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THE SIGNIFICANCE OF THE UNION CHAPEL MINE SITE: A LOWER PENNSYLVANIAN (WESTPHALIAN A) ICHNOLOGICAL KONZENTRAT-LAGERSTÄTTE, ALABAMA, USA

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ABSTRACT: The Union Chapel Mine site (Steven C. Minkin Paleozoic Footprint Site) is located in Walker County, Alabama. The fossil-bearing horizon is in the Mary Lee coal zone (above the Mary Lee coal bed) of the Pottsville Formation (Early Pennsylvanian: Westphalian A). It yields diverse and extensive vertebrate and invertebrate ichnofaunas as well as plant and arthropod body fossils. The significance of the tracksite can be evaluated based upon size, ichnotaxonomy, taphonomy, paleoecology, ichnofacies, geography, biogeography, stratigraphy, biostratigraphy, paleoenvironment, preservation, education, sociology and history. The Union Chapel site is globally significant in most of these categories.

INTRODUCTION

The Union Chapel fossil site (now known as the Steven C. Minkin Paleozoic Footprint Site) is a very large fossil site in northern Alabama of Early Pennsylvanian age. It yields an abundant fossil fauna that includes tetrapod tracks (Minkin, 2000; Haubold et al., 2003, 2005), fish traces (Martin, 2003a), invertebrate trace fossils (Rindsberg and Kopaska-Merkel, 2003, 2005; Lucas and Lerner, 2005), plant megafossils (Dilcher et al., 2005) and arthropod body fossils (Atkinson, 2005). This site is obviously significant, but how does it compare with other fossil sites of similar age and scope? The purpose of this paper is to answer that question.

The majority of the significant fossils from the Union Chapel Mine are tetrapod tracks. Therefore, we establish a set of categories by which the significance of tetrapod tracksites can be assessed, and evaluate the Union Chapel Mine against them.

UNION CHAPEL MINE LOCALITY

The partially abandoned Union Chapel Mine is located in Walker County, Alabama, about 48 km northwest of Birmingham (Fig. 1). The track-bearing horizon at the Union Chapel Mine is in the Mary Lee coal zone, just above the Mary Lee coal bed of the Pottsville Formation (Early Pennsylvanian: Westphalian A) (Pashin, 2005; Fig. 2)(Fig. 1). The majority of ichnofossil and other specimens were collected by members of the Alabama Paleontological Society and the Birmingham Paleontological Society on the surface of "spoil piles" that consist of rock from the overburden of the Mary Lee coal bed. During an 18-month period, more than 1200 slabs containing both vertebrate and invertebrate ichnofossils were salvaged from the Union Chapel Mine site (Allen, 2005; Buta and Minkin, 2005; Atkinson et al., 2005). Another less significant, and slightly older locality is the Number 11 Mine of the Galloway Coal Company near Carbon Hill (Aldrich and Jones, 1930).

The track-bearing interval at the Union Chapel Mine is in sandstone-shale couplets interpreted as tidal rhythmites (Pashin, 2003, 2005). Invertebrate ichnotaxa in these strata include abundant xiphosuran trails (*Kouphichnium*), insect feeding traces (*Treptichnus*), burrows (*Arenicolites*), as well as less common arthropod walking and feeding traces (Rindsberg and Kopaska-Merkel 2003, 2005; Lucas and Lerner, 2005; Uchman, 2005). Fish swimming traces (*Undichna*) are also present, as are the tracks of small amphibians (*Batrachichnus*) and small captorinomorph reptiles (*Notalacerta* and *Cincosaurus*) (Haubold et al., 2003, 2005; Martin, 2003a). Indeed, tracks assigned to *Cincosaurus* so dominate the footprint assemblage that local collectors refer to the track-bearing strata at the Union Chapel Mine as the "*Cincosaurus* beds" (e.g. , Minkin, 2005). Larger tetrapod tracks include *Attenosaurus subulensis*, *Alabamasauripus aldrichi*, and *Dimetropus* isp. (Hunt et al., 2004). Although the Union Chapel Mine also contains large (>15 cm long) and fragmentary plant debris and three body fossils of insects and arachnids (Dilcher et al., 2005; Atkinson, 2005), the site otherwise yields a fossil record that consists entirely of trace fossils. There are also brachiopods at the locality, but they probably derive from a different stratigraphic horizon (Pashin, 2005).

UNION CHAPEL MINE AS A LAGERSTÄTTE

The term Lagerstätte was introduced by Seilacher to refer to fossil localities that display exceptional preservation in quality, quantity and diversity, after the German word for "motherlode" (Seilacher, 1970; Seilacher

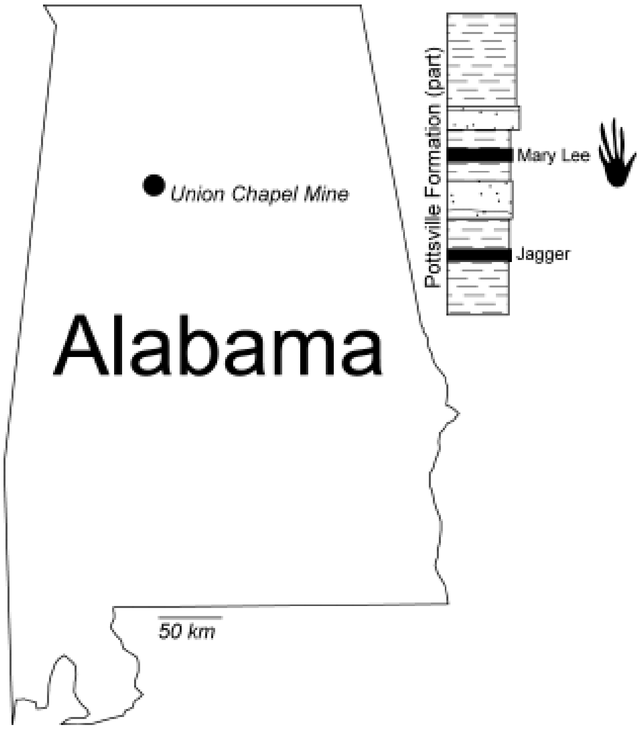

FIGURE 1. Map of Alabama showing location of Union Chapel Mine and generalized stratigraphy of the Pottsville Formation showing location of Mary Lee coal zone and track horizon.

et al., 1985; Seilacher, 1990). This term has since been overused, and arguably only about a dozen fossil localities in the fossil record merit such designation (Selden and Nudds, 2004). These would include famous sites such as the Jurassic Solnhofen quarries of Germany, the Cambrian Burgess Shale of British Columbia and the Chengjiang Biota of Yunnan Province, China.

However, there are a large number of Carboniferous localities that have been "designated" as Lagerstätten, including the Gaskohle of Germany (Fritsch, 1899), Montceau-les-Mines in France (Rolfe et al., 1982), Granton "shrimp-bed" in Scotland (Briggs et al., 1991) and the Castlecomer fauna of Ireland (Orr and Briggs, 1999). In North America, such Lagerstätten include the Bear Gulch Limestone of Montana (Grogan and Lund, 2002), Buckhorn Lagerstätte of Oklahoma (Nutzel et al., 2000), Hamilton Quarry in Kansas (Cunningham et al., 1993), Kinney Brick Quarry in New Mexico (Zidek, 1992), Carrizo Arroyo in New Mexico (Lucas and Zeigler, 2004), Joggins in Nova Scotia (Ferguson, 1988) and Mazon Creek in Illinois (Baird et al., 1985).

Seilacher (1970) recognized two forms of Lagerstätten: (1) Konzentrat-Lagerstätten ("concentration mother lodes") contain large numbers of fossils that largely exclude the preservation of soft parts; these include shell beds and bone beds; and (2) Konservat-Lagerstätten ("conservation mother lodes") are distinguished by the preservation of soft parts and a diversity of taxa and include the Burgess Shale, and the German Posidenienschiefer. Thus, Konzentrat-Lagerstätten are distinguished primarily by quantity, whereas Konservat-Lagerstätten are distinguished by the quality of preservation (Seilacher, 1990).

The Union Chapel Mine has the characteristics of a Konzentrat-Lagerstätte because of the abundance of fossils, although we are not aware of this term having been previously applied to an ichnological assemblage. However, the diversity of taxa of ichnofossils and body-fossils is relatively low, as is the overall representation of phyla. In addition, although there are instances of exquisite preservations, such as the insect wings (Atkinson, 2005), the majority of the fossils are invertebrate and tetrapod trace fossils, and these are dominantly undertracks, and, significantly, there is not extensive preservation of soft tissue (Seilacher, 1970, 1990; Hunt et al., 2004; Haubold et al., 2005). Thus, Union Chapel does not qualify as a Konservat-Lagerstätte.

SIGNIFICANCE OF TERRESTRIAL ICHNOFOSSIL LOCALITIES

Size

Large sample sizes of any fossil are important for a variety of reasons. This is largely because the variability of the morphology of fossil species, and particularly ichnospecies, is usually very poorly understood. A large sample has implications for most of the following categories, not only because of sample size (e.g., ichnotaxonomy, taphonomy) but also because of public impact (education, sociology).

Ichnotaxonomy

Tracksites can, by virtue of large sample size or significant individual specimens, provide for a greater understanding of existing ichnotaxa or reveal new ichnotaxa. The Robledo Mountain tracksites from the Lower Permian of southern New Mexico acted as a "Rosetta Stone" for the understanding of global Permian tetrapod ichnotaxonomy (Haubold et al., 1995; Hunt et al., 1995b; Lucas et al., 1995; Haubold, 1996). The Robledo Mountain tracksites are important for ichnotaxonomy because of their large sample sizes and because they preserve a very large range of extramorphological variants, including transitional forms between "ichnotaxa." In addition, in the Robledo Mountains it is possible to collect a series of successive underprints as well as the original tracks, which allows an understanding of the different morphologies displayed on different sedimentary layers.

Taphonomy

The taphonomy of nonmarine ichnotaxa, particularly tetrapods, is relatively little studied, with some notable exceptions (e. g., McKee, 1947), although there have been important advances in the past few years (e.g., Gatesy et al., 1999; Gatesy, 2003; Manning, 2004). Individual tracksites can provide information about unknown or unstudied taphonomic contexts. For example, the Clayton Lake tracksite in the Lower Cretaceous of northeastern New Mexico preserves tracks made in a very wet substrate, which produces apparently "webbed" dinosaur tracks and multiple tail drags (Lockley and Hunt, 1994; Hunt and Lucas, 2004a).

Paleoecology

Tracks were produced by the behavior of living organisms, in contrast to body fossils, which represent carcasses. Therefore, tracks can provide information about aspects of the ecology of organisms that are not possible to infer from body fossils. A classic example of this is Ostrom's (1972) paper on gregarious behavior in theropod dinosaurs based on an Early Jurassic tracksite.

Ichnofacies

Tracksites can establish new ichnofacies or help to elucidate aspects of named ones or extend their ranges. For example, the Paleozoic tracksites of Grand Canyon National Park allowed Baird (1965) to recognize redbed and eolian ichnofacies that were formalized as the *Chelichnus* and *Batrachichnus* ichnofacies (Lockley et al., 1994; Hunt and Lucas, 2005).

Geography

Tracksites can have an importance due to their geographic location. For example, Paleozoic tracks are rare in the southern continents, so relatively low ichnodiversity localities in Argentina (Melchor, 1997, 2001; Melchor and Poiré, 1992; Melchor and Sarjeant, 2004) have a greater importance than they would in Laurasia.

Paleobiogeography

Tracksites can provide valuable paleobiogeographic information. Thus, for example, Lucas et al. (1999) documented an Early Permian tracksite from the Caucasus, Russia, which greatly expanded the paleobiogeographic range of the tetrapod ichnogenera *Dimetropus* and *Dromopus*.

Stratigraphy

Often tracks are restricted to specific intervals within stratigraphic units such as, for example, the tetrapod tracks in the Lower Permian Coconino Sandstone in Arizona (Santucci et al., 2003), the "Dakota" Group of southeastern Colorado and adjacent areas (Lockley et al., 1992) and the Middle Jurassic Entrada Sandstone of central Utah (Lockley and Hunt, 1995). In such instances, the distribution of tracks can have utility in stratigraphic resolution (e.g., correlation by way of track-bearing intervals).

Biostratigraphy and Biochronology

In general, tetrapod ichnotaxa have long stratigraphic ranges because most of them correspond to family or higher taxonomic levels of biotaxa (Lucas, 2005). However, in the absence of other fossils, they can have limited utility for both biostratigraphy and biochronology. Indeed, in some instances, trace fossils provide the only evidence of an organism's stratigraphic occurrence (Carrano and Wilson 2001).

Paleoenvironment and Paleogeography

Because tetrapod tracks are formed *in situ* and cannot be reworked, they provide *prima facie* evidence of a terrestrial environment and often are indicators of very specific environmental conditions. For example, Mesozoic dinosaur tracks from the Mediterranean area demonstrated that strata formally considered to be shallow marine in origin were actually emergent, with significant implications for the paleogeography of the region (Bosellini, 2002). Statistically significant numbers of one ichnofossil taxon restricted to one lithological horizon, or unit of rock, can serve as predictable paleoenvironmental indicators (e.g., Seilacher, 1967a, 1967b).

Preservation

Relatively few fossil sites are preserved and protected. However, tracksites have a greater potential for *in situ* preservation than other kinds of fossil sites. Most tetrapod bones are relatively sensitive to weathering (and human interference), so most that are preserved *in situ* are housed within buildings (e.g., Dinosaur National Monument in Utah, Hot Springs Mammoth Site in South Dakota, Dashanpu Dinosaur Museum in Sichuan, China, etc.). However, tetrapod bones are rarely preserved in a natural environment. Two exceptions are Jurassic dinosaur bones in the western United States at Dinosaur Ridge near Denver, Colorado, and near Moab, Utah. Tracksites are much more robust, and although some are preserved within buildings or structures (e.g., Rocky Hill Dinosaur State Park, Connecticut; St. George Dinosaur Discovery Site at Johnson Farm, Utah; Lark Quarry, Australia), many are preserved in an unprotected state (Dinosaur Ridge, Clayton Lake State Park, BLM site near Moab). Indeed, there are preserved tracksites on every continent except Antarctica.

Education

Tracks are of intrinsic interest to the public, and they readily invoke past environments and ecologies. Because tracksites are often preserved and open to the public (at different levels), they provide great potential for public education. Probably the most educationally developed tracksite is at Dinosaur Ridge near Denver, which has both adult- and child-oriented exhibits and guidebooks that address both the tracks and other natural history (mainly geological) features of the area (e.g., Lockley and Hunt, 1994; Lockley, 2001).

Sociology

Paleontology is one the few sciences in which volunteers/avocationalists (nonprofessionally trained and employed) individuals can and do make a huge contribution. Often this involves the finding of fossils, but it can also include important examples in which volunteers not only discover, but also develop and prepare, the fossils. A great example of this important role is the Peterson Dinosaur Quarry in the Upper Jurassic Morrison Formation of New Mexico, which was found by Rod and Ron Peterson, who now oversee the field collection of specimens (Heckert et al., 2000). Subsequently, the bones are prepared for research and display at the New Mexico Museum of Natural History and Science (NMMNH) by volunteers. The Jurassic Supergiants Exhibit at NMMNH, which opened in August 2004, is the culmination of the work of these volunteers.

Untrained paleontologists have had a great impact on the science of vertebrate ichnology in the past few years. Notable are the efforts of two individuals, whose work has resulted in the study (and in one case preservation) of important tracksites in western North America. Jerry MacDonald found, and brought to scientific attention, the Robledo Mountain tracksites in southern New Mexico, which are the largest and most significant assemblage of Permian tracks known (MacDonald, 1994; Lucas and Heckert, 1995; Lucas et al., 1998). Andrew R. C. Milner played a similar role with respect to Early Jurassic tracksites at St. George in Utah, although he was not the original discoverer. One of these tracksites is preserved at the St. George Dinosaur Discovery Site at Johnson Farm, and in 2006 it will be the subject of a scientific monograph. In Nova Scotia, several significant Paleozoic tracksites have been developed by amateurs, notably Blue Beach (Chris Mansky), Brule (Howard van Allen), Joggins (Don Reid, Brian Hebert), and West Bay (Eldon George).

History of Discovery

There is a level of serendipity in the importance of tracksites related to the timing of their discovery. For example, Early Jurassic tracks have been known in northeastern North America since 1802 (Steinbock, 1989). Thus, more recent finds have less scientific impact because the basic composition of the ichnofauna and its distribution are well understood. This is not to say that new sites might not provide new information or that they might not be important for other reasons, such as preservation and interpretation (e.g., Rocky Hill Dinosaur State Park). In April 2005, the St. George Dinosaur Discovery Site at Johnson Farm opened to the public in Utah. The St. George Dinosaur Discovery preserves the same basic ichnotaxa that are well-known from New England, such as the dinosaur ichnogenera *Grallator* and *Eubrontes*, but it has importance historically because it is the first large tracksite of this age from western North America that is preserved and readily accessible to the public.

SIGNIFICANCE OF UNION CHAPEL SITE

Size

The Union Chapel Mine is the largest Carboniferous tracksite known in terms of abundance of track specimens within a narrow stratigraphic range (Cotton et al., 1995; Hunt et al., 1995a; Lucas, 2003). The current collections lack long trackways (cf. Lucas et al., 2004b), but this clearly reflects the fact that the specimens were all collected from spoil and were not excavated from bedding plane exposures. We hope that bedding plane collections will be made in the future. The Union Chapel Mine site is only surpassed in terms of abundance among Paleozoic tracksites by the Robledo Mountains localities in the Lower Permian of New Mexico (Lucas and Heckert, 1995).

Ichnotaxonomy

The Union Chapel ichnofauna is of relatively low diversity despite the large number of specimens. Indeed, Pyenson and Martin (Pyenson and Martin, 2001; Martin and Pyenson, 2005) consider that most of the tetrapod tracks from the Union Chapel Mine are assignable to a single ichnotaxon represented by growth stages (however, two of us [APH and SGL] do not accept this conclusion).

The majority of tracks from the Union Chapel Mine site pertain to *Cincosaurus cobbi*, and the ichnotaxonomy of this ichnospecies is now much better understood (Haubold et al., 2005). Large tracks from Union Chapel are conventionally attributed to *Attenosaurus subulensis* (Haubold et al., 2005). However, Hunt et al. (2004) recognized three large ichnotaxa, including *Attenosaurus subulensis*, *Alabamasauripus aldrichi* and *Dimetropus isp*. (Fig. 2). There is consensus about the ichnotaxonomy of the smaller, rarer temnospondyl track *Matthewichnus caudifer* and the amniote *Notalacerta missouriensis*. Two of us (APH and SGL) consider the small temnospondyl that Haubold et al. (2005) assign to *Nanopus reidiae* to pertain to the ichnogenus *Batrachichnus* and are unsure whether it represents a new ichnospecies. All six of the identifiable ichnospecies from the Union Chapel Mine recognized by APH and SGL (Table 1) are restricted to the southeastern United States.

It is important to note, as did Haubold et al. (2003, 2005) and Hunt et al. (2004), that the vast majority of the Union Chapel Mine tracks are undertracks. This is not a collecting bias, but a true reflection of the ichnofaunas. Thus, although this assemblage is one of the largest Carboniferous ichnofaunas known in terms of number of specimens collected, it lacks diversity and thus is of limited value to ichnotaxonomy. This ichnofauna is thus not as useful a “Rosetta Stone” for Pennsylvanian tracks as the Robledo Mountains assemblages of New Mexico are for Early Permian tracks (Haubold et al., 1995; Hunt et al., 1995a).

Taphonomy

The Union Chapel site has a very unusual taphonomy. Despite the huge sample of tetrapod tracks, virtually all are undertracks (Hunt et al., 2004; Haubold et al., 2005).

Clearly, at the Union Chapel Mine site, a cyclic sequence of events included a wetting event when the tracks were imprinted followed, in almost all cases, by erosion of the surficial laminae that preserved the true tracks.

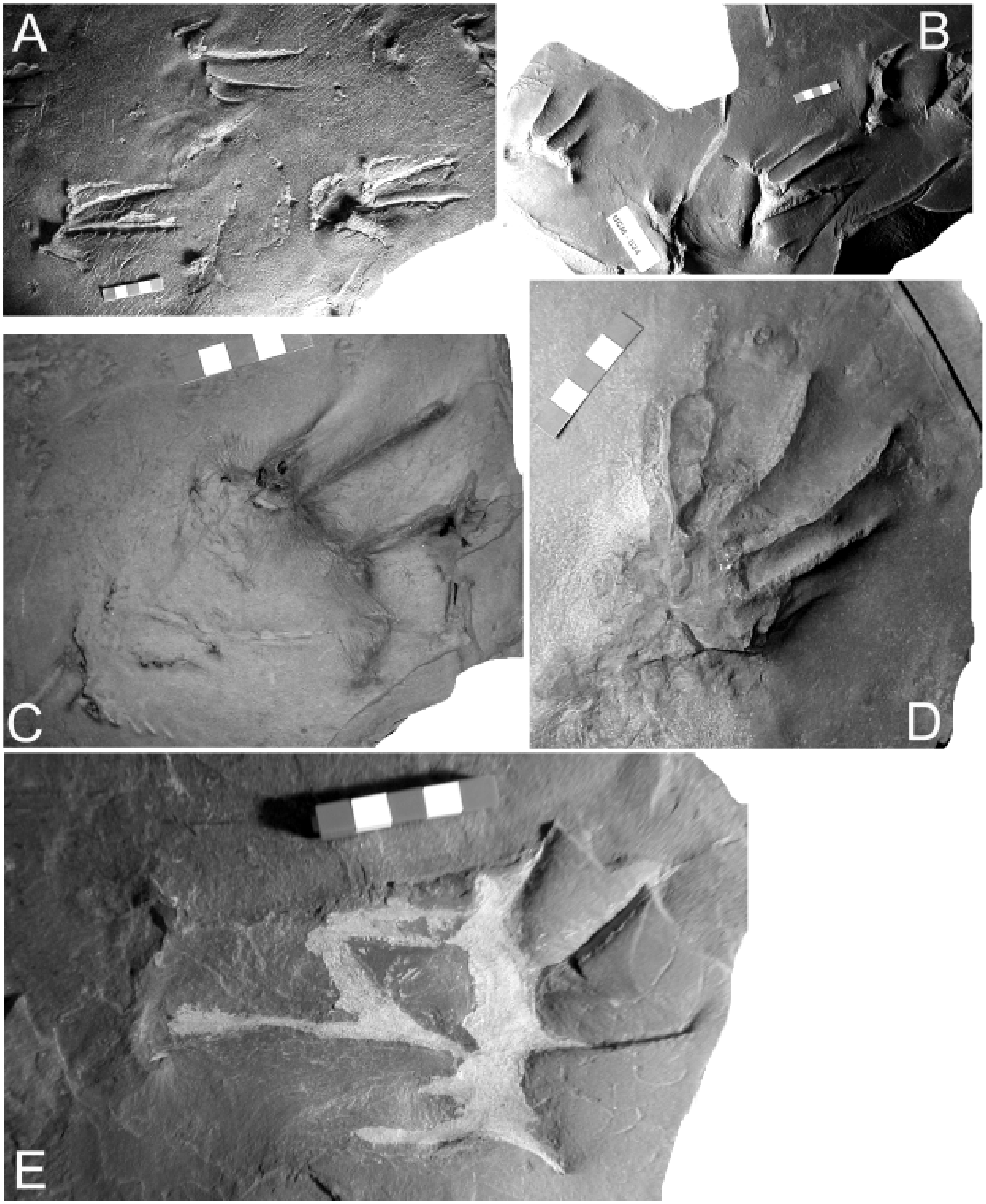

FIGURE 2. Photographs of selected large tetrapod tracks from the Union Chapel Mine. A, ALMNH unnumbered, *Attenosaurus subulensis*. B-C, *Alabamasauripus aldrichi*. B, UCM 024, *Alabamasauripus aldrichi*. C, ALMNH PV987.0001, *Alabamasauripus aldrichi*. D, UCM 021, *Dimetropus* sp. E, NMMNH P-40012, holotype of *Alabamasauripus aldrichi* (after Hunt et al., 2004).

TABLE 1. Differing opinions about the tetrapod ichnotaxonomy of the Union Chapel ichnofaunas

Trackmakers	Haubold et al. (2005)	Hunt et al. (2004; APH and SGL, this paper)
Temnospondyls	*Nanopus reidiae*	*Batrachichnus reidiae*
	Matthewichnus caudifer	*Matthewichnus caudifer*
Anthracosaurs	*Attenosaurus subulensis*	*Attenosaurus subulensis*
Amniotes	*Cincosaurus cobbi*	*Cincosaurus cobbi*
	Notalacerta missouriensis	*Notalacerta missouriensis*
		Alabamasauripus aldrichi
		Dimetropus isp.

The thin-bedded nature of the sediment allowed impression of the tracks through multiple bedding planes. This broad pattern of preservation is typical of other tidal flat deposits (e.g., Robledo Mountains tracksites). However, *the pervasive nature of preservation as undertracks in such a large sample is unique for any time period.*

Paleoecology

The Union Chapel site preserves an array of paleoecological data, including evidence of both individual and group behavior (Pyenson and Martin, 2001; Martin and Pyenson, 2005). The most important feature of the site is the oldest occurrence of group behavior in tetrapods demonstrated by ichnological data (Pyenson and Martin, 2001; Martin and Pyenson, 2005). There is also interesting evidence of schooling in fish as evidenced by the trace fossil *Undichna* (Pyenson and Martin, 2001; Martin and Pyenson, 2005). Furthermore, there is a variety of unusual individual behaviors, including obstacle avoidance demonstrating stimulus response (Pyenson and Martin, 2001; Martin and Pyenson, 2005). It is important to note that the track-bearing Pottsville Formation is devoid of tetrapod body fossils. Thus, our only knowledge of the tetrapod fauna of this age in Alabama is based on the ichnological record. The Union Chapel site thus provides a window into an Early Pennsylvanian ecosystem, especially with regard to tetrapods, fish, arthropods, and plants. However, it lacks many components of the ecosystem that are found in other Carboniferous Lagerstätten.

Ichnofacies

The tetrapod ichnofauna of the Union Chapel Mine is significant because it is the best known Carboniferous example of the *Batrachichnus* biotaxonichnofacies of Hunt and Lucas (2005). This widespread Paleozoic biotaxonichnofacies is present in water-laid nonmarine strata, and it has previously been referred to as the "redbed ichnofacies" (e.g., Hunt et al., 1995c; Hunt and Lucas, 1998b) or the *Anthichnium-Limnopus* assemblage (Lockley and Meyer, 2000). This ichnofacies extends from the ?Early Mississippian to the Early Permian (Lucas et al., 2004; Hunt and Lucas, 2003, 2004b, 2005). The type ichnofauna of this biotaxonichnofacies is from the Lower Permian Robledo Mountains Formation of the Hueco Group in southern New Mexico.

Geography

The Union Chapel site is by far the largest tracksite in the Paleozoic of eastern North America. All previously described localities from this region had only yielded a very small number of track-bearing slabs (Aldrich and Jones, 1930; Cotton et al., 1995; Lucas, 2003) (Fig. 3).

Paleobiogeography

All the recognized ichnospecies from the Union Chapel Mine (*Attenosaurus subulensis*, *Alabamasauripus aldrichi*, *Matthewichnus caudifer*, *Notalacerta missouriensis*, *Batrachichnus reidiae*, *Cincosaurus cobbi*) are apparently restricted to an Appalachian paleobiogeographic province that includes Alabama, Kansas, Kentucky, Missouri, Oklahoma and Tennessee. However, we expect that ongoing studies of the ichnotaxonomy of other areas, notably Nova Scotia in eastern Canada and western Europe, will demonstrate that this apparent paleobiogeographic province is larger than now perceived (cf. Permian; Hunt and Lucas, 1998a).

Stratigraphy

There are two principal, documented tracksites in the upper Pottsville Formation. The older locality is the Number 11 Mine of the Galloway Coal Company near Carbon Hill (Aldrich and Jones, 1930). The younger is the Union Chapel Mine near Jasper (Pashin, 2003, 2005). The track-bearing horizon at the Number 11 Mine is in the shale immediately above the Jagger coal seam, whereas at the Union Chapel Mine it is above the Mary

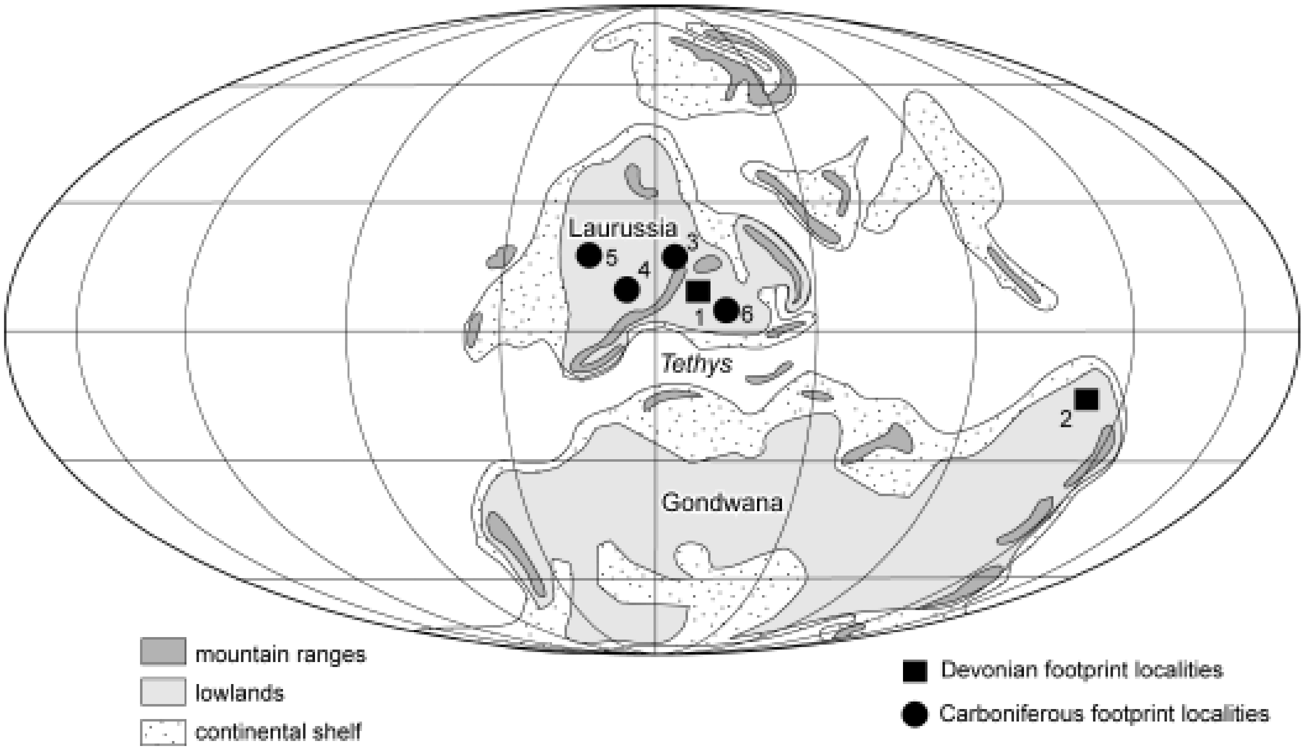

FIGURE 3. Global map of Devonian and Carboniferous tetrapod ichnofaunas showing distribution of principal tetrapod tracksites. Devonian sites are: 1, Ireland and Scotland, 2, eastern Australia. Carboniferous sites are: 3, Nova Scotia, 4, eastern United States, 5, western United States, 6, western Europe. Base map after DiMichele and Hook (1992).

Lee coal bed. The stratigraphic separation of the two track horizons is about 20 m (Metzger, 1965). These two track zones may have importance for correlation within the Pottsville Formation outcrop belt.

In addition, J. Lacefield has collected many specimens from two other sites whose stratigraphic setting has not been documented (Haubold et al., 2005). Thus, there is need for more work to document the stratigraphic level of all tracksites in the Pottsville Formation.

Biostratigraphy and Biochronology

The stratigraphic distribution of tetrapod tracks in the Paleozoic of the eastern United States is poorly understood, and this limits the biostratigraphic utility of the Union Chapel Mine tracks. However, it is likely that more work will demonstrate long stratigraphic ranges for the ichnotaxa from Union Chapel and that they will have limited use in biostratigraphy and biochronology. Lucas (2003; Fig. 4) has demonstrated that only three intervals can be recognized in the Carboniferous track record:

1. The Mississippian track record (mostly known from North America) is temnospondyl-dominated and has rare captorhinomorph tracks.

2. The Early-Middle Pennsylvanian (Westphalian) record, including the Union Chapel Mine, shows a mixture of temnospondyl tracks (e.g., *Limnopus*, *Schmidtopus*, *Paleosauropus*, *Cursipes*) and captorhinomorph (e.g., *Pseudobradypus*, *Asperipes*) tracks. It is the abundance of the captorhinomorph tracks that distinguishes the Westphalian sites from the Mississippian sites, and Lucas (2003) termed this interval the *Pseudobradypus* biochron.

3. The Late Pennsylvanian track record includes the lowest occurrences of *Batrachichnus*, *Ichniotherium*, *Dromopus*, *Gilmoreichnus* and *Dimetropus*, ichnotaxa characteristic of the younger, Early Permian ichnofauna. This is the beginning of the *Dromopus* biochron, which continues through the Early Permian.

Paleoenvironment and Paleogeography

Superficially, the sedimentological context of the Union Chapel site resembles other Permo-Pennsylvanian tracksites. Buildex in Kansas (Pennsylvanian), Mansfield in Indiana (Pennsylvanian), Keota in Oklahoma (Pennsylvanian) and the Robledo Mountains in New Mexico (Permian) are all associated with freshwater tidal flat settings, as is Union Chapel (Lucas et al., 2004b; Pashin, 2005). These tracksites are all characterized by arthropod locomotion, resting and grazing traces, fish swimming traces and an abundance of tetrapod tracks (Lucas et al., 2004). However, the Union Chapel site is conspicuous by its absence of the characteristic insect resting trace *Tonganoxichnus*, which gives its name to the assemblage (or ichnofacies) that includes these other sites. This suggests that Union Chapel represents a significant variant of tidal flat environment.

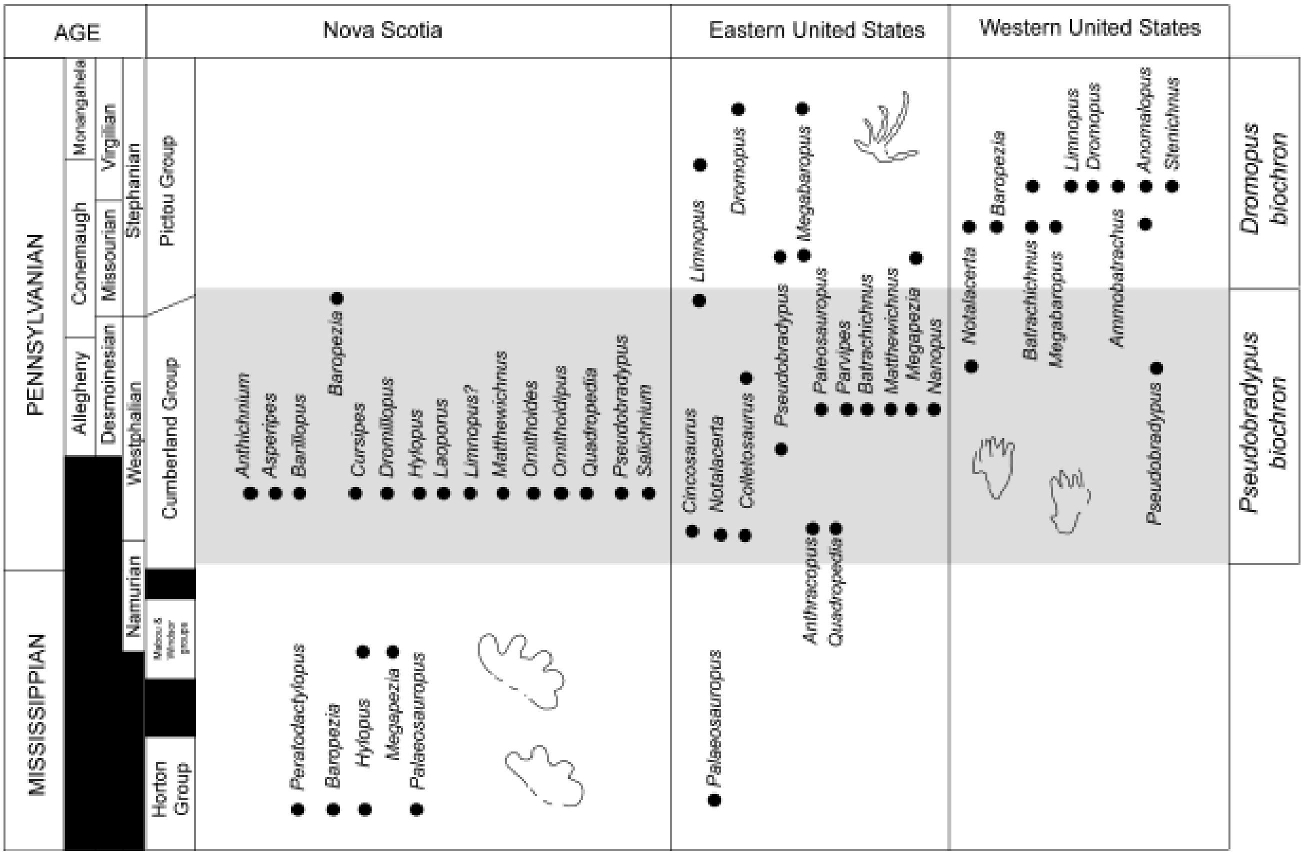

FIGURE 4. Temporal distribution of Carboniferous tetrapod footprint ichnogenera in North America (after Lucas, 2003). Section in Nova Scotia based on Calder (1998)

An alternative hypothesis is that *Tonganoxnichnus* ichnotraces were removed by the frequent erosion of track-bearing bedding planes, which is indicated by the prevalence of tetrapod undertracks.

An interesting sedimentological inquiry would be to investigate why tetrapod tracks are apparently stratigraphically restricted within the Pottsville Formation. In most cases paleontologists construct essentially *ad hoc* hypotheses to explain fossil preservation at a given location instead of viewing the fossil preservation as an indicator of a certain set of environmental and/or diagenetic criteria.

Preservation

The Union Chapel Mine site is unusual in several aspects of its preservation. Many other preserved tracksites from the Lower Cretaceous of Australia to the Lower Jurassic of Poland are contained within buildings or under canopies. Virtually all other preserved tracksites display to the public one large bedding plane (e.g., Lark Quarry in Australia) or large exposures of several bedding planes (e.g., Clayton Lake State Park in New Mexico). The Union Chapel site is the only tracksite of which we are aware that preserves a spoil pile and unexcavated strata. This could provide a model for the preservation of the Permian Robledo Mountains tracksites of southern New Mexico.

Education

Tetrapods are intrinsically interesting to the public as they readily invoke past environments. The Union Chapel site has been of tremendous educational utility to the members of the Alabama Paleontological Society and those with whom they have interacted. The Steve Minkin Paleozoic Footprint Site at Union Chapel has tremendous potential for education through signage, printed matter, audio-visual treatments and web-based resources.

Sociology

There are interesting comparisons to be made between the development of the Union Chapel site and other tracksites. As with the Robledo Mountains tracksites in southern New Mexico and the St. George tracksite in Utah, the site was championed by volunteer effort with early interaction from professional paleontologists. The Union Chapel story differs markedly from the others in that a talented and diverse group of amateurs collaborated in the development of the site (Atkinson et al., 2005; Buta and Minkin, 2005; Lacefield and Relihan, 2005). In the case of the Robledo Mountains and St. George sites, a single amateur (Jerry MacDonald and Andrew R. C. Milner, respectively) carried the torch. As at St. George, the Union Chapel Mine was saved for posterity

(Atkinson et al., 2005), whereas the Robledo sites, although demonstrated to be of global significance, are being quarried for flagstone or left to be vandalized and eroded.The Alabama Paleontological Society and its associates deserve high praise—they caught the attention of the paleontological community, saved the site from infilling and stimulated a comprehensive study of this site. Two interesting and unique aspects of the promotion of the Union Chapel site are the "Track Meets" (meetings of the Alabama Paleontological Society to catalog and document specimens in private collections) and the superb website that excited the attention of many paleontologists around the world (Buta and Minkin, 2005; Atkinson et al., 2005; Lacefield and Relihan, 2005).

History of Discovery

The Union Chapel site is important historically as the first large Carboniferous tracksite discovered in the world and as the first significant Paleozoic tracksite found in the eastern United States. A tracksite from the Early Mississipian of Nova Scotia is potentially the oldest large tracksite known (Lucas et al., 2004a).

CONCLUSIONS

The Union Chapel Mine site (Steve Minkin Paleozoic Footprint Site) is significant because:

1. It is the largest Carboniferous tracksite known.
2. It clarifies the ichnotaxonomy of some of the Carboniferous tetrapod ichnotaxa of the southeastern United States.
3. It has a unique taphonomic setting that preserves abundant tetrapod tracks, which are virtually all undertracks.
4. It preserves the oldest ichnological evidence for group behavior in tetrapods and fish.
5. It is the best known Carboniferous example of the *Batrachichnus* biotaxonichnofacies.
6. The Union Chapel site is by far the largest tracksite in the Paleozoic of eastern North America.
7. It appears to provide evidence for an Appalachian paleobiogeographic province in Carboniferous tetrapods.
8. The track zone may have utility for correlation.
9. It represents a previously unrecognized type of Permo-Pennsylvanian ichnofauna in a freshwater tidal flat setting that lacks *Tonganoxichnus*.
10. It is a preserved tracksite that is neither under a man-made structure nor exposes one or more extensive bedding planes.
11. It has a proven importance for public education.
12. The history of its preservation is unique in that a talented and diverse group of amateurs collaborated in the development and preservation of the site.
13. It is the first large Carboniferous tracksite discovered in the world and the first significant Paleozoic tracksite in the eastern United States.

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