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STOP 6 THE TRIASSIC DINOSAURS AND THE TROSTLE QUARRY

Discussants: Marcus M. Key, Jr., Helen L. Delano

INTRODUCTION

Fifty-six years ago this summer, in July of 1937, approximately 50 dinosaur footprints were found in the rocks of the Trostle Quarry near York Springs in Adams County ([Cleaves], 1937a). The quarry is in the Triassic-age Gettysburg Formation within a zone where the normally red shale, siltstone and sandstone have been altered by "baking" or contact metamorphism from the nearby diabase sill. The quarrying activity ceased many years ago, but some rocks remain, with a variety of sedimentary structures, and always the possibility of more tracks.

PALEOGEOGRAPHIC AND STRUCTURAL SETTING

As Pangaea was rifting apart in the Late Triassic, south central Pennsylvania was situated at 0-10^{o} south latitude (van der Voo, 1988). During rifting, trough-like basins formed in a belt along the east coast of North America from present day Nova Scotia to South Carolina. The outcrop of this belt is located in the Piedmont physiographic province and roughly parallels the Appalachian fold belt (Rodgers, 1970). This belt consists of a series of fault-bounded, narrow, elongate basins (Figure 11),

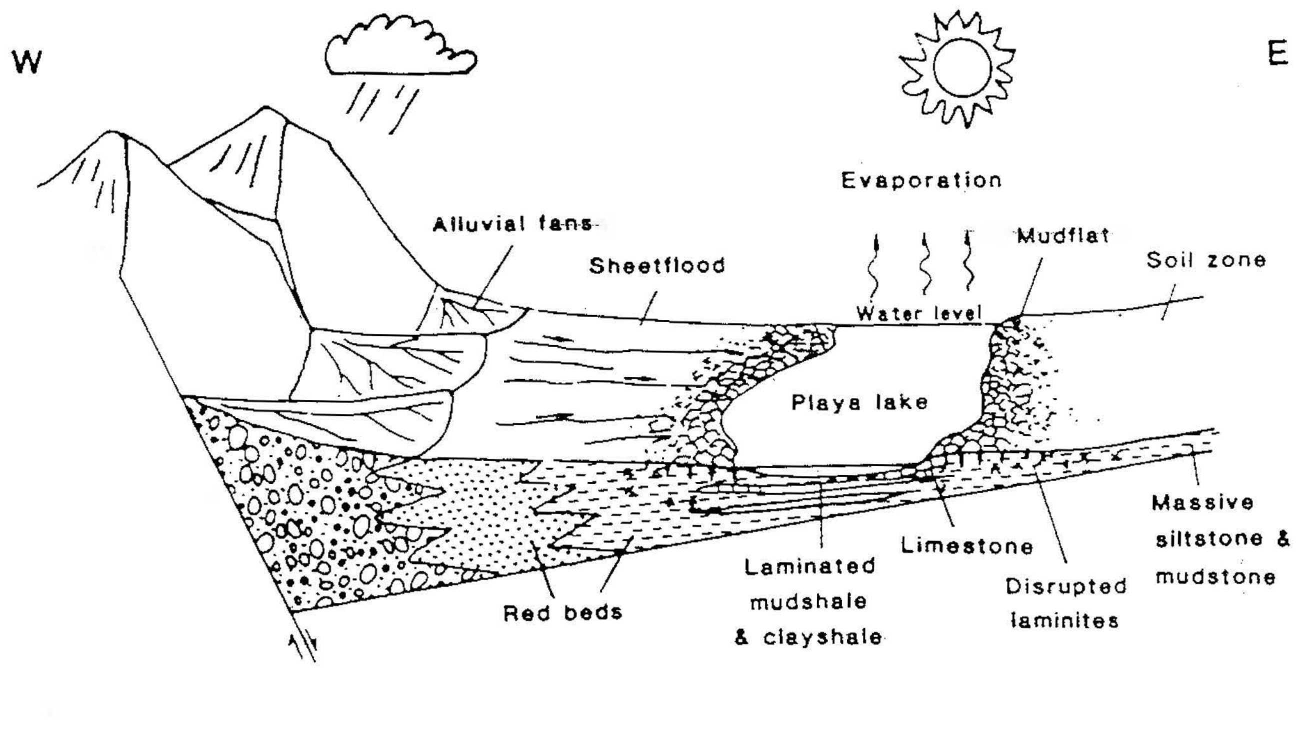

FIGURE 11 - Cross-section and paleoenvironmental model of a Triassic-Jurassic rift basin. From Gore (1988, Figure 15-13A).

which formed in response to proto-Atlantic crustal extension during continental rifting which preceded coastal plain deposition and the development of the modern Atlantic continental margin (Benson and Doyle, 1988; Manspeizer, 1988).

The Gettysburg Basin is one of these. It extends from Maryland through southeastern Pennsylvania and connects with the Newark Basin to the east. Roughly 250 km long, it ranges in width from 7 to 30 km (Glaeser, 1966). Calculations of sediment thickness in the basin vary from 4,880 to 9,000 m (Stose and Bascom, 1929; Stose, 1932; Stose and Jonas, 1939; Stose, 1953; Fauth, 1978; Manspeizer, 1988). The basin consists of a series of small, roughly parallel, long, narrow, smaller basins which deepen to the northwest due to downfaulting along the northwestern margin of the basin (Stose and Bascom, 1929; Stose and Jonas, 1939; Wood and Johnston, 1964; Root, 1977). The rocks were intruded by an igneous sill which trends southwest-northeast across Adams County (Stose and Bascom,1929). The sill is composed of medium to coarse-grained crystalline tholeiitic diabase containing plagioclase, pyroxene, and accessory magnetite (Smith et al., 1975).

The sedimentary rocks of the Gettysburg Basin are too young to have been affected by the late Paleozoic Alleghanian Orogeny which produced most of the structural features in central Pennsylvania. Several origins have been proposed for the deformation which produced the observed northwestward-dipping monocline (Stose, 1932; Faill, 1973; Root, 1977). Most workers since Rogers (1858), who attributed the dips to original deposition in a delta assume the bedding has been rotated to attain its present dip of 10 to 40 degrees (average 25 degrees) to the northwest (Stose and Bascom, 1929; Stose, 1932; Stose and Jonas, 1939; Stose, 1953; Wood and Johnston, 1964; Wood, 1980; Taylor and Royer, 1981).

STRATIGRAPHY

The sedimentary rocks of the Gettysburg Basin rest unconformably on deeply eroded Precambrian and Paleozoic rocks (Stose 1953; Wood and Johnston 1964; Root 1977). They are dominantly red beds and belong to the Conewago Group of the Newark Supergroup (Froelich and Olsen, 1984). Two formations, the New Oxford Formation (lower) and the Gettysburg Formation (upper), have traditionally been recognized in the Gettysburg Basin (Glaeser, 1963). Of the three members of the Gettysburg Formation, only the Heidlersburg Member has been named. It occurs near the middle of the formation (Stose and Bascom, 1929; Stose, 1932; Stose and Jonas, 1939; Stose, 1953; Glaeser, 1963, 1966; Berg et al., 1983).

The ages of the Gettysburg Basin rocks have been determined both biostratigraphically and radiometrically. The pollen flora from the Heidlersburg Member of the Gettysburg Formation indicates a Late Triassic (Norian) age (Cornet, 1977; Cornet and Olsen, 1985). Fossils of the Late Triassic age crustacean arthropod Pseudoestheria are known from Adams County (Hoskins, 1969). Plant fossils from adjacent York County indicate a Late Triassic age (Wanner and Fontaine, 1900). Footprints of the reptile Rhynchosauroides from Adams County (Baird, this volume) indicate a Late Triassic (Carnian) age (Olsen, 1988). Tracks of the dinosaur Atreipus milfordensis (Baird, this volume) from Adams County also indicate a Late Triassic (late Carnian to early Norian) age (Olsen and Baird, 1986). These biostratigraphic ages equal an absolute age of 230-208 Ma (Palmer, 1983).

K-Ar radiometric dating of the Aspers diabase sills and dikes which cross-cut the sedimentary rocks yields an age of Early Jurassic (Hettangian) (Benson and Doyle, 1988; Manspeizer, 1988; Olsen and Baird, 1986). This equals an absolute age of 208-206 Ma (Palmer, 1983).

SEDIMENTOLOGY

The Gettysburg Formation crops out across the northwestern two-thirds of the basin and is dominated by nonresistant red beds. It contains generally poorly sorted, micaceous, interbedded soft red shales and friable sandstones with numerous gray, white, green, and buff sandstones (Stose and Bascom, 1929; Stose, 1932; Stose and Jonas, 1939). Many of the sandstones are calcareous or arkosic (Glaeser, 1966). Locally there are beds of red limestone conglomerates and quartz-pebble conglomerates, as well as black and green shales (Stose and Bascom, 1929; Stose, 1932). The Heidlersburg Member is mapped near the middle of the formation on the basis of its gray and white sandstones and non-red shales, although it too is largely made up of red shales and sandstones. Adjacent to the highlands to the northwest, conglomerates form fan-shaped deposits along the western edge of the basin (Figure 11) and contain clasts of Cambrian quartzites and Cambro-Ordovician limestones (Stose and Bascom, 1929, Fig. 7; Stose, 1932, Fig. 6; Root, 1977; Wood, 1980). The entire formation exclusive of the intruded igneous bodies is 4,600-5,800 m thick (Stose and Bascom, 1929; Stose, 1932; Stose and Jonas, 1939; Glaeser, 1963; Root, 1977).

The depositional setting of the Triassic-Jurassic red beds along the eastern margin of North America has traditionally been interpreted as a semi-arid alluvial terrestrial environment based on several independent sources of data. Sedimentological analysis of the red beds suggests a variety of semi-arid terrestrial environments including alluvial fan, fluvial, paludal, lacustrine, playa, and eolian deposits (Lorenz, 1988; Smoot and Olsen, 1988). Geochemical analysis of the red color of the rocks has been interpreted to indicate a semi-arid alluvial terrestrial environment (Van Houten, 1961, 1968). Paleontological analysis of the fauna has revealed a diverse community of fresh water pelecypods, gastropods, ostracodes, shrimp, and fishes as well as terrestrial plants, insects, reptiles, dinosaurs, and mammal-like reptiles (Olsen, 1988).

The hypothesized semi-arid alluvial terrestrial environment is also supported by local evidence from the Gettysburg Basin in general and from Adams County in particular. A variety of inorganic sedimentary structures such as symmetrical and asymmetrical ripple marks, mud cracks, and salt crystal molds have been reported (Stose and Bascom, 1929; [Cleaves], 1937b; Stose and Jonas, 1939; Hoff et al., 1987). The common red, mostly immature, feldspar-rich sandstones have been interpreted to reflect an arid environment (Glaeser, 1966). Several fossils also support the hypothesized environment. These include the fresh water crustacean arthropods Estheria ovata (Stose and Bascom, 1929; Stose and Jonas, 1939) and Pseudoestheria sp. (Hoskins, 1969), the fresh water arthropod trace fossil Scoyenia (Olsen and Baird, 1986; Baird, this volume), terrestrial plant fossils of ferns, cycads, ginkgos, conifers, and grasses (Wanner, 1889; Wanner and Fontaine, 1900), and terrestrial dinosaur footprints (Olsen and Baird, 1986; Baird, this volume).

THE TROSTLE QUARRY AND DINOSAUR TRACKS

Triassic and Jurassic dinosaur skeletons and tracks are well known from the Triassic-Jurassic rift basins of Connecticut and Massachusetts. In the Gettysburg Basin in Pennsylvania, only a few dinosaur tracks from Adams and York Counties are known. Dinosaur tracks were first found in the Trostle quarry in Adams County on July 27, 1937 ([Cleaves], 1937a; Stose and Jonas, 1939). The quarry produced building stone, and stone from this or a similar quarry can be seen in the stone arch bridge where Latimore Creek Road crosses over Bermudian Creek just upstream from the quarry (Figure 12).

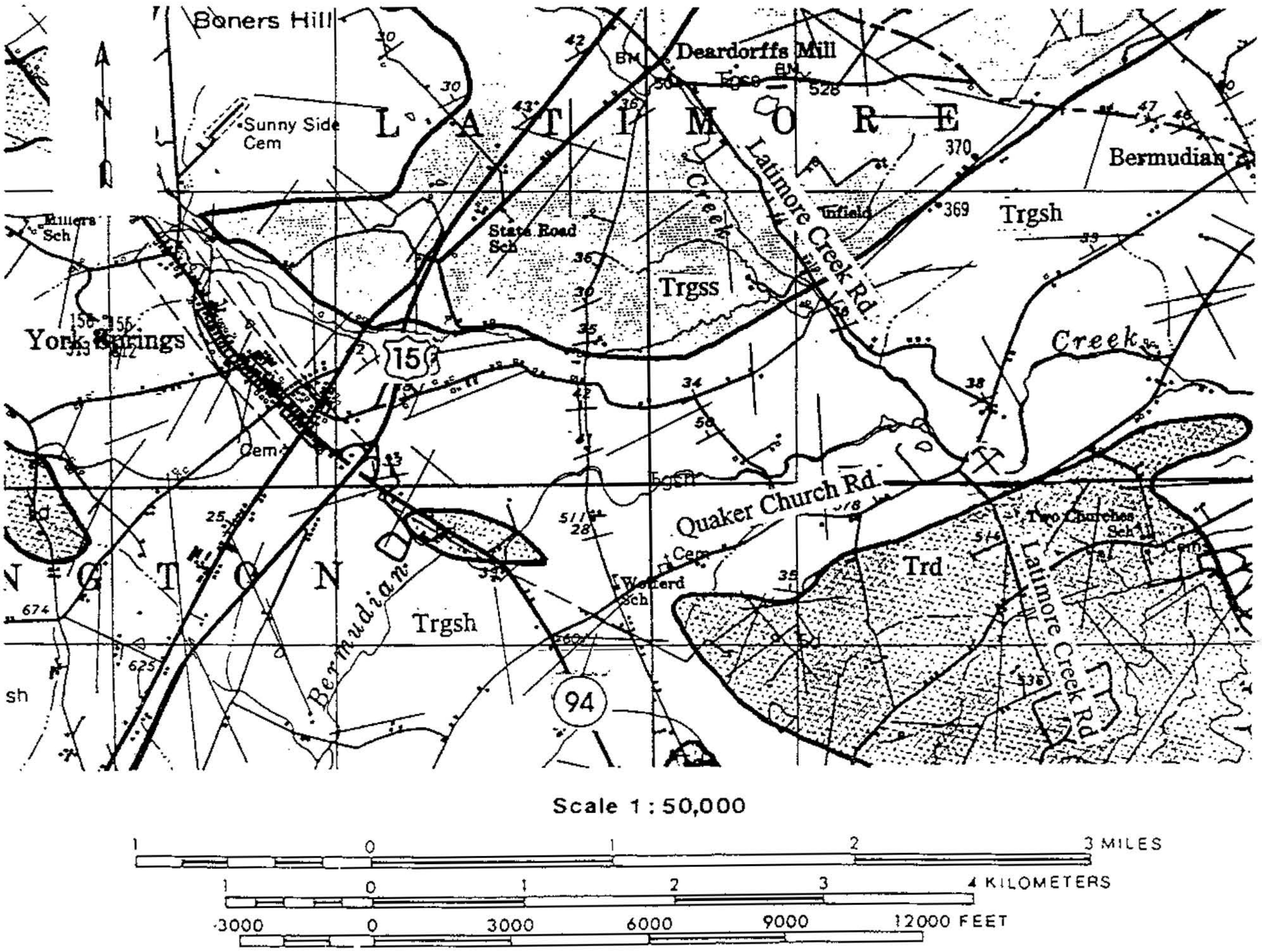

FIGURE 12 - Location and geologic map for Trostle Quarry. Trd = diabase. Trgsh = Gettysburg Formation shale unit. Trgss = Gettysburg Formation sandstone unit. Modified from Wood (1980, Pl.1, Pt.1).

The date of this bridge is unknown, but bridges of similar design in Adams County predate the Civil War (Stose, 1932). The location suggests the quarry may have been opened to supply stone for the bridge.

The quarry is located approximately 5 km east of York Springs, on the south bank of Bermudian Creek (Figure 12). The geologic maps (e.g. Stose, 1932, 1953; Wood, 1980; Berg and Dodge, 1981) show the quarry site in the Gettysburg Formation, stratigraphically below the Heidlersburg Member (Trgss unit on Figure 12). The quarry is very close to the edge of the diabase sill (Figure 12), and Stose's 1932 and 1953 maps show the zone of local metamorphism from the intrusion extending to Bermudian Creek at this location. This contact metamorphism has altered the (presumably) original red color of the rocks to grayish red-purple, grayish yellow-green, red-purple, and dark gray. The "baking" has also affected the durability of the rock. The unaltered red sandstones and siltstones have been quarried in a number of places in Adams County and used as building stone (Stose, 1932). As can be readily seen at the 1790 vintage Huntington Quaker meeting house located about 3 km west of the quarry on Quaker Church Road, the red rock is susceptible to scaling and splitting after long exposure to the weather. The "baked" rocks are more resistant to weathering, but the argillite layers are described as breaking into such small pieces as to be better suited for crushed stone. Many of the siltstone beds in the Trostle quarry appear to be well-suited for dimension stone, with bed thicknesses of 15 to 60 cm, and nearly rectangular jointing perpendicular to bedding.

Stose (1932) describes the effects of contact metamorphism as extending at most 100 feet (30 m) into the sedimentary rocks. The contact between the Gettysburg Formation and the sill is mapped approximately 250 m south of the quarry (Wood, 1980). Either the metamorphism here has extended unusually far, or the sill extends farther north below the surface. Cleaves (1937a) described the upper beds in the quarry as red, but today little if any red rock remains. Perhaps increasing alteration as quarrying progressed toward the diabase was a factor in determining the useful life of the quarry.

The present exposure in the old quarry is a somewhat irregular face approximately 100 m long, trending N 70 degrees W, and nearly 20 m high. The quarry face is very steep, about 37 degrees. The bedding strikes N 43 degrees E, and dips 41 degrees to the northwest. This dip is steeper than most of the dips in the Gettysburg Basin and may be related to the proximity of the diabase intrusion a small distance to the south (Stose and Bascom, 1929; Stose, 1932). Approximately 60 m of the section is exposed here.

The quarry exposure reveals alternating layers of massive siltstone and thin bedded shales. The siltstones display small scale cross-bedding, clay drapes over ripple marks, and soft sediment deformation structures such as load casts. Ripple marks, load casts, and trace fossils can be found on bedding planes in the siltstones. The finer grained units commonly contain mud cracks. Individual beds are planar and generally continuous across the exposure. No channel forms or scoured surfaces were observed. Although carbonate cement is very common in the nearby red beds, none of the quarry rock tested showed a reaction to acid.

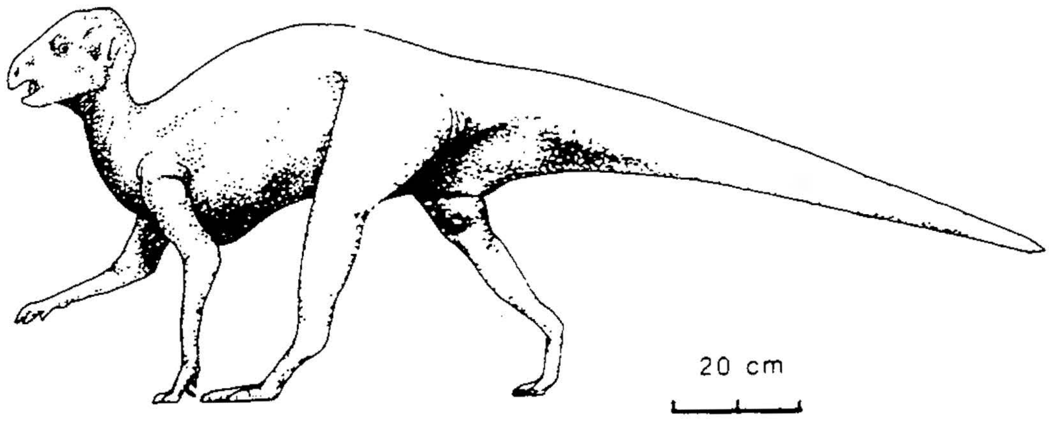

FIGURE 14 - Hypothetical reconstruction of Atreipus milfordensis, the habitually quadrupedal ornithischian dinosaur responsible for the majority of the Trostle quarry tracks. From Olsen and Baird (1986, Figure 6.17C).

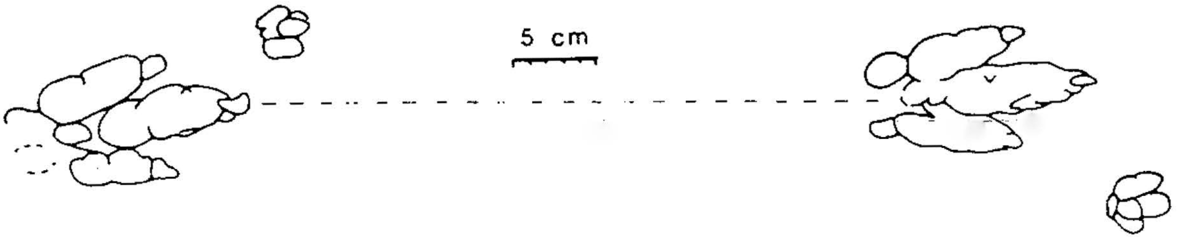

FIGURE 13 - Outline pattern of the most common dinosaur track (Atreipus milfordensis) from the Trostle quarry. Larger tracks are from the back feet while the smaller tracks are from the front feet (see Figure 14). From Olsen and Baird (1986, Figure 6.5B).

The slabs containing the footprints came from the middle of the quarry about halfway up the 20 m high quarry wall ([Cleaves], 1937a). This places them about 6,000 m above the base of the New Oxford Formation, 450 m below the base of the Heidlersburg Member of the Gettysburg Formation, and 3,900 m below the base of the Aspers basalt (Olsen and Baird, 1986). The footprints were found on bedding planes of greenish-gray, siltstones, and shales ([Cleaves], 1937a; Hoff, person communication). These slabs also contain ripple marks, mud cracks, and miniature load casts (Stose and Bascom, 1929; [Cleaves], 1937b; Hoff et.al., 1987). In the past, the miniature load casts were incorrectly identified as dinosaur skin or rain drop imprints (Hoff et.al., 1987).

Most of the slabs containing footprints were donated to the Carnegie Museum of Natural History in Pittsburgh. Several of the slabs were used as capstones on the bridge over Plum Run in Gettysburg National Battlefield (Hoff et.al., 1987). The State Museum of Pennsylvania in Harrisburg received two slabs, and the Adams County Historical Society in Gettysburg received one slab (Don Hoff, personal communication).

A total of almost 50 three- and four-toed footprints were found ([Cleaves], 1937a, b). The footprints (Figure 13) were originally identified as belonging to three different species of theropod dinosaurs: Grallator tenuis, Anchisauripus sillimani, and Anomoepus sp. ([Cleaves], 1937a, b). Dinosaur footprints belonging to the same species had been reported from a quarry between Yocumtown and Goldsboro in York County, Pennsylvania (Wanner, 1889; Hitchcock, 1889; Hickock and Willard, 1933; Willard, 1934; Stose and Jonas, 1939; Willard, 1940). These original species designations were erroneous because they were based on the incorrect assumption that the rocks of the Gettysburg Basin were contemporaneous with the younger rocks of the Connecticut valley (Olsen and Baird, 1986; Baird, this volume). The Trostle quarry footprints have been reassigned to the following quadruped taxa: Atreipus milfordensis (Figure 14), Brachychirotherium eyermani, Rhynchosauroides brunswickii, and Pentasauropus sp. (Olsen and Baird, 1986; Baird, this volume).

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