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PALEOENVIRONMENT OF THE *CINCOSAURUS* BEDS, WALKER COUNTY, ALABAMA

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ABSTRACT: Early Pennsylvanian rocks in the Black Warrior Basin of north central Alabama in the Pottsville Formation represent large volumes of fluvial-deltaic sediments spanning a broad range of marine and terrestrial environments. The environmental setting of the Union Chapel Mine trackway beds was that of an estuarine tidal flat in a coastal lowland region near the paleoequator. The tropical area supported extensive peat swamps. Tracks of tetrapods and invertebrates were made on the tidal flats at low tide. Tetrapod tracks, invertebrate tracks, traces, burrows, and fish trails were made in both the subaerial and subaqueous environments of the tidal flats, tidal channels, and coastal marine environments.

INTRODUCTION

Pennsylvanian vertebrate and invertebrate trace fossils have been collected since 2000 in an inactive part of the Union Chapel Mine, an abandoned surface coal mine in Walker County, Alabama (Fig. 1). The vertebrate tracks are similar to material previously collected in Walker County, Alabama (Aldrich and Jones, 1930; Rindsberg, 1990). The tracks are in shale of the Mary Lee coal zone of the Pottsville Formation, 1.5-3 m (5-10 ft) above the Mary Lee coal bed. The trackways were collected in the spoil piles near the highwall that remained after mining was completed. Collecting trackway specimens from undisturbed shale layers was not feasible due to the instability of the high wall and thickness of overburden which reached heights of 30 m (100 ft) or more. The Alabama Paleontological Society (APS) members who collected the track fossils and fossil plants for an 18-month period made important observations on the rocks exposed in the Union Chapel Mine. These observations help explain the depositional environment of the track-bearing Mary Lee rocks.

STRATIGRAPHY AND PALEOGEOGRAPHY

The Pennsylvanian strata exposed in the Union Chapel Mine consist of interbedded shale, siltstone, sandstone, and coal in the Mary Lee coal zone of the Pottsville Formation (Pashin, 2005). The coal-bearing strata of the Mary Lee zone were deposited near the paleoequator in a coastal lowland along a shallow seaway that covered parts of eastern North America during the Pennsylvanian Period (Fig. 2). The depositional patterns in the Union Chapel Mine are typical of fluvial-deltaic deposits in Pennsylvanian rocks of the Appalachian and Black Warrior Basins. Rain forests were prevalent in the coastal areas of the Pennsylvanian equatorial land masses. Streams that were fed by high rainfall deposited enormous quantities of sandy, silty, and muddy sediment. Waterlogged lowland environments supported extensive forests of wetland plants dependent on the reliable supply of fresh or brackish water. Coastal plain forests were dominated by aborescent lycopods such as *Lepidodendron*, *Lepidophloios*, *Sigillaria*, and seed ferns, pteridosperms, sphenophytes (*Calamites*) and *Cordaites*. The edges of the lowland environments were periodically exposed along tropical swamp margins during ebb tide. Highland areas of the Appalachian Mountains were being lifted landward of the coastal region. Much of this area was drained by a large river system terminating as a delta and estuarine environment responsible for depositing large volumes of sediment into the subsiding Black Warrior Basin. The sediments exposed in the Union Chapel Mine represent deposition in this estuarine and deltaic system.

OBSERVATIONS

The track-bearing rocks and fossil plants were found in spoil piles next to the west-facing highwall of the Union Chapel Mine (Fig. 3). The highwall reaches a height of about 30 m (100 ft) and much of the outcrop is unstable and dangerous. However, a north-south examination of the highwall was made by Jack Pashin during an APS field trip. The traverse was made along the highwall to examine the shale sequence overlying the Mary Lee coal seam (Pashin, personal commun., 2001). To the north along the highwall, the dark gray shale overlying the Mary Lee coal seam contains abundant macerated plant material including an *in-situ* seed fern stump and *Calamites*. This is represented by area A in Fig. 3. Proceeding south along the highwall, the shale overlying the coal grades into a lighter-colored shale and contains the highest concentration of vertebrate and invertebrate tracks in the Union Chapel Mine. This area is illustrated as area B in Fig. 3. The large tetrapod tracks, seen in Fig. 4, were collected from area B of the spoil piles directly in front of the highwall. The small tetrapod tracks, seen in Fig. 5, were also collected in the spoil piles of area B. In addition to the tetrapod tracks, numerous invertebrate tracks were also collected in area B. A horseshoe crab trackway from area B is shown in Fig. 6. A myriapod trackway, also collected in area B, is shown in Fig. 7. The predominant track-bearing rock is a red-brown, dark gray, or black shale. The shale is very well-sorted, very fine-grained, and generally lacks macroscopic plant material. However, *Calamites* are present in life position in the track-bearing shale. In many

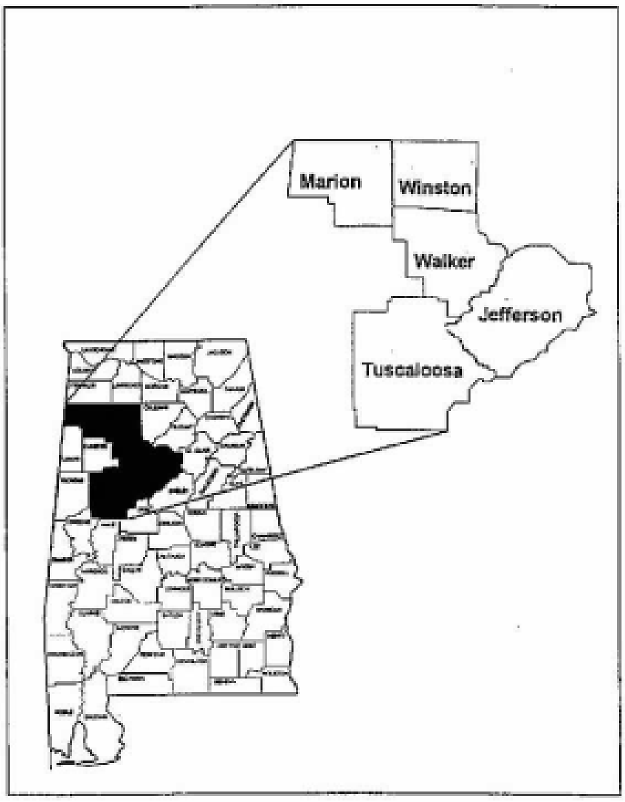

FIGURE 1. Walker County and Black Warrior Basin, Alabama

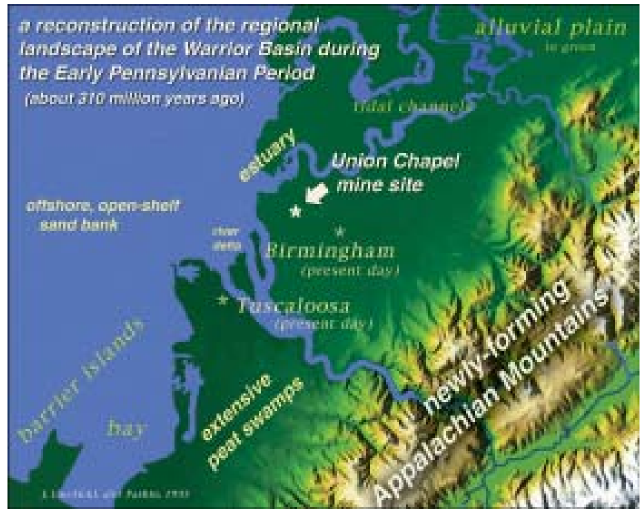

FIGURE 2. Paleogeographical setting of Union Chapel Mine in the Pennsylvanian Period (from Lacefield, 2000).

cases, the track-bearing shale has a sheen due to the presence of very fine-grained mica and possibly also the alignment of clay minerals. The color ranges from red-brown to gray to black; however, gray is the predominant color of the track-bearing shale. The red-brown color is the result of weathering, indicating the presence of pyrite (iron sulfide). Generally, the vertebrate and invertebrate tracks, preserved in the very fine-grained shale, are sharply defined and well-preserved. Tracks are usually absent in the part of the shale unit that grades vertically and laterally into sediment containing silt, sand, coarse mica flakes, or macroscopic plant material. The tracks occur in laminated to thin-bedded shale strata from 0.5 to 2 cm (0.25 to 1 in) thick. The well-sorted, very fine-grained shale grades laterally, southward, along the highwall into a highly burrowed shale containing abundant macroscopic plant material and a lighter gray siltstone. Ripple marks and cross beds are in the silt-shale. The large tetrapod tracks have been identified from the burrowed shale and gray siltstone. These large tracks commonly have curled or bent toes, indicating that the tetrapod toes were flexible in the soft, water-saturated mud (Fig. 8). Another type of vertebrate trail observed in this shale is *Undichna*, interpreted as fin traces of swimming fish (Martin and Pyenson, 2005; see Fig. 9).

ENVIRONMENTS OF DEPOSITION

The vertebrate and invertebrate trackways collected from the Union Chapel Mine are believed to have been made by animals that inhabited an estuarine tidal flat environment during the deposition of the Pottsville sediments in the Early Pennsylvanian (Fig. 10). The animals apparently moved across the mud flat for feeding or transit to another area. No body fossils of the tetrapods or horseshoe crabs, though abundant as trace fossils, have been found in the estuarine *Cincosaurus* beds of the Union Chapel Mine. Fig. 11 shows a north-south profile of the lateral relationships of the estuarine and tidal flat environments along the highwall. Large and small tetrapod trackways were made in the intertidal environment. Burrows, large tetrapod trackways, and fish and larval amphibian traces were made in a subaqueous environment. The vegetation of the Pennsylvanian swamps was established beyond the limits of the Union Chapel Mine on ground upslope from the tidal flat. The tetrapod tracks range from small footprints about 1.0 cm (0.5 in) long (Fig. 5) to large footprints longer than 15 cm (7 in) (Fig. 4). Small tetrapod tracks are restricted to fine-grained shale, which is interpreted as an intertidal mud flat that was exposed during low tide. Once this area was exposed to the atmosphere, vertebrates and invertebrates moved about on the tidal flat. The foot, tail, and body impressions were made in the soft mud. Many of the trackway impressions do not show the tail and body impressions because these tracks represent footprints (underprints) made in layers of soft mud levels below the surface where the animal traversed. The tracks in the mud that grades upslope into a coarser sediment are less distinct or nonexistent. Sediment that changes from the tidal flat mud upslope toward a vegetated area generally contains abundant macerated plant material in the mud, and tracks are less distinct or nonexistent in this lithology also. The small tetrapods and small invertebrates left their trackways and trails in the soft, moist mud near the edge of the water. Once the small animal stepped from the shoreline into the water body, the track became distorted due to the water saturated mud surface. Small animals were not tall enough to travel across deep water. The well-defined small tet-

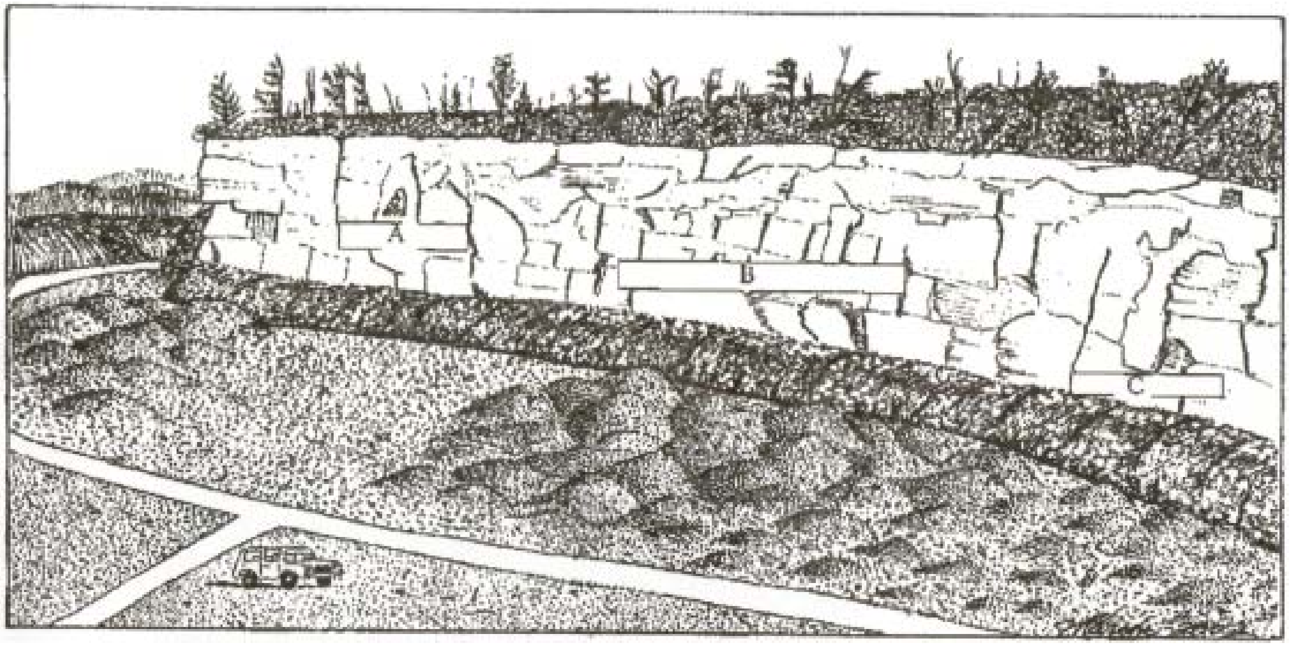

FIGURE 3. West-facing highwall at Union Chapel Mine. North is to the left. A, B, and C refer to different locations along the highwall above the coal seam, discussed in the text.

rapod and invertebrate trackways higher up on the mud flat were filled with fine sediment during the next tidal cycle, possibly during ebb tide when mud was supplied by the continuing fresh water influx, with fine particles being deposited as these fluvial systems met the calmer waters of the estuary within hours of being made. The very fine-grained, well-sorted trackway-bearing shale may have a reddish-brown color indicative of subaerial weathering of pyrite in the tidal flat. Although subaerially exposed, the lack of mud cracks suggests that this area was continually moist. Burrows are typically not present in the track-bearing shale of the tidal mud flat. Large amounts of macroscopic plant material were generally not observed in the track-bearing shale. However, *in situ Calamites* have been described from the low-diversity environment of the tidal mud flat. Large tetrapod tracks have been collected from sediments distributed over a more widespread extent than the fine-grained tidal flat mud sediments that contain the small tetrapod and invertebrate trackways. The large tetrapods left impressions in the same well-sorted, fine-grained mud as the small tetrapods; however, the larger animals evidently could also wade across shallow bodies of water adjacent to the subaerially exposed tidal flat. The smaller animals could not wade across shallow bodies of water. Footprints of the larger animals were commonly distorted due to the weight of the heavy animal on the saturated mud surface under water. Large tetrapod tracks were collected in silty mudstone and are commonly associated with vertical and horizontal burrows and current ripple marks which support a subaqueous interpretation for these trace fossils. In addition, large tetrapod tracks have also been described from sediments containing silt, sand, and abundant plant material which suggests that the weight of the animal was sufficient for its feet to make impressions in coarser sediment. The smaller tetrapod and invertebrate tracks are generally absent from this lithology because the lighter animals' feet would not be able to make much of an impression in the coarser sediment containing sand or plant fragments. The larger invertebrate trackways consist mainly of xiphosuran (horseshoe crab) trackways. Tracks and other traces of horseshoe crabs, as well as tetrapod tracks, have been documented from surface coal mines in Walker County (Rindsberg, 1990). The horseshoe crab trackways have been generally identified from the Mary Lee tidal mud flat sediments, but have also been collected from subtidal, tidal, and shallow nearshore marine siltstones.

SUMMARY

The north-south traverse along the Union Chapel Mine highwall shows a lateral facies change from terrestrial forest carbonaceous shale southward to estuarine tidal flat shales to nearshore marine siltstones. The daily tidal cycle exposed a tidal flat composed of very fine-grained mud that partially dried during the brief subaerial exposure. Once this environment was exposed, large and small vertebrates and invertebrates crossed the tidal flat during the ebb tide. The drying mud was an ideal substrate for small tetrapods and invertebrates to leave their tracks and trails. The animal tracks were quickly covered with mud during the next tidal cycle, which accounts for their excellent preservation. The tidal flat was an area of low plant diversity (Dilcher et al., 2005), but was close to a terrestrial forest or swamp on the edges of the estuarine channels. The Pennsylvanian forests, swamps, and marshes were inhabited by abundant vertebrate and invertebrate animals. The tidal flats were areas that these vertebrates and invertebrates went in search for food or crossed during ebb tide, then

FIGURE 4. Typical large tetrapod trackway.

FIGURE 5. Typical small tetrapod trackway.

FIGURE 6. Possible horseshoe crab trackway (but see Haubold et al., 2005).

FIGURE 7. Myriapod trackways *(Diplichnites).*

FIGURE 8. Large tetrapod trackway in gray silt shale made with flexible toes in soft mud.

FIGURE 9. Fish swimming trail (*Undichna*)

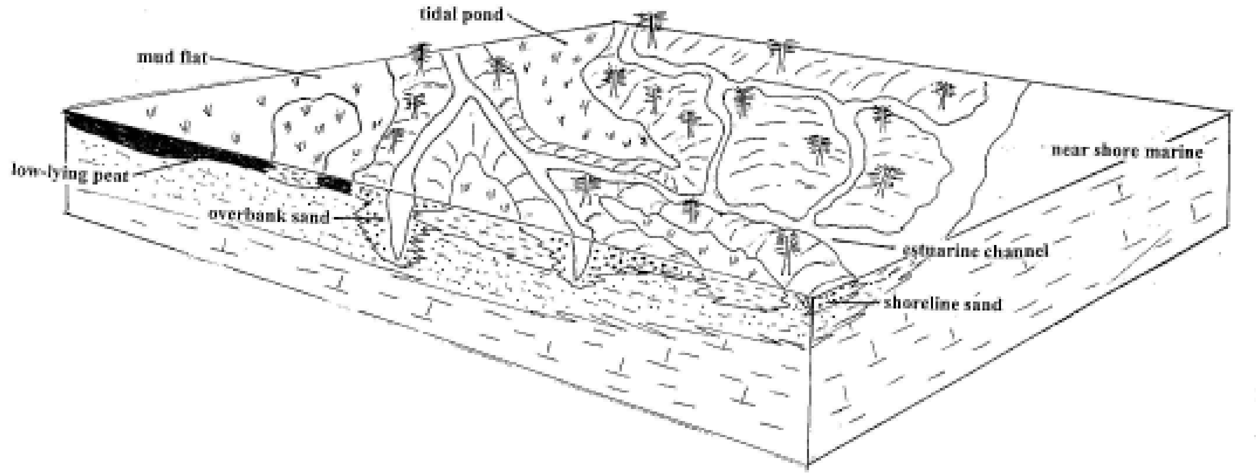

FIGURE 10. Estuarine tidal flat environment of the track-bearing Mary Lee shale.

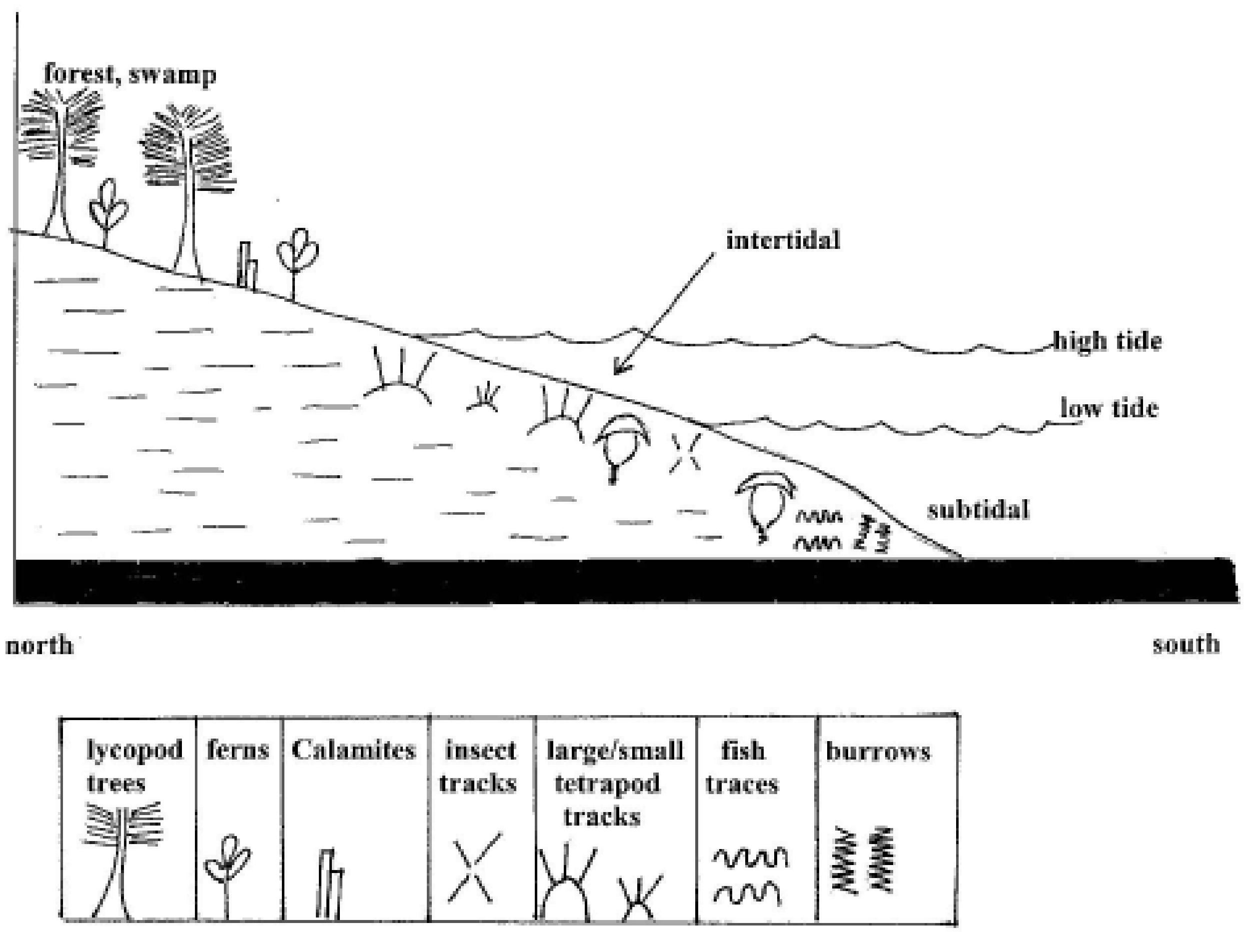

FIGURE 11. Profile of estuarine tidal flat environments and track-bearing sediments. The symbol immediately below the arrowhead refers to a xiphosuran trace.

returned to their terrestrial habitats once the tidal mud flat again became inundated with the next high tide.

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