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AN AMPHIBIAN TRACKWAY (*CINCOSAURUS COBBI*) FROM THE LOWER PENNSYLVANIAN ("POTTSVILLE") OF LOOKOUT MOUNTAIN, GEORGIA: A FIRST OCCURRENCE

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ABSTRACT—An amphibian trackway collected from outcrops of the Whitwell Shale Member of the Crab Orchard Mountain Formation on Lookout Mountain, Georgia represents the first known report of Paleozoic amphibian remains from Georgia. Lower Pennsylvanian rocks associated with the amphibian locality were deposited in a transitional environment that includes tidal flat, tidal channel, alluvial, beach, and delta facies. The tracks occur in the Whitwell Shale tidal flat facies, which consists of flaser, wavy, and lenticular bedded fine-grained sandstone and black siltstone, that immediately underlies a thick massive channel lens of the Newton Sandstone.

The trackway was made by a five toed salamander-shaped amphibian with a long gleno-acetabular distance and divergent fifth digits. Average measurements of the tracks are: pace, 3.95 cm; pace angulation, 93°; trackway width 3.4–3.9 cm; gleno-acetabular distance, 14.6 cm; manus breadth, 1.58 cm; manus length, 2.2 cm; pes breadth, 1.6 cm; pes length, 2.6 cm. The tracks are identified as *Cincosaurus cobbi* Aldrich; the trackmaker was probably a member of the Class Amphibia, Subclass Labyrinthodontia, Order Anthracosauria, Suborder Embolomeri. *Cincosaurus* has its closest affinities with *Paleosauropus primaevus* but differs in having straight, divergent fifth digits on both manus and pes.

INTRODUCTION

A SERIES of amphibian tracks belonging to the species *Cincosaurus cobbi* Aldrich (*in* Aldrich and Jones, 1930) was found by the senior author in flaser, wavy and lenticular bedded sandy siltsone of the Whitwell Shale Member of the Crab Orchard Mountain Formation ("Pottsville" Group) in northwest Chatooga County, Georgia (Figure 1). This trackway (USNM 339335) represents the first known occurrence of fossil amphibians from Georgia.

The ridge and valley province of northwest Georgia contains a well-exposed section of Cambrian to Pennsylvanian age rocks. Carboniferous rocks deposited during progradation of a clastic sequence grade upward from marine and nearshore mudstone to massive beach, delta front, and alluvial sandstone (Schlee, 1963; Hobday, 1974). In this paper we describe amphibian tracks from the Lower Pennsylvanian rocks and discuss their bearing on interpretations of the depositional environment.

Geology.—Lower Pennsylvanian rocks of the Crab Orchard Mountain Formation are the youngest beds exposed on Lookout Mountain and overlie Carboniferous rocks of the Mississippian Pennington Formation and clastic rocks of the Pennsylvanian Gizzard Formation. Although there has been a recent, and sometimes confusing, proliferation of Pennsylvanian stratigraphic terms for the southeastern United States (see Wilson, 1975; Thomas and Cramer, 1979; Bergenback et al., 1980) we use a combination of the nomenclature of Butts (1946), Butts and Gildersleeve (1948), and Culbertson (1963). We think that the term "Pottsville" is roughly synonymous with Lower Pennsylvanian rocks and agree with the subdivision into the Gizzard and Crab Orchard Mountain formations.

The Lower Pennsylvanian rocks contain massive cliff-forming sandstone interbedded with gray, silty laminated shales, siltstones, and coal seams. Also present are fine- to medium-grained, horizontally-stratified and cross-bedded sandstone units. The lower contact of most sandstone units is irregular and channeled with basal pebble conglomerate fining upward to clean sand; overlying contacts are gradational with shale units. The Sewanee Conglomerate Member of the Crab Orchard Mountain Formation, a typical Lower Pennsylvanian sandstone, ranges from matrix-rich wackes to silica-cemented ortho-

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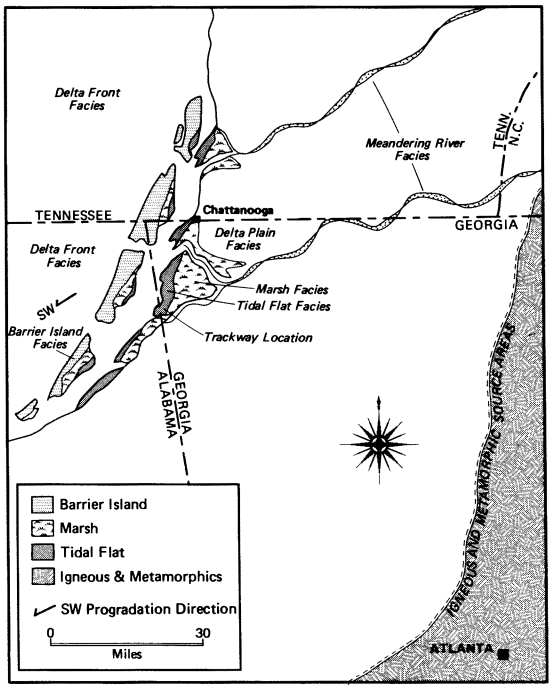

FIGURE 1—Location map and Lower Pennsylvanian paleoenvironmental facies map of a prograding littoral sequence in northwest Georgia, Alabama, and Tennessee. Arrow indicates the Double Hollow Amphibian Locality where the amphibian trackway was found.

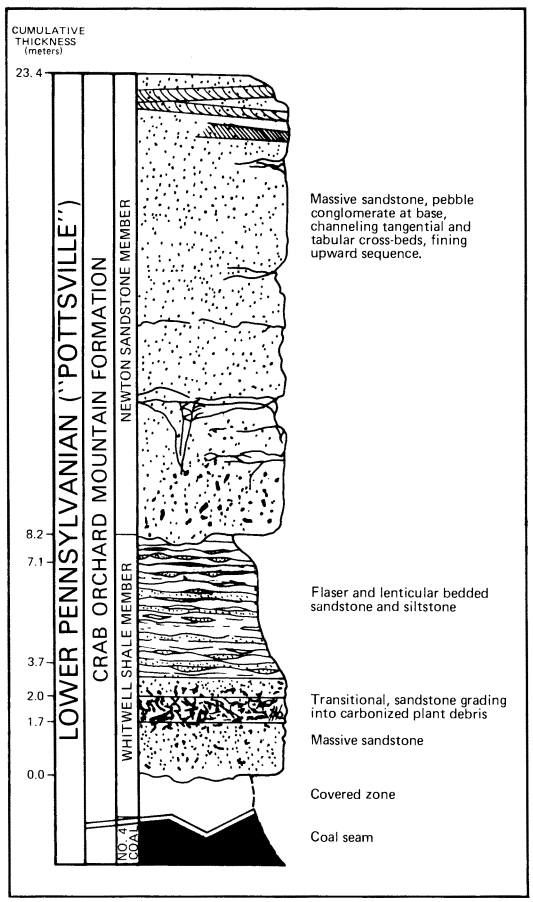

FIGURE 2—Measured stratigraphic section at the Double Hollow Amphibian Locality. The amphibian trackway described in this report was collected from the lenticular bedded unit at approximately 7.1 m.

quartzites (Bergenback, 1978). The trackway described in this report was found in the Whitwell Shale Member of the Crab Orchard Mountain Formation immediately underlying a large lens of the Newton Sandstone Member and overlying the Number 4 Coal (Figure 2).

Location.—The amphibian trackway was discovered in an abandoned coal mine located on Lookout Mountain (lat. 34°32′44″N, long. 85°30′12″W), in the northwest corner of Chatooga County, Georgia, at an elevation of 488 m (1,600′) MSL on the Valley Head, Ala.-Ga. 1:24,000 USGS topographic sheet (Figure 1). We have named this site the Double Hollow Amphibian Locality after the name of the draw in which the coal mine is located. The highwall of the abandoned mine exposes, in stratigraphic sequence, the Number 4 Coal at the base, the Whitwell Shale, and a lens of Newton Sandstone (Figures 2, 3).

RESULTS

Structure and lithology of trackway slab.—The trackway is preserved as a cast of an impression on a slab (USNM 339335) 40 cm long, 35 cm wide and 4 cm thick. The slab consists of fine-grained rippled sandstone in isolated lenses to sub-continuous layers, alternating with lenses to continuous layers of dark gray siltstone. Thus, bedding varies from flaser to lenticular as described by Reineck and Singh (1980) and probably represents deposition in a tidal-influenced environment. The sandstone lenses are 2.5–8 mm thick, with tangential ripple cross laminations 3–5

FIGURE 3—Photograph of the Double Hollow Amphibian Locality. The amphibian trackway was found immediately underlying the massive channel sandstone. Staff is 1.5 m long in 10 cm divisions.

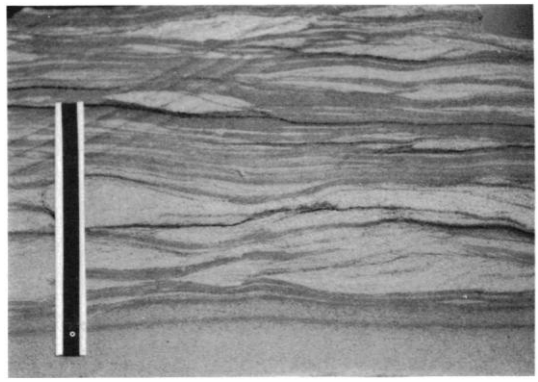

FIGURE 4—Flaser to lenticular bedding of the Whitwell Shale. Bar is 5 cm long.

mm long (Figure 4). Siltstone interbeds are 1–5 mm thick. Fusiform-shaped siderite nodules occur randomly within the slab lithology. Low-amplitude asymmetric ripple marks and tool marks on the surface of the slab represent lower flow regime currents.

A stratigraphic section (Figure 2) measured at the Double Hollow site shows that bedding of the trackway slab is representative of the entire Whitwell Shale Member. Numerous plant fossils, including *Lepidodendron, Sigillaria, Calamites, Lyginopteris* and *Alethopteris,* found in fragmented, discontinuous carbonaceous seams at the Double Hollow Locality help confirm a Lower Pennsylvanian age designation. Sedimentary structures in lens-shaped sandstone units within the Whitwell Shale include cross-beds, current ripples, bioturbation features, numerous worm burrows, and internal soft-sediment slumps. Overlying the flaser to lenticular bedded sandstone and siltstone is a massive, thick, alluvial channel sandstone that fines upward to large-scale tangential cross-bedded sandstone (Figures 2, 3). Because the shales overlie a coal seam, we interpret the depositional environment to have been near a delta front with brackish water tidal flats (possibly a fair distance upstream), tidal channels and rivers. These environments are likely places for amphibians that require wet, moist, lowland areas.

Description of the trackway.—The trackway from the Double Hollow site (Figure 5), consists of nine sequential sets of footprints. A trackway usually consists of a minimum of three sequential sets of impressions (six footprint casts or molds) so that the gait of the trackmaker may be determined (Sarjeant, 1975).

The tracks are casts of original impressions in which the five-digit imprints appear in positive relief (Figure 5). The trackmaker made an S-shaped path that does not include tail drag marks. Peabody (1959) found that fossil amphibian tracks from the Tertiary compare well with modern salamander mechanics. Thus, we used comparisons between the trackway described here and modern salamander locomotion to help reconstruct the trackmaker animal. A salamander's walking gait on dry land consists of one hindfoot (pes), followed by the forefoot (manus) on the same side, then the pes and manus of the opposite side (Sarjeant, 1975). The feet are placed so that they point forward, not laterally. Salamanders move in deep water by lateral undulations of the body unaided by limbs and in shallow water by a combination of walking and swimming movements (Peabody, 1959).

The trackway was traced on an overlay so spatial relationships and measurements of the tracks could be studied (Table 1). The stride, forward movement of the feet on the right and left side of the body, was measured from a fixed point on the divergent fifth digit of the manus on the left side of the trackway to

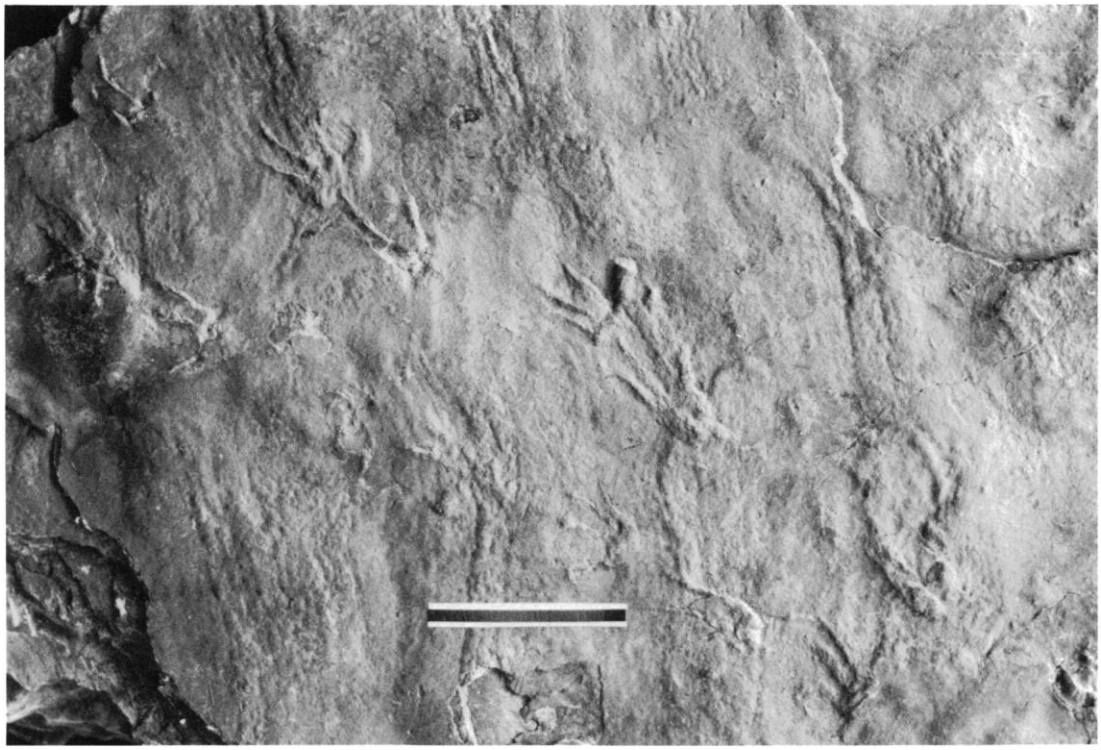

FIGURE 5—Photograph of the trackway slab (USNM 339335) showing nine sequential tracks of *Cincosaurus cobbi*. Bar is 5 cm long.

the same point on the next impression. The stride on the right side was measured from the base of the third digit on the pes to the next pes impression of the left and right pes (Figure 6). The average of alternating angles produced by connecting the geometric centers near the base of the third digit of consecutive pes impressions gives the pace angulation (Figure 6). This measurement indicates the proportional spacing of foot impression to relative width of the trackway (Peabody, 1959) and can be uniformly compared to other trackways. Width of the trackway was measured from midpoints of alternating manus and pes tracks used in the pace angulation measurement (Figure 6).

A measurement of importance in quadrupeds, the gleno-acetabular distance ("wheelbase"), is the distance from the glenoid fossa of the shoulder girdle to the ace-

TABLE 1—Measurements of *Cincosaurus cobbi* trackway (USNM 339335).

	Measurements	Number of measurements	Average
Pace	3.0–4.2 cm	4	3.95 cm
Pace angulation	93°		
Trackway width	3.4–3.9 cm		
Stride	6.7 cm (left)–7.5 cm (right)		7.0 cm
Manus width	1.2–2.0 cm	6	1.58 cm
Manus length	1.7–3.0 cm	6	2.2 cm
Pes width	1.3–1.8 cm	7	1.6 cm
Pes length	2.2–3.1 cm	7	2.6 cm
Gleno-acetabular distance	14.6 cm		

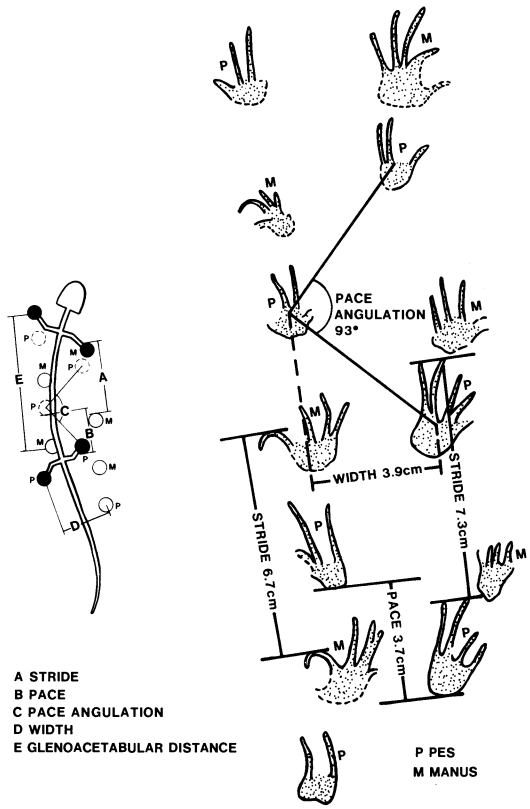

FIGURE 6—Measurements of stride, pace, pace angulation, and width of *Cincosaurus cobbi*. Drawing on the left illustrates movement of a modern salamander used in analysis of fossil trackway (inset modified from Peabody, 1959).

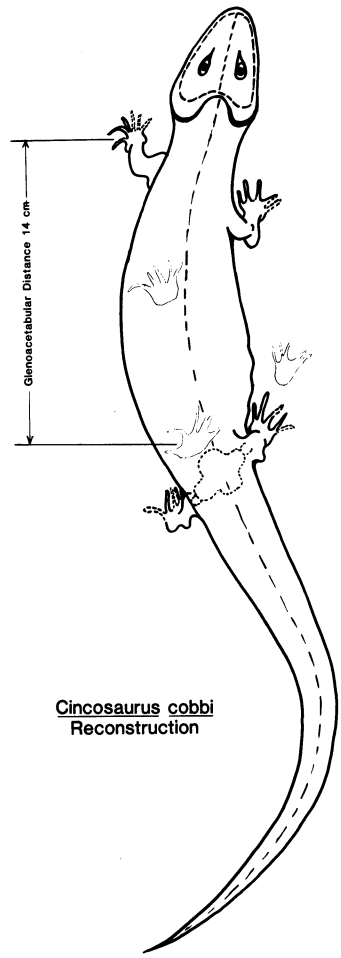

FIGURE 7—Reconstruction of the trackmaker, *Cincosaurus cobbi*. Gleno-acetabular distance determined the approximate body length. Tail length was estimated to be roughly equal to the body length (head and trunk combined).

tabulum of the hip (Figure 7). This distance approximates body length, but is not exact in amphibians because of their sinuous body motion. We computed the body length of the trackmaker based on a gleno-acetabular distance obtained by using the set of pes prints two modules behind a set of manus prints (i.e., a long "wheelbase"; Figure 6).

No standard method exists for reporting detailed measurement of each impression, thus, length and breadth of impressions is usually measured in whatever direction the author desires (Sarjeant, 1975). Following Sarjeant (1975), we measured the length parallel to digit three and the breadth perpendicular to the length (Figures 8, 9). Digit divergence was determined by measuring angles between digits using the third digit as the midpoint from which to draw rays to others toes (Figure 9). In most impressions, notably the manus, the fifth digit was markedly divergent compared to the other four toes (Figures 8, 9).

DISCUSSION

Tracks of *Cincosaurus cobbi* from the Double Hollow Amphibian Locality were made by an amphibian with a long gleno-acetabular distance (14.6 cm) computed using the set of pes prints two modules behind the manus prints. Because no other trackways or skeletal remains of amphibian life have been discov-

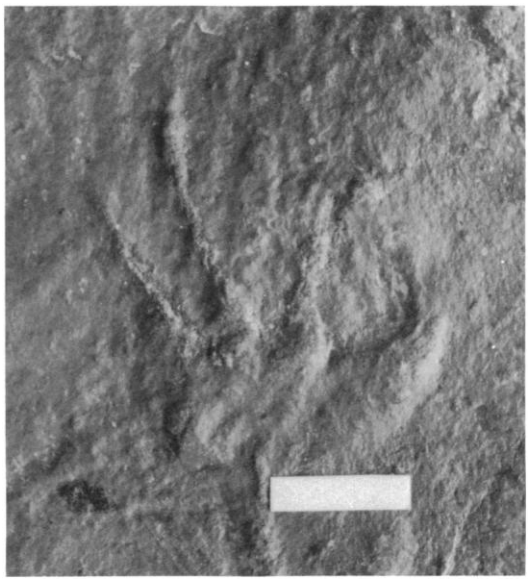

FIGURE 8—Manus impression of *Cincosaurus cobbi* (USNM 339335). Note divergent fifth digit. Bar is 1 cm long.

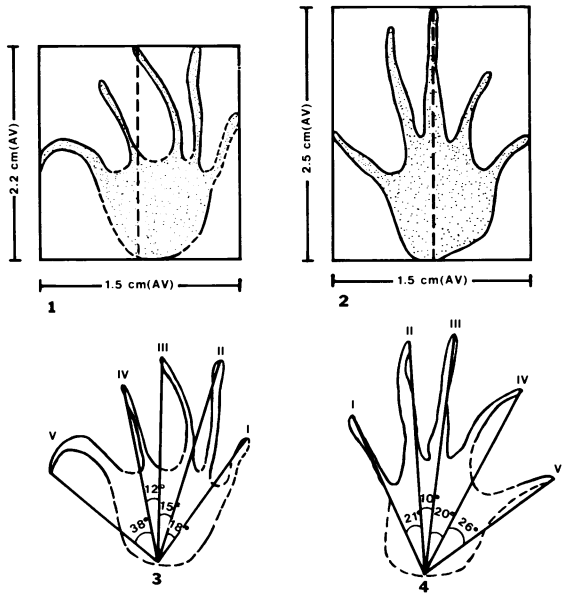

FIGURE 9—Measurements of the manus and pes impressions of *Cincosaurus cobbi* trackway described in this report. *1*, length–breadth of manus. *2*, length–breadth of pes. *3*, interdigital angle of manus. *4*, interdigital angle of pes.

ered in Lower Pennsylvanian rocks from Georgia, this find represents a significant contribution to the vertebrate paleontology of Georgia.

C. cobbi was first identified from trackways discovered in shale above the Jagger coal in the Lee Series, Walker County, Alabama (Aldrich and Jones, 1930). We believe the Lee Series to be equivalent to the "Pottsville" and Crab Orchard Mountain Formation in Georgia (Wanless, 1946). Similar tracks from Marion County, Tennessee, occur in an unpublished specimen (PU 21771) collected by Gerard R. Case and donated to Princeton University Museum of Natural History (Baird, written communication, 1982). All of these tracks are from Pennsylvanian rocks and occur in Whitwell Shale equivalent rocks.

C. cobbi trackways are of definite amphibian origin. The Pennsylvanian age of the Whitwell Shale predates most reptilian Orders and definite amphibian skeletal remains have been discovered in Pennsylvanian age rocks (Romer, 1966). The *C. cobbi* tracks were probably made by a member of the Class Amphibia, Subclass Labyrinthodontia, Order Anthracosauria, Suborder Embolomeri. Distinguishing characteristics of the Order, preserved in our trackway, are divergent fifth digits on both manus and pes. Four digits are roughly parallel to each other and a fifth at a sharply divergent angle (Thurmond and Jones, 1981).

C. cobbi has its closest affinities with *Paleosauropus primaevus,* but differs in having stout, straight, divergent fifth digits on both manus and pes (Baird, written communication, 1981). Individual tracks show a moderate degree of variation due to infilling with sand and from modification by water currents. The pace angulation of *C. cobbi* (93°) compares well with that of modern salamanders (90°). A low value of 60° indicates a sprawling type of locomotion while a high value in excess of 100° indicates locomotion with limbs well under the body (e.g., dinosaurs, mammals; Peabody, 1959). The 93° pace angulation in our specimen substantiates salamander affinities. *C. cobbi* was probably limited to a simple, slow, plodding gait because an attempt at marked acceleration in salamanders leads to unbalanced locomotor movements (Peabody, 1959).

Most amphibians have a tail length varying

from half their body length to equivalent to the body length (Peabody, 1959). Even though no tail drag is present on our specimen, we have reconstructed the tail of *C. cobbi* to be equivalent to its body length. Low amplitude ripple marks and tool marks indicate that the amphibian was in shallow water. Because no tail drag mark is visible on the slab, we assume that as *C. cobbi* propelled itself, water buoyancy kept its tail floating. The variation in manus and pes proportions and the sinuous movements substantiate a part swimming, part walking locomotion. This means of locomotion accounts for the relatively high pace angulation and the less than sprawling gait.

By using the gleno-acetabular distance (approximate shoulder to hip length), stride, pace, and width, we drew a reconstruction of *C. cobbi* (Figure 7). Cranial construction was modeled using drawings of Pennsylvanian age amphibian skeletons (Romer, 1966). Tail length was drawn to equal the length of the head and trunk combined.

Environments of deposition at the Double Hollow Amphibian Locality consist of lagoon marsh, tidal flat, tidal channel, and a meandering river sequence. The lowest exposed rock unit is the Numer 4 or Tatum Coal, which was mostly mined away. Overlying the coal is the Whitwell Shale that we interpret as accumulating in a tidal flat environment. Interbedded non-laterally persistent sandstone lenses formed from secondary tidal channels. We have stratigraphically placed the trackway near the upper contact of the Whitwell Shale with the Newton Sandstone. The Newton Sandstone exhibits a pebbly channel lag at the base, but fines upward to clean sandstone that has tangential crossbeds. This sandstone lens represents deposition in a meandering river channel. These depositional environments are supported both by the absence of a tail drag in the amphibian trackway, indicating shallow water, and by the presence of embolomerous amphibians that require semi-aquatic habitats. Because embolomeres ate fish (Romer, 1966) the *Cincosaurus* diet required a life close to water in environments such as those described above. Even though we argue for a tidal flat environment, we feel uncomfortable in having the amphibian in a normal saline marine tidal flat due to the problem of sodium regulation. Thus, the tidal flat of the Whitwell Shale was probably far up the river or delta system in relatively fresh water, but still tidally influenced.

CONCLUSIONS

The trackway, *Cincosaurus cobbi,* discovered at the Double Hollow site was made by a Paleozoic embolomere amphibian. The animal was a salamander-shaped amphibian approximately 25 cm long and 4 cm wide. Spacing of manus and pes impressions, a sinuous trackway pattern, and the absence of a tail drag indicate a part walking, part swimming locomotion.

The *Cincosaurus cobbi* trackway was found in the Whitwell Shale Member of the Crab Orchard Mountain Formation ("Pottsville"). The age as determined by stratigraphic correlation and by plant fossil remains is Early Pennsylvanian. We interpret the depositional environment as a tidal flat, possibly some distance up on the delta in brackish or fairly fresh water.

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