed, some of which are over "swimmer" prints, and then it became drier (so firmer, faint prints) before becoming wetter again (because some faint prints are covered by deep prints).

Coombs' interpretation is possible but Farlow and Galton (2003) argue that walking on a very firm substrate cannot be ruled out because some of the features of the "swimmer" prints are duplicated in footprints made when a live lesser rhea (*Rhea pennata*) walked across a surface of nearly hardened plaster of Paris. These prints (Fig. 19E), that consist of only the impressions of the claws with some forming linear grooves, are similar to the theropod "swimmer" footprints. However, the rhea prints do not appear to be any narrower than those made when rheas walk across a softer substrate; nor are there any small mounds of sediment piled up behind the rhea's claw marks. However, it should be noted that most of the "swimmer" prints lack such mounds that are not shown by the prints illustrated by Coombs (1980: Figs. 2A, B, D) or those shown (Figs. 11D-G). Farlow and Galton (2003) consider that the bird prints are similar enough to the "swimmer" prints to indicate that the odd features of the latter may be due to substrate conditions rather than indicating swimming. Further support for this view is provided by the work of Thulborn and Wade (1989), who described and analyzed the sequence of different print types that occur on mud of decreasing water content at a Lower Cretaceous site at Lark Quarry in Queensland, Australia. The high variability of print form (see Thulborn and Wade, 1984) is analyzed in terms of exactly when the foot penetrates the substrate, and the subsequent pes-substrate interactions during the three phases of interaction, viz., touch-down or T-phase, weight-bearing or W-phase, and kick-off or K-phase. They discuss four successive generations of footprints that were made during increasing degrees of dessication of the substrate. The fourth generation were made on a muddy substrate that was exposed long enough to have achieved a firm plastic consistency.

Thulborn and Wade (1989: 55) noted for the fourth generation prints that some did sink into the firm plastic substrate during the T-phase or the W-phase (Fig. 22W top row). However, "in many cases the (coelurosaurian) foot did *not* sink into the (firm plastic) substrate during the T-phase or the W-phase (Fig. 22T, W lower row). This seems to have happened very frequently, judging from the large number of "gaps" or "missing" footprints in the coelurosaurian trackways at Lark Quarry. We suspect that the coelurosaurs had relatively large and broad-spreading feet that acted as analogues of snowshoes. Nevertheless the sharp tips of their claws did commonly break through the surface of the substrate during the K-phase, when the animal's body mass would have been supported by a small (and diminishing) area of the foot's undersurface (Fig. 22Ba). Then, quite frequently, the sunken tips of the toes lost their purchase in the muddy substrate and slithered backwards to leave a footprint consisting of superficial furrows or retro-scratches (Fig. 22Bb, Bc)."

The "swimmer" trackways of Coombs (1980) were characterized by their abrupt beginning and end, with many as isolated prints, and the prints as impressions just of the tips of the toes with sub-parallel grooves, features matched in the firm substrate coelurosaur trackways from Australia. An examination of the surface at Rocky Hill failed to show any "swimmer" prints comparable to the size of the normal prints so the closer position of digits II and IV to the midline is probably partly a function of the smaller size of the "swimmer" *Eubrontes* footprints (certainly the case for those referred to *Anchisauripus*) compared to the normal *Eubrontes* prints on the same main track surface. One character not matched by the Australian prints is the presence of small mounds of sediment at the ends of the superficial furrows or retro-scratches as occur on some of the "swimmer" tracks at Rocky Hill. However, the presence of mounds is indicated for *Skartopus* in the side view during the K-phase (Fig. 22Bb - top part, in the plan the : at the posterior end of each groove in lower part presumably indicates the mound shown in side view). If these posteriorly situated mounds were not dispersed by the last part of the K-phase, then the resulting print would be similar to the "swimmer" prints with posterior mounds at Rocky Hill.

A more detailed analysis of the "swimmer" tracks is in progress to determine whether the "swimmer" trackways demonstrate an atypical behavior, swimming as suggested by Coombs, or are part of a wide spectrum of prints made on exposed mud, with the differences due to changing water content of the mud and its effect

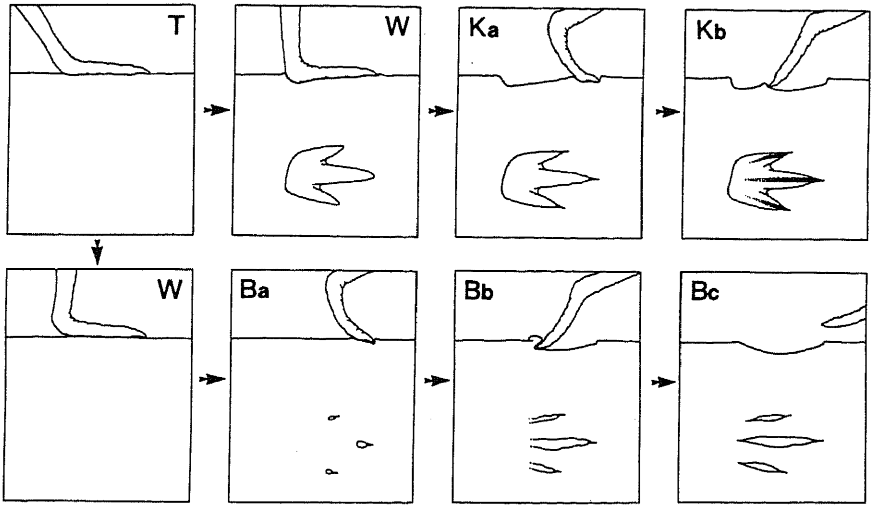

FIGURE 22. ***Morphological features of footprints of coelurosaurian theropod* Skartopus australis *from the Lower Cretaceous of Lark Quarry, Queensland, Australia. Each diagram shows position of foot in profile (above) and corresponding plan view of right footprint (below). T, touch-down phase - the foot makes little or no impression on the substrate; W (upper row), weight-bearing phase, the foot sinks into the substrate, Ka, kick-off phase, as foot is lifted from substrate the tips of the toes produce sharp imprints of the claws; Kb, kick-off phase (frequently following Ka), tips of the toes slip backwards, incising grooves in floor of footprint. W (lower row), weight-bearing phase - the foot fails to sink into the substrate; Ba, kick-off phase - only the tips of the toes break through the surface of the substrate; Bb, Bc (frequently following Ba), kick-off phase - tips of the toes slip backwards to form sub-parallel furrows. From Thulborn and Wade (1989). For Rocky Hill trackways, there is no match for sequence T-Kb but sequence T-Bc would account for the morphology of most of the "swimmer" footprints. In some of the Rocky Hill "swimmer" prints the departing tips of the toes did not eliminate the mounds of mud pushed up in Bb (: at posterior end of furrows in plan view presumably represents the mounds shown in the side view) so these remain at the ends of the sub-parallel furrows or retro-scratches.***

on foot-substrate interactions. If the latter turns out to be the case, then the tracks at Rocky Hill could have been made over a much shorter period of time, maybe only a day or two at the most.

10. EXHIBITS - INSIDE AND OUTSIDE

Initially, the only exhibits were the trackway areas, both large and small (Figs. 8D, 13, 15), and their derivatives. These include the overlying beds that were left as small "cliffs", one to the immediate south of the large area (Fig. 8B) and the other bordering the southwest side of the exhibit area (Figs. 4B, 5B), plus odd blocks of stone from the excavation site that showed ripple marks, other sedimentary features, and footprints. Some of the latter were soon set up in a separate area, where visitors could use them to make their own plaster casts (Fig. 8C), and this remains extremely popular to this day, with groups of visitors arriving at the Park carrying the requisite bags of plaster of Paris. The Park provides a large rock either bearing a natural *Eubrontes* cast or a footprint, a metal ring with a release catch, a cold water tap, and a ranger to give advice; the visitor provides 45 kg of plaster of Paris, 10 cc of cooking oil, and the labor.

Since the Park first opened, guides have given 30 minute talks (with ~10 minutes for questions), while standing on the exhibit trackway surface, to school groups (prearranged) or to any visitors present at the scheduled time(s) each day. The tracks were viewed from the northern end where the retaining wall, which was made of railway ties, was at its lowest; there was no guard rail so many students in the front row of the audience would sit down with their feet dangling over the edge. One of the first guides (who also contributed to some of the early explanatory exhibits) was Robert T. Bakker, then an undergraduate at Yale University, who subsequently became an authority on dinosaurs with many controversial ideas (see Bakker, 1986).

The first purchase was a life size model of the small theropod *Coelophysis* in 1969 (Figs. 4E, 5B). Sid Quarrier also acquired several footprint-bearing blocks of Portland Sandstone (Lower Jurassic) that were donated by Wesleyan University in nearby Middletown. These trackways, which were excavated in the 1890's, came from the large quarry in operation since the 1670's on the east bank of the Connecticut River in what is now Portland (then it was still part of Middletown; see McDonald, 1996: 7, Fig. 4; Guinness, 1996, in press). These early exhibits and their labels sat on a surface of water-worn gray pebbles (Fig. 5B).

Since his arrival in 1970, Richard Krueger has planted much of the 4 hectares adjacent to the exhibit building with numerous species of ferns, conifers, katsuras, ginkgos, magnolia, and other living representatives of plant families that first appeared in the Age of Dinosaurs. Indeed, the arboretum at the Park is now famous in its own right as one of the top sites in North America for its variety of species and cultivars of conifers, with over 200 different ones planted and labeled. In addition, there is a 3.2 km long nature trail meandering through the remaining park grounds, the total area of which is now over 24 hectares due to additional acquisitions over the years. The trail includes a red maple and shrub swamp, with a 90 m long boardwalk, forest areas of sugar maple, birch, hickory, oak and beach, open meadows, and a traprock ridge. Here delicate spring wildflowers bloom among broken pieces of basaltic rock, rock that once flowed as hot larva to cover the habitats of the Connecticut Valley's dinosaurs, killing everything in its path.

In 1975, Rich Krueger received a request from Wesleyan University to remove any remaining blocks of interest of Portland Sandstone from Portland, by then stored in the basement of a student dormitory (those left over after best ones were built into the wall of the Science Building in the late 1960's). This resulted in the donation of several large blocks, including the enormous one (approximately 3.35 x 0.9 x 0.1 m) containing the *Otozoum* trackway (DSP WU 680, Figs. 19A, B). The latter was removed from the basement with much difficulty by a team from the State Park Division, using metal pipes as rollers and a lot of effort, transported on a truck with a power lift, and maneuvered into the inflatable building through the entrance for the air lock (two overhead doors). This specimen is important because it shows the impression of scales on the undersurface of the pes. Lull (1904: 513) accepted the so called "web" of *Otozoum moodii* of Hitchcock (1858: 123). However, later on he noted that it is nothing more than the wave of plastic mud displaced by the animal's weight, as is clearly shown by DSP WU 680 in which the dermal papillae on the concave phalangeal pad impressions abruptly cease when the convex impression of the "web" is reached (Lull, 1915: 223, see Pl. 12, Fig. A for an oblique view of the complete block). The nature of *Otozoum* is still unclear, with several proposed makers. It probably represents a prosauropod dinosaur (Lull, 1915, 1953; Lockley and Meyer, 2000; Rainforth, 2000, in press), but other suggested makers include an ornithopod ornithischian dinosaur (Thulborn, 1990), a basal armored thyreophoran ornithischian (something similar to *Scelidosaurus* from Lower Jurassic of England; Gierliński, 1995; Wright, 1996), or a ?crocodiliomorph *Batrachopus*-derivative (Baird, 1954; Olsen, 1980).

The collapse of the inflatable building in January, 1976 prompted local supporters of the Park to form "The Friends of Dinosaur Park Association, Inc.", a nonprofit organization that acts as an advocate for the protection of the trackway and the development of the Park. The members of the Association do a large amount of volunteer work at the Park, run the bookstore, and raise money for the Park in a variety of ways, and their support resulted in many of the improvements in the Park exhibits over the next 20 years. The new permanent building was opened in 1978 and it included concrete retaining walls (poured in front of railway ties), wooden retaining rails and a new feature, a wooden boardwalk over the northwest part of the trackway (see photo in Lessem, 1999: 94). Phase I consisted of the Temcore Geodesic Dome and just the exterior block walls; the interior of the dome remained unfinished until Phase II (1984-85), when the walls were covered with vinyl paint and carpeting replaced the gravel floors (Anonymous, 1986). Additional fossils and exhibit pieces were obtained, including a life size model of *Dilophosaurus* (Fig. 18C) in 1980, life sized models of the Upper Triassic archosaurs *Stegomus* and *Rutiodon*, and the x1/12 size Triassic-Jurassic diorama in 1988 (Fig. 4F). However, the exhibits were still set against the plain painted inside concrete walls of the building (see photos in Waters, 1981: 6; Lessem, 1999: 94; for complete 1988 floor plan with positions of exhibits and a short description of each, see Dunnigan, 1988). This all changed in 1995 when the building was closed for a year or so and, after an investment by the state of about $2.5m on renovations, including a new ceiling, lighting, computer controlled special light and sound effects, and exhibits, the building was reopened by Governor John G. Rowland on June 30, 1996. These exhibits, the current ones, include the trackways from Wesleyan University, numerous Connecticut Valley fossils donated or loaned by N. McDonald (Westminster School, Middletown), plus others donated by Bruce Cornet and Bextram Bernstein.

The visitor follows a *Eubrontes* "trackway", that consists of footprints painted onto the concrete from the parking lot along a pathway, that is marked out with the time line for the history of life with important "landmarks" indicated, to the building entrance (Fig. 8A) and then on the carpet to the pedestrian walkway via the exhibit area, the different parts of which are indicated as A-Z on the building plan (Fig. 7):

A. The trackways are first viewed (Fig. 18A) from a 4 m long open area, with waist high glass panels with a metal guard rail, which is above the deepest southeastern part of the exposure. Here the displays on the retaining rail include a photograph of the Triassic-Jurassic diorama and a line drawing showing a reconstruction of a dinosaur making the "swimmer" prints, one of which can be viewed through a fixed view telescope mounted on the railing.

B. Two large slabs of Rocky Hill stone standing upright - one with a *Eubrontes* footprint and the counterpart with the natural cast - plus a model backhoe, an oil drum, and the road sign "Dino Discovery Ahead" (Fig. 8E).

C. A large inset enclosed area containing a much enlarged background photograph of the large trackway area when it was first exposed, a photograph of the excavation of the exhibit area (Fig. 4A), a TV monitor that shows a video of the excavation of the exhibit area, and a chronology of events at Dinosaur State Park (Fig. 8F).

D. On the opposite wall are related photographs including a 1967 aerial view of the Park and a large copy of the photo mosaic (Fig. 13).

E. A glass topped cabinet contains original copies of Hitchcock's monographs of 1841 and 1858 plus casts of the first dinosaur bones discovered in the Connecticut Valley in 1820 [prosauropod *Anchisaurus*, see Galton (1976), originally described as possibly human by Smith (1820) but several tail vertebrae (Hall, 1821) so reptilian (Hitchcock, 1841; Wyman, 1855)]. Above this is a large poster display on the paleontology of the Connecticut Valley.

F. A large slab with an *Anaeompus* trackway, which was probably made by an ornithischian dinosaur (Figs. 10C, D), showing manus and pes prints and a tail drag.

G. Photographs and imaginary road signs recreate part of the road cut through the East Berlin Formation at the exit ramp connecting Routes 9 and 372 (Fig. 4D) in nearby Cromwell.

H-I. A life size road cut section forms a cliff extending along the exhibit building wall (Fig. 4C). This section shows the tilted successive beds of shale, sandstone, and basalt, each with a built in door (Fig. 4C) that can be pulled down to reveal information about the rock, a hand sample, and a high magnification photograph of a thin section of the rock. There is also a vertical fault line in the middle of the section, which is overlain uncomformabily by glacial till. In front of the cliff are trackways, mostly ones from the Portland Sandstone of Portland - the enormous block with the *Otozoum moodii* trackway (DSP WU 680, Figs. 19A, B) plus smaller ones that include negative overprints and tracks of invertebrates, *Anomoepus* (DSP WU), *Batrachopus* (DSP WU 370), *Grallator* (DSP WU 182), and *Antipus* (a sphenodontid). There is also a TV monitor that shows a cartoon video to explain the geological changes that have occurred in the world through geological time and the mode of formation of the footprints at Rocky Hill.

J. On the inside wall of the exhibit area are displays that explain what a dinosaur is and the contrasting structures of the feet and footprints of carnivorous theropods and herbivorous bipedal ornithopod ornithischians.

K. *Coelophysis* is represented by a cast of two skeletons from the Upper Triassic of New Mexico (similar to the one shown in Fig. 16D). There is also a real tooth of a small theropod, mounted under a lens for clearer observation, which came from the Lower Jurassic of North Guildford, Connecticut (N. McDonald Collection; Anonymous, 1980b).

L. The original model (Fig. 5B) of *Coelophysis* is now displayed against a large background photograph showing the Louis Paul Jonas Studio of New Jersey in the process of making the life size reconstruction of the sauropod *Brontosaurus* (now *Apatosaurus*) for the 1964 World Fair held in New York at Flushing Meadows, Long Island (Fig. 4E).

M. A large print of the preliminary map in pencil of the exhibit area with individual trackways indicated in different colors (Fig. 14).

N. General section with exhibits covering dinosaur footprints, sociality, and speed.

O-P. Display windows that include a x1/12 Triassic-Jurassic diorama (Fig. 4F), fossil fish and plants, and an underwater Lower Jurassic diorama (Fig. 8G).

Q. Large stone blocks showing sedimentary structures: ripple marks, raindrops, and mudcracks.

R. Another viewing area looking over the footprints towards the Upper Triassic diorama and the pedestrian walkway (Fig. 18B). On pushing buttons, the individual prints of three trackways are illuminated one at a time, with a different color for each trackway.

S. The new metal pedestrian walkway, with glass side panels, passes over the northwestern part of the trackway (Figs. 18A, B). It provides an excellent view of the life size Lower Jurassic diorama (T-X) with woodlands at either end and a large area of mud flats in between, an ideal area for the formation of footprints by passing dinosaurs. The lake is near its maximum size and there has been a recent rainstorm.

T. The wooded area at the right end of the diorama includes horsetails, ferns (*Clathropteris*, *Dicotyophyllum*), cycadeoids (*Otozamites*), cycads, conifers (*Araucarites*, *Pagiophyllum*), and ginkgos (Figs. 18A, C-F); this area also has models of two flying individuals of the long tailed flying reptile (rhamphorhynchoid pterosaur) *Dimorphodon* (Lower Jurassic, England) (Figs. 18E, F).

U. The model of *Dilophosaurus* is on the mudflats close to the bordering horsetails (Figs. 18C, D).

V. The second *Dilophosaurus* shown in the distance on the mud flats is a painting (Figs. 10E, 18A).

W. Bordering horsetails with models of a fabrosaurid ornithischian similar to *Lesothosaurus* (Lower Jurassic, southern Africa) (Figs. 10C, D), the probable maker of *Anaeompus* trackways.

X. The wooded area on the left (Figs. 10A, B, 18G) includes a couple of prosauropod dinosaurs (*Anchisaurus*), one a model and the other a painting (Figs. 10A, B).

Y. The small cliff formed by the overlying strata (Figs. 4B, 18G). The layers (with depositional conditions and environment, which differ slightly from those near Cromwell, Fig. 9B), are as follows going upwards from immediately above the footprint bearing level (Fig. 4B):

a. Blocky gray sandstone - Shallow water (Lake plain, shallow lake)

b. Thinly layered gray sandstones and mudstones with buff-colored clay seams (Lake plain, shallow lake)

c. Dark gray to black, organically rich shale - Deep water (Deep lake bottom)

d. Gray sandstone (Lake plain, shallow lake)

e. Cross-bedded sandstone and maroon siltstone - Arid with seasonal floods (Braided stream floodplains) (at left end, not visible in Fig. 4B but visible on top left half of cliff, Fig. 18G).

Z. The life sized Upper Triassic diorama is at the bottom of the larger section of the exhibit trackways (Fig. 18B). The diorama (Fig. 10F) shows the rapidly eroding hills in the distance that mark the position of the Connecticut Valley's great eastern border fault that is hidden beneath fan-shaped piles of sediment washed out from the eastern highlands. The sand choked river flows slowly to the southwest through a semiarid landscape with plants colonizing the wet shifting sands. Plants shown in the diorama include horsetails (*Equisetites, Neocalamites*), clubmosses (*Selaginellites*), ferns (*Cladophlebis, Clathropteris*), ginkgos, cycadeoids (*Ishnophyton, Macrotaeniopteris*), conifers (*Pagiophyllum*) and a primitive flowering plant (*Sanmiguelia*). A couple of large aquatic animals are shown basking on the sand bank (Figs. 10F, G), an amphibian (*Metaposaurus*) and a crocodile-like parasuchian (phytosaurian) archosaurian reptile (*Rutiodon*), and the dinosaur *Coelophysis* is close by [other animals as models or paintings include *Hypsognathus* and a sphenodontid (both small and lizard-like), *Terrestrisuchus* (a small terrestrial crocodile) and an ornithischian dinosaur].

The bright sunshine of the Lower Jurassic diorama is interrupted three times an hour by audiovisual effects simulating a storm - a light and sound show that is particularly appreciated by children. The peaceful chirping sound of insects is disturbed by the sound of moving vegetation and the thomp, thomp, thomp sounds of an approaching *Eubrontes* walking nearby, and then roaring and trumpeting sounds. The sky gets progressively darker, with more louder thumps, snorting sounds and roars, and then the sound of falling rain and thunder plus flashes of lightning. After a short time the storm is over, the rain stops, there are roars from the receding *Eubrontes*, the sky brightens, the insects start chirping, and the sun comes out again to complete the cycle.

11. ACKNOWLEDGEMENTS

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