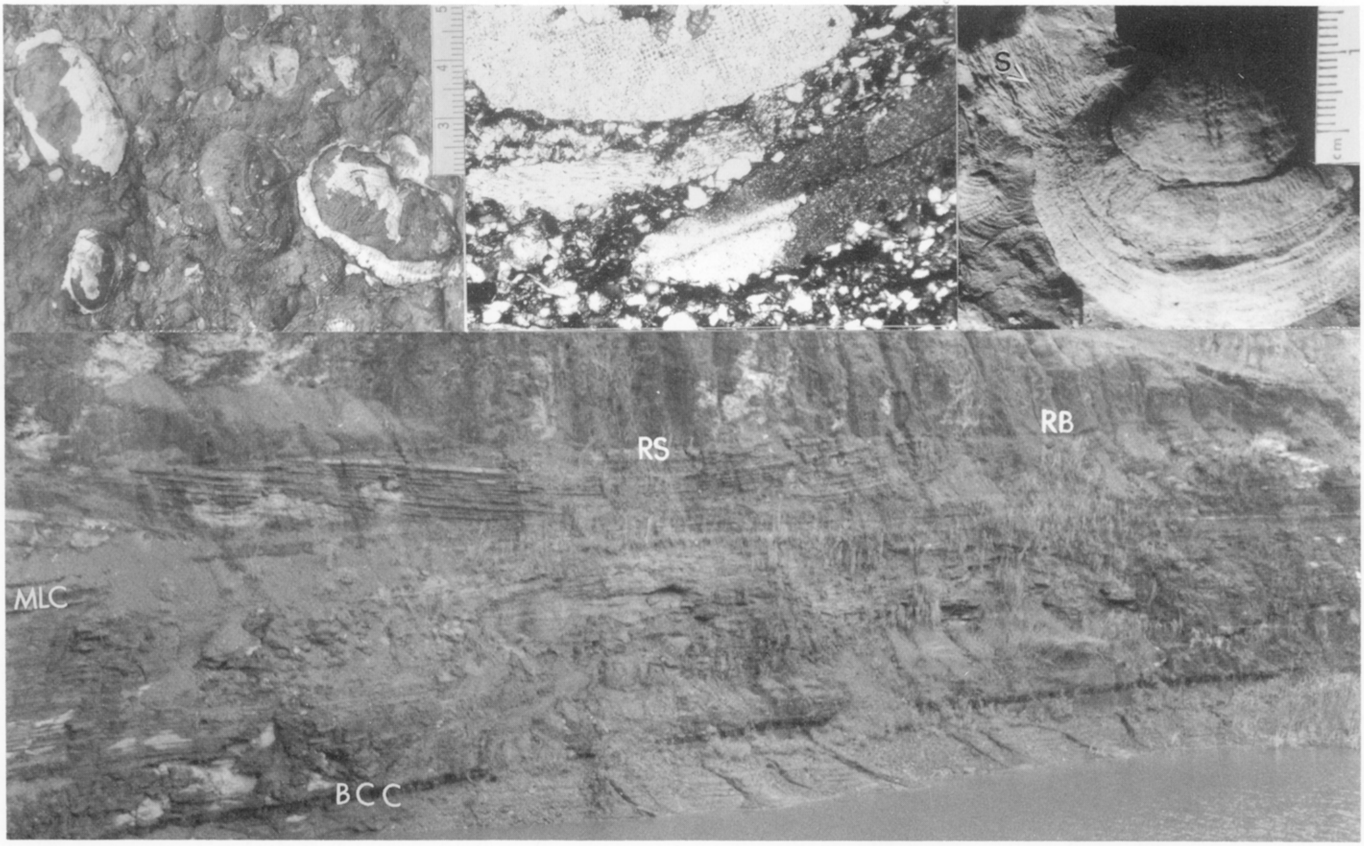
CARBONIFEROUS COASTAL ENVIRONMENTS AND PALEOCOMMUNITIES OF THE MARY LEE COAL ZONE, MARION AND WALKER COUNTIES, ALABAMA

GUIDEBOOK FOR FIELD TRIP VI

Robert A. Gastaldo, Timothy M. Demko, and Yuejin Liu



Tuscaloosa, Alabama
April 7-8, 1990

Cover photograph: Field occurrence of the ravinement surface (RS) at the Gateway Malls Hope Gateway mine (Carbon Hill, 7.5-Minute Quadrangle, sec. 14, T 13 S., R. 10 W.). The Blue Creek (BCC) and Mary Lee coals (MLC) are beneath a channel-form sandstone, which is truncated by the overlying ravinement surface. The ravinement bed (RB) overlies the ravinement surface. In habitat macroinvertebrates and the variability of the ravinement bed are illustrated by the autochthonous macroinvertebrate assemblage comprised of productid brachiopods (Birmingham Coal and Coke mine, NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 25, T. 14 S., R. 8 W., Jasper, Alabama, 7.5-Minute Quadrangle); photomicrograph of the ravinement bed sandstone consisting of fine- to very fine-grained quartz, scattered feldspar, and bioclasts; and *Cancrinella boonensis* with attached spines (S) in the mudstone bed. Scale in cm.

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CONTENTS

CONTENTS—CONTINUED

ILLUSTRATIONS

ILLUSTRATIONS—CONTINUED

ILLUSTRATIONS—CONTINUED

TABLES

INTRODUCTION

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The field trip is designed to examine the northwestern part of the Warrior basin, a triangular foreland basin located at the southern end of the Appalachian orogen (Thomas, 1976) (fig. VI-1). The basin is bounded on the north by the Nashville dome, on the southeast by the Appalachian structural front, and on the southwest by the deeply buried Ouachita tectonic trend. The interval under consideration is the Mary Lee coal zone (lower Valley Creek interval; sensu Raymond and others, 1988) of the Lower Pennsylvanian "Pottsville" Formation (Westphalian A equivalent; fig. VI-2). The "Pottsville" is greater than 3000 m thick in the center of the basin (Hewitt, 1984), but thins and crops out to the north due to both depositional thinning and post-Pennsylvanian erosion. We have adopted the use of quotation marks around the "Pottsville" for several reasons. First, it has been used both as a lithostratigraphic and chronostratigraphic term indiscriminately. Second, the Pennsylvanian rocks in the Warrior basin are over 1,000 km away from the type section of the Pottsville Formation in Pennsylvania. Third, the U.S. Geological Survey has abandoned this term for time-equivalent rocks in the proposed Carboniferous Stratotype in Virginia and West Virginia.

Many factors operating together, although on different temporal and spatial scales, ultimately contributed to the deposition and

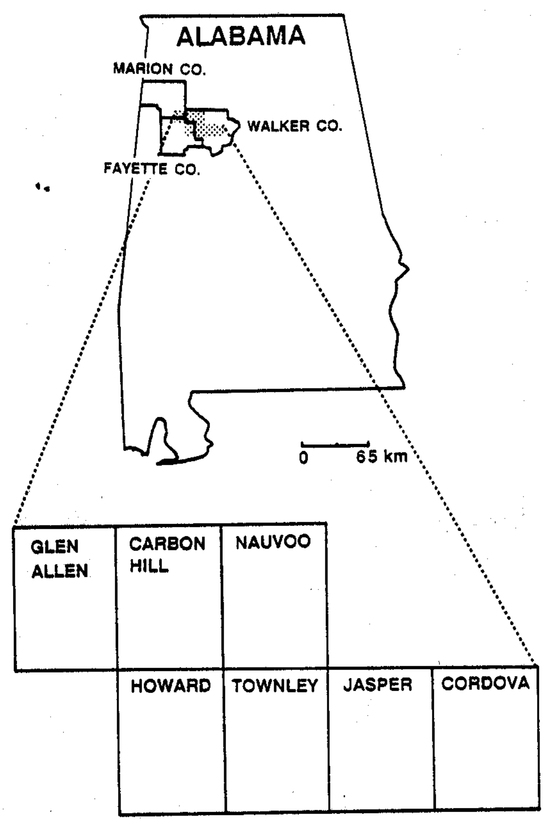

Figure VI-1.--Map of study area in Marion, Fayette, and Walker Counties showing 7.5-Minute Quadrangles.

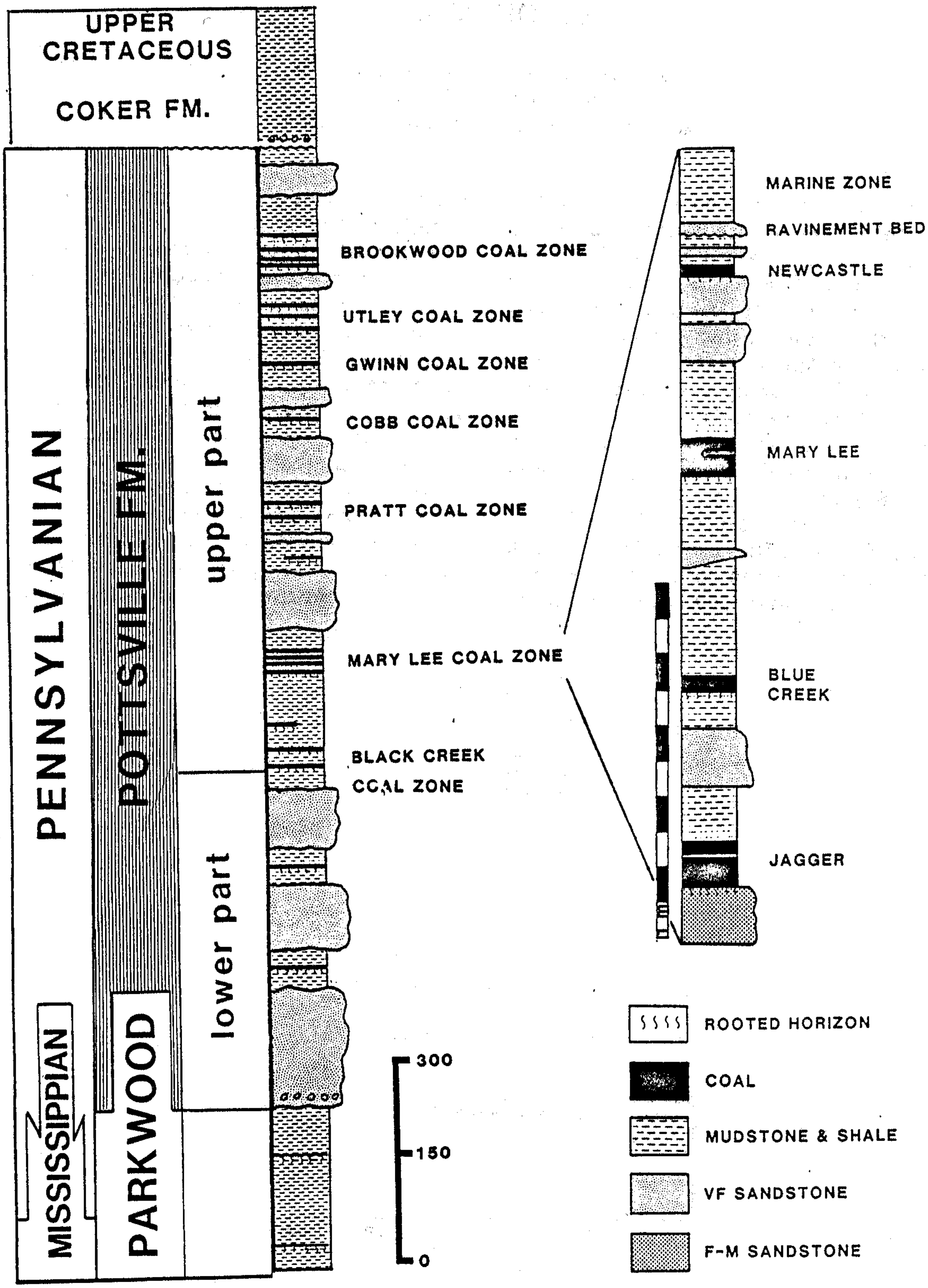

Figure VI-2.--Generalized stratigraphic column of the upper part of the Carboniferous section in the Black Warrior basin, with the study interval highlighted. Scale in meters.

preservation of coastal and near-coastal terrestrial facies during the Early Pennsylvanian. Basin subsidence, foreland basin collapse in front of the Appalachian thrust front, created space or allowed accommodation of the "Pottsville" Formation as a whole. Its present thickness, all of which is reported to be Westphalian A in age (Gillespie and Rheams, 1985), implies a tremendous depositional rate as compared to contemporaneous basins (e.g., midcontinent and central and northern Appalachians in North America). Pennsylvanian sediments in the Warrior basin are terrestrial and shallow marine clastics. These deposits provide evidence of continued, constant subsidence to keep pace with sediment loading.

Eustatic sea level change, due to Gondwana continental glaciation and/or Milankovitch orbital cycles (Wanless and Shepard, 1936; Heckel, 1986; Veevers and Powell, 1987) controlled the position of the shoreline within the basin. These shoreline fluctuations resulted in the development of the marginal marine sequences between coal zones. At least ten basin-wide marine macroinvertebrate horizons have been recognized in the "Pottsville" (Metzger, 1965; Gillespie and Rheams, 1985). In the Mary Lee coal zone the recognized macroinvertebrate horizons mark the boundaries of the genetic package (see Demko, this guidebook and Liu, this guidebook).

Regional subsidence, or the differential movement on fault-bounded tectonic blocks, probably controlled the positions of regional depocenters and the locations of major clastic pathways. Thomas (1968) and Weisenfluh and Ferm (1984) have demonstrated synsedimentary movement on normal faults (typically downthrown block to the south) in the basin during the Carboniferous. This movement, like that of the overall basinal subsidence, was probably enhanced by additional sediment loading.

Sediment supply to any particular coastal depositional environment was a strong factor in determining facies distribution. Sediment supply to coastal zones during the Early Pennsylvanian in the Warrior basin was controlled by many factors. These include: (1) the relief of the source area highlands and their proximity to the coast; (2) the climate in both the source area and the coastal zone; (3) the number and position of clastic pathways (major rivers, estuaries, coastal streams, and tidal creeks) along the coast; and (4) the longshore or littoral movement of sediment. Local subsidence due to differential compaction (over a relatively short time span in comparison to the above mechanisms) was the overriding control on facies changes (peat-accumulating swamps versus clastic swamps) within the Mary Lee coal zone (Gastaldo and others, in press).

The Mary Lee coal zone is one of nine coal zones in the "Pottsville" Formation (Lyons and others, 1985). It is the most productive coal zone in the basin and is, therefore, the best exposed "Pottsville" interval. It traditionally contains the Ream, Jagger, Blue Creek, Mary Lee, and Newcastle coal seams (Raymond and others, 1988) (fig. VI-2). The Jagger, Blue Creek, Mary Lee, and Newcastle are all of minable thickness in the study area. The stratigraphically lowest seam, the Ream, is thin, unminable and, therefore, not well exposed. The interval reported on in this study represents two genetic packages; one is a regressive terrestrial unit, the another is a transgressive marine unit. The sequence encompasses the stratum immediately below the Jagger coal to the strata immediately above the Newcastle coal. Outcrops extending over 1000 km^2 occur as surface mine highwalls, roadcuts, and natural exposures. These exposures extend laterally over several km; sometimes in two or three oblique to near perpendicular directions. This allows a three-dimensional view of the architecture of the sedimentary facies, and provides an opportunity to acquire a detailed data base from which to interpret and reconstruct this Early Pennsylvanian coastal system.

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DEPOSITIONAL ENVIRONMENTS OF THE LOWER MARY LEE COAL ZONE, LOWER PENNSYLVANIAN "POTTSVILLE" FORMATION, NORTHWESTERN ALABAMA

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ABSTRACT

The depositional history of the lower part of the Mary Lee coal zone, Lower Pennsylvanian "Pottsville" Formation, of the Warrior basin in Alabama is a record of sedimentation of an overall regressive nature. The depositional environments range from tidally influenced offshore/nearshore sand ridge fields (the "Jagger bedrock") near the base of the coal zone, to terrestrial swamps (both clastic-dominated alluvial swamps and peat-accumulating swamps) at the top of the section. Excellent exposures and preservation of autochthonous plant fossils and trace fossils in the sequence provide an opportunity to evaluate both the lithofacies and biofacies relationships in an offshore to onshore transition.

INTRODUCTION

The Mary Lee coal zone is one of nine coal zones in the "Pottsville" Formation in the Warrior basin of Alabama (Lyons and others, 1985). It is one of the most productive coal zones in the basin and is well exposed in surface mines in northwestern Walker County. It contains the Ream, Jagger, Blue Creek, Mary Lee, and Newcastle coal seams. Of these, the Jagger, Blue Creek, Mary Lee, and Newcastle all attain minable thickness in the study area (Gastaldo and others, this guidebook, fig. VI-1). The stratigraphically lowest seam, the Ream, is thin, not commercially minable and, therefore, not well exposed. The stratigraphic sequence herein discussed includes the rock unit immediately below the Jagger coal (the "Jagger bedrock"), the Jagger coal, the Jagger to Blue Creek coal interval, the Blue Creek coal, and the Blue Creek to Mary Lee coal interval (Gastaldo and others, this guidebook, fig. VI-2). This sequence, and the interval above the Mary Lee (examined in detail in Liu, this guidebook) make up a genetic depositional sequence. The lithofacies and interpreted depositional environments of this interval will be described in and around the area of the field trip stops (Glen Allen, Carbon Hill, Howard, and Townley Quadrangles).

"JAGGER BEDROCK"

The Jagger coal is the stratigraphically lowest coal in the Mary Lee coal zone that is mined in the study area. Immediately below the Jagger coal is a hard, very fine- to medium-grained quartzose sandstone, informally called the "Jagger bedrock." This sandstone correlates with the Lick Creek Sandstone Member of Raymond and others (1988). Outcrops in the field trip area expose approximately the top 10 m of the sandstone. This part of the sandstone is characterized by spectacular large-scale trough cross-stratification, best seen adjacent to Mallard and Trinity Creeks (Stops 1 and 1A) along U.S. Highway 78 in Marion and Walker Counties. The cross-bed cosets of these large-scale trough sets make up long (>15 m), shallow, sloping, bounding surfaces of troughs of a larger scale. The bounding surfaces of individual cross-bed cosets are gently sloping and sometimes truncate the cross lamination of the set below. Cross-bed dip directions of the troughs are to the southeast and southwest (fig. VI-3).

Other primary depositional structures in the sandstone include small-scale trough and tabular cross beds, and ripple lamination (rippled surfaces in bedding plane exposures). The dip directions of small-scale cross beds are predominantly to the southeast and southwest. The strikes of ripples, as determined from rippled surfaces and ripple lamination, are oriented northeast-southwest (fig. VI-3).

Soft-sediment deformation has disrupted some of the bedding and cross bedding within

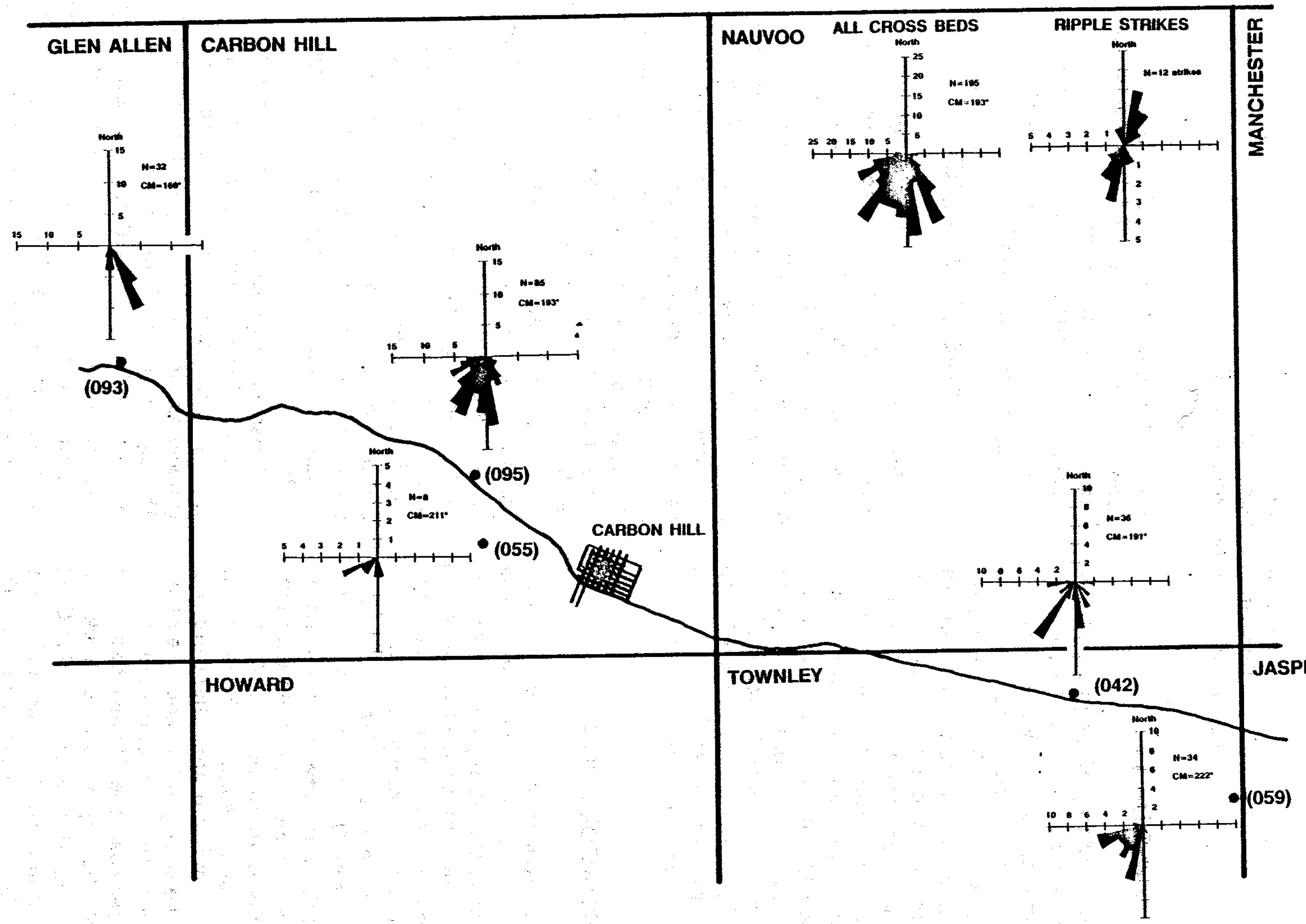

Figure VI-3.--Rose diagrams of paleocurrent directions as measured from cross-bed dip directions in the upper part of the "Jagger bedrock." Numbers in parentheses refer to field station numbers. Total cross bed direction and ripple strike orientations are presented in the upper right of the diagram. **N** is the numbers of observations at each station. **CM** refers to the vector mean of current directions.

the "Jagger bedrock." Slumping, slump folds, and overturned cross bedding are common. However, these structures seem to be concentrated along specific horizons or glide planes. These horizons can be traced laterally in outcrop for distances of several hundred meters. Both the slumps and the overturned cross bedding indicate movement towards the south-southeast.

Unfortunately, no one outcrop completely exposes the entire thickness of "Jagger bedrock." However, general changes in depositional style can be discerned from detailed examination of outcrops that expose the top part of the unit, and also from logs of drill cores which penetrate the entire thickness of the unit (generally 20 to 50 m where well developed). The bottom contact of the sandstone is erosional. A siderite-pebble conglomerate is reported at or near the base of sandstone in drill logs (Known Recoverable Coal Resource Areas drill logs or KRCRA #21, #22; Law and others, 1981) from the Glen Allen and Hubbertville Quadrangles. The Ream coal occurs immediately beneath the "Jagger bedrock" in some drill logs (KRCRA #15, #17, #20; Law and others, 1981), but a variable thickness (0.03 to 9.0 m) of dark-gray to black shale with a fragmental marine fauna separates the two units in others (KRCRA #16, #21, #22; Law and others, 1981). The variable thickness between Ream coal and "Jagger bedrock" is due to erosional truncation by the sandstone.

A vertical trend from thick bedding with long, shallow, sloping, trough-shaped cross-bed sets of large-scale troughs to thin bedding with small-scale trough and tabular cross beds can be seen in outcrops in the Glen Allen (Stop 1) and Carbon Hill (Stop 1A and Day 1 mileage 26.3) Quadrangles. However, these outcrops only expose approximately the top 10 meters of the unit.

The shape and external geometry of the sandstone body(s) is not directly known or observable. Outcrops are limited in the study area, and only the top of the sandstone is exposed during surface mining. However, general trends in the paleotopography (at several scales; table VI-1) of the top of the unit can be determined from structure contour maps, isopach maps of the Jagger coal to Blue Creek coal interval, and observations of available exposures.

The thickness of the Jagger coal and the interval from the Jagger coal to the Blue Creek coal is sensitive to the paleotopography on top of the "Jagger bedrock." The Jagger coal, and the interval between the Jagger and Blue Creek coals, thicken in paleotopographic lows and thin over highs on top of the sandstone body. A structure contour map of the top of the unit (or, conversely, the bottom of the Jagger coal; fig. VI-4), an isopach of the Jagger coal (fig. VI-5), and an isopach of the Jagger-Blue Creek interval (fig. VI-6) show two large-scale features. These are "ridges" separated by "valleys," oriented northeast-southwest.

Medium-scale paleotopographic features can be seen in surface mine exposures of the top of the unit (the floors of pits in the Jagger coal)

Table VI-1.--Hierarchy of depositional features in the "Jagger bedrock"

Depositional feature	Observable scale	Example of time scale of process (YRS) (Miall, 1989)
Cross laminations Cross beds Ripple bedforms	Small scale (outcrop)	10^{-5} - 10^{-4}
Cross beds sets Diurnal and neap-spring tidal bundles Dune/megadune bedforms	Medium scale (outcrop and large scale maps)	10^{-4} - 10^{-1}
Sloping bounding surfaces Sand waves	Large scale (maps)	10^{-1} - 10^{0}
Sand wave fields Sand ridge		10^{2} - 10^{4}

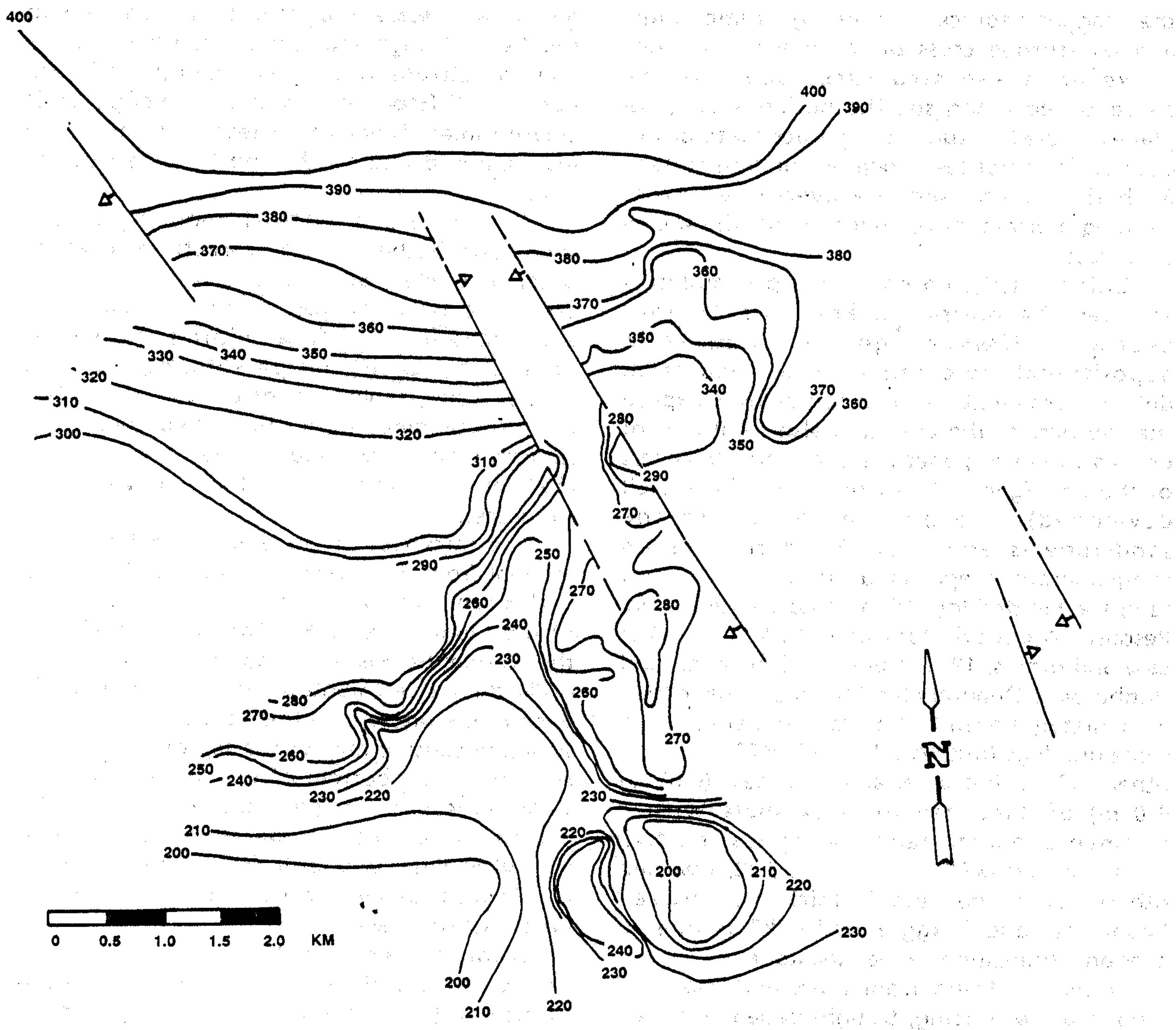

Figure VI-4.--Structure contour map of the top of the "Jagger bedrock" in the Townley Quadrangle. Data derived from Barnett (1986), and subsurface data from Drummond Company, Inc. Contour interval is 10 feet (3.048 m).

and at Stop 1A (a large bedding plane exposure in an old sandstone quarry). "Rolls" are ubiquitous in Jagger coal pit floors in the study area. These rolls probably represent megaforms, possibly sandwaves, at the top of the sandstone body. A structure contour map (fig. VI-7) of the bottom of the Jagger coal at the Gateway Malls Incorporated Hope-Galloway North mine (Stop 2) reveals one of these paleotopographic features. It is a curvilinear ridge approximately 1,500 m long, oriented roughly east-west. Other medium-scale features, in the form of megadune- to dune-sized rolls, can also be seen at this location. These are superimposed on the larger scale structures and are oriented northeast-southwest in the North Mine area. Flanks of these structures dip 7° to 10° to the north and south. The abandoned quarry at Stop 1A exposes a surface near the top of the sandstone unit. At this location, bedforms can be seen in plan view. One can walk over the exhumed paleotopography and see the relationships between large- and medium-scale features, bedforms, and current directions.

Fossils in the "Jagger bedrock" are rare. Fragmented lycophyte and calamite trunk

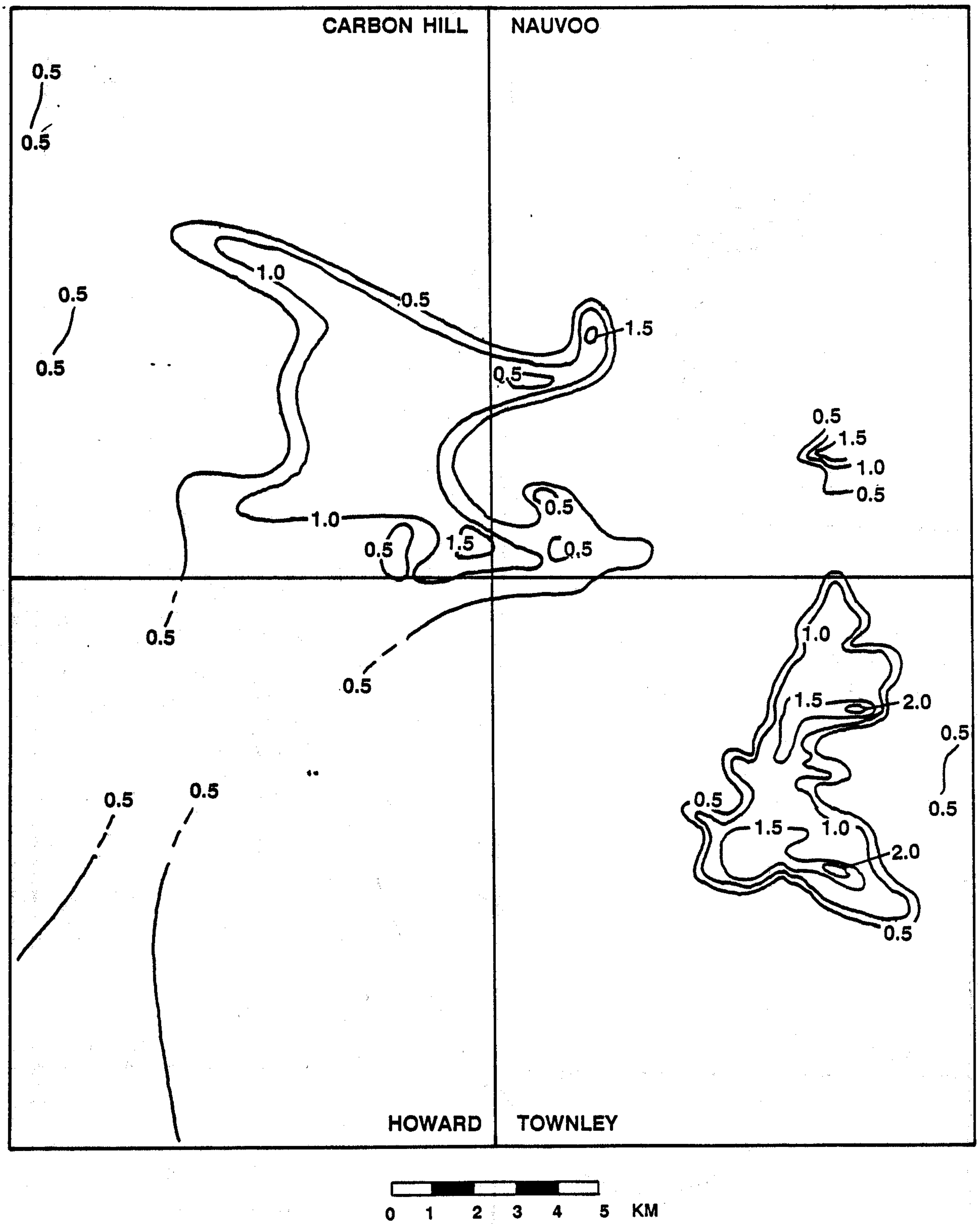

Figure VI-5.--Isopach of the Jagger coal. Data acquired from Ward (1986), Barnett (1986), open-file reports of the Geological Survey of Alabama, Gateway Malls, Inc., Drummond Company, Inc., open-permit files at Alabama Surface Mining Commission, and field data. Contour interval is 0.5 m.

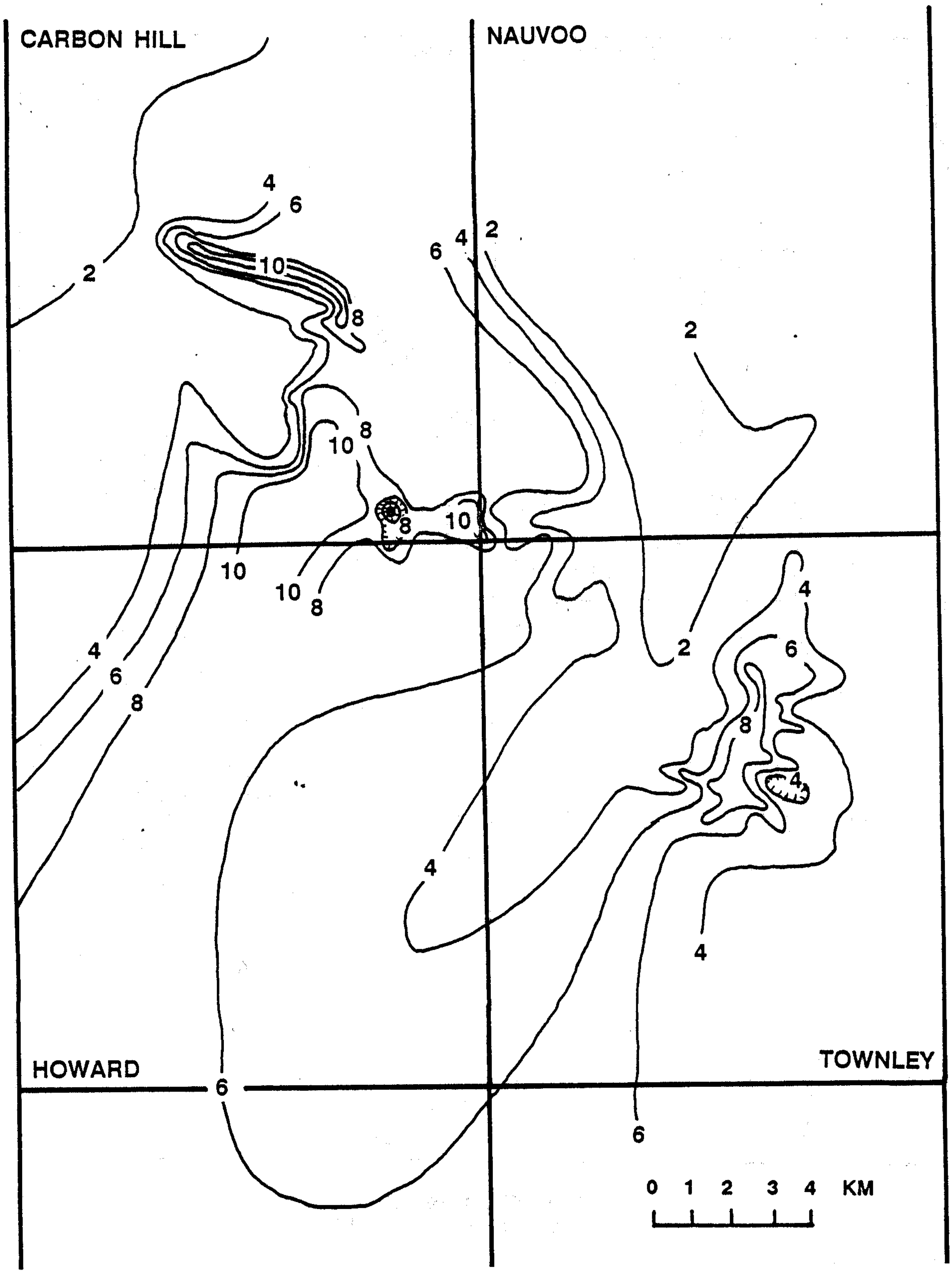

Figure VI-6.--Isopach of the Jagger to Blue Creek clastic interval. Data acquired from Ward (1986), Barnett (1986), open-file reports of the Geological Survey of Alabama, Gateway Malls, Inc., Drummond Company, Inc., open-permit files at Alabama Surface Mining Commission, and field data. Contour interval is 2 m.

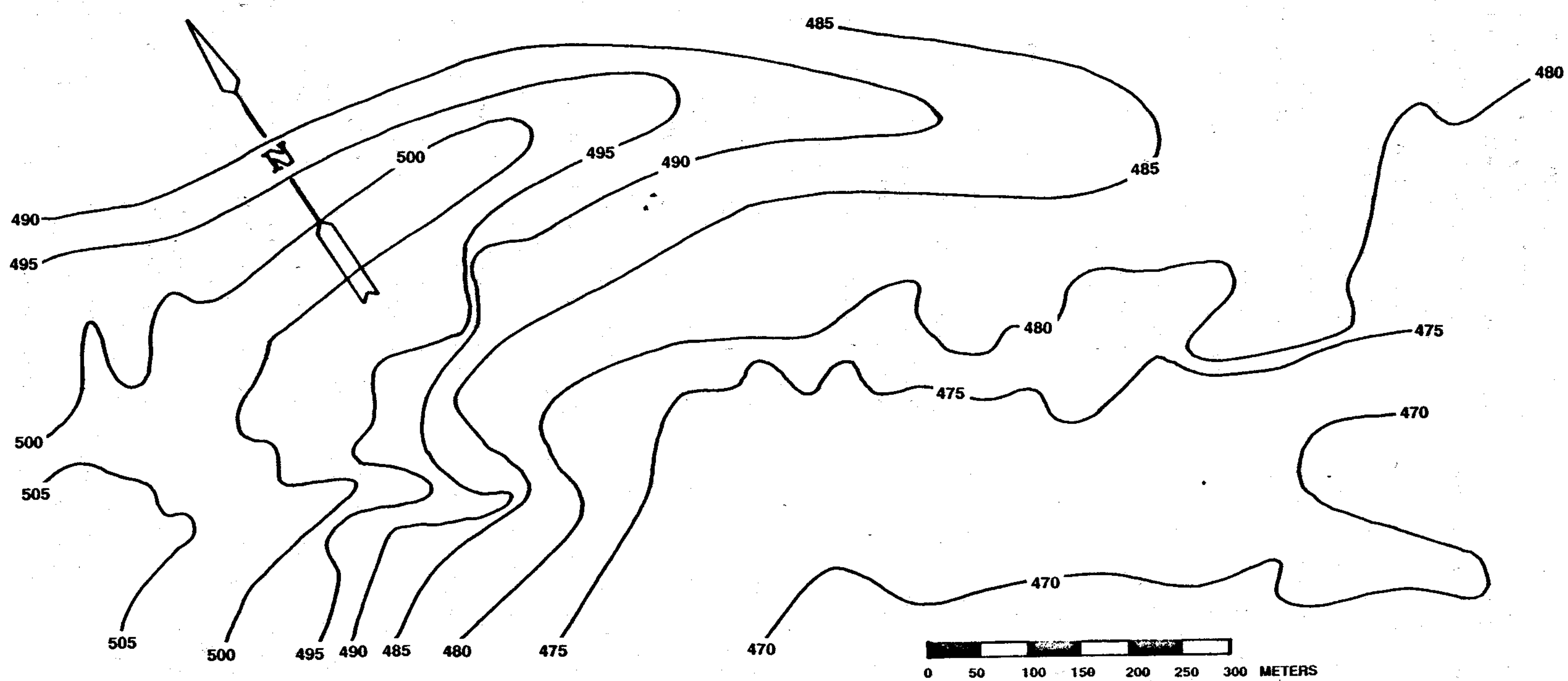

Figure VI-7.--Structure contour map of the top of the "Jagger bedrock" at the Hope Galloway North mine (Stop 2). Data acquired from Gateway Malls, Inc., and field data. Contour interval is 5 feet (1 m).

material, and unidentified, comminuted plant material can be found rarely along bedding planes. A few trace fossils (unidentified surface trails) and a possible eurypterid body fossil were found at the abandoned quarry at Stop 1A. The top 0.5 m of the sandstone is moderately root-worked and contains abundant stigmarian axes and rootlets.

The "Jagger bedrock" is interpreted to have been deposited as a series of sand ridges in a nearshore (estuarine?) environment. The large-scale trough cross beds in the thick-bedded sequence in the exposed, upper part of the unit are interpreted to be the result of shoreward (southeast to southwest) migration of low, curve-crested sandwaves driven by flood-dominated tidal currents. Bounding surfaces between cross-bed sets are interpreted to enclose tidal bundles, possibly reflecting neap-spring tide cyclicity. Internal down dipping of cross-bed cosets in the same direction of cross-bed dip direction implies that these sandwaves formed by migration over previously developed megaforms. This thick-bedded part of the sandstone is interpreted to have been deposited in completely subaqueous (subtidal) conditions. The soft-sediment deformation structures (especially overturned cross bedding) are indicative of this type of setting and might be the result of liquefaction during a large storm or seismic event (Doe and Dott, 1980).

The unit shoals upward. The uppermost part of the unit, characterized by thin bedding, large-scale trough cross beds, small-scale trough and tabular cross beds, ripple lamination, and rippled surfaces is interpreted to have been deposited in a subtidal to intertidal setting. The cross beds are again believed to be the result of shoreward (southeast to southwest) migration of bedforms. In this case, curve- and straight-crested sandwaves and megaripples are believed to have been formed by flood-dominated tidal currents. The ripple lamination and rippled surfaces are the result of ebb-current modification of the previous flood-current bedforms. These are similar to those reported by Haas and Gastaldo (1987) in the Bremen Sandstone Member, lower in the "Pottsville" Formation. At the abandoned quarry at Stop 1, one can actually see how the ebb current flowed around the sandwaves and megaripples, reworking and smoothing the top 1 to 2 mm of sand and superimposing current ripples on the lee slopes of the sandwaves. The ebb current also formed shallow, current-rippled runnels in the lee of, and around, the flood-current bedforms.

Although the lowest part of the unit was not directly observed, the presence of a marine fossil horizon immediately beneath the sandstone, which may itself represent a ravinement surface similar to that above the Mary Lee coal zone (Liu and Gastaldo, 1989), and the possible eurypterid body fossil near the top of the unit, are circumstantial evidence of a marine to brackish depositional setting.

The small-scale elements (ripples, troughs) are parts of the medium-scale features (megadunes and sandwaves), which, in turn, make up the individual, large-scale ridges of figure VI-6. These shoreward-prograding ridges are believed to represent an estuarine system along the Early Pennsylvanian coastal system of the Warrior basin.

JAGGER COAL

Where exposed, the Jagger coal seam sits immediately on top of the "Jagger bedrock." Although the Jagger coal horizon is fairly persistent throughout the study area, the thickness of the coal is not. Thickness can range from 2.3 m to only a few centimeters over distances less than a kilometer. These lenticular coal bodies are thickest in swales of the underlying "Jagger bedrock" and thinnest over ridges (fig. VI-5). An underclay is often reported in drill logs in holes where the Jagger seam is thinnest over these ridges.

A persistent, carbonaceous shale parting (0.1 to 0.2 m) splits the Jagger seam into a thick lower bench (0.5 to 1.3 m) and thinner upper bench (0.2 to 0.3 m) in thick coal areas. This parting contains abundant lycophyte leaf material, erect and prostrate lycophyte trunks, and stigmarian axes and "rootlets." Where the Jagger thins, its seems to be at the expense of the lower bench and this parting (Barnett, 1986). The Jagger coal is low sulfur (0.9 to 1.0 percent) and moderate in ash content (10 to 15 percent, excluding the parting) (Barnett, 1986).

A thin (0.03 to 0.27 m) coal seam is present locally below the Jagger coal but above the "Jagger bedrock" in a small area around Gateway Malls Incorporated North (Stop 2) and South mines (secs. 23 and 13, T. 13 S., R. 10 W.). The interval reported in drill holes between this coal and the Jagger coal is 1.5 to 5.0 m. The lithology of this interval is reported as shale where the interval is thickest, and siltstone or sandy shale where thinnest. However, this seam is infrequently mined in conjunction with the Jagger seam and has not been examined in outcrop. It is presumed to be a lower split of the Jagger, present only in the lowest paleotopographic lows between the "Jagger bedrock" ridges.

The depositional environment of the Jagger coal is interpreted to have been a complex of autochthonous peat bodies deposited in coastal swamps. The superposition of a low-sulfur coal immediately over an offshore sandstone body implies not only regression, but also a hiatus in deposition between the last sandstone and accumulation of the first peat. Stigmarian axes and appendages have been observed penetrating the underlying sandstone, probably originating in the Jagger coal. The sandstone must have still been fairly soft to allow "rooting" of lycophytes. Although the entire surface of the sandstone may have been colonized by pioneering plants soon after subaerial exposure, initial peat accumulation began only in the lowest paleotopographic lows (the local coal below the Jagger and above the "Jagger bedrock" in the Carbon Hill Quadrangle). This early peat accumulation phase was interrupted by clastic deposition, possibly tidal mud flat or alluvial swamp sedimentation similar to that above the Jagger coal. Peat deposition then resumed, this time uninterrupted for a longer interval, resulting in the geographically more extensive accumulation of the thick lower bench of the Jagger. Again, peat accumulation occurred only in the paleotopographic lows between "Jagger bedrock" ridges. These thick peat accumulations were localized in the Carbon Hill and Townley Quadrangles. This longer period of peat accumulation was interrupted by clastic deposition, represented by the carbonaceous claystone parting in the thick-coal areas. This episode of clastic deposition was short lived and possibly catastrophic—perhaps a large flood or storm event. The claystone was recolonized by lycophytes and the final phase of peat accumulation began, covering the entire study area. This phase is represented by the upper bench of the Jagger in the thick coal areas located in the paleo-lows and the thin Jagger coal present over the paleo-highs. The underclay reported in drill holes below the thin Jagger (over paleo-highs) could represent kaolinization of the underlying sandstone by tropical weathering and leaching during the time of exposure (Gardner and others, 1988). This weathering would have been contemporaneous with the deposition of the lowest two benches of the Jagger (the local coal and the thick lower bench), and their associated clastic intervals.

JAGGER COAL TO BLUE CREEK COAL INTERVAL

This interval was only described in the areas where the Jagger coal was being mined. For that reason, the following description is biased toward the thickest (both of the Jagger coal and Jagger to Blue Creek interval) areas. In areas where the Jagger was too thin to mine, the interval was logged by drillers as sandy shale or siltstone. These thin coal areas are invariably over paleotopographic highs in the "Jagger bedrock." The interval is usually less than 3 m thick in these drill holes.

A layer of fossiliferous mudstone (0.5 to 0.75 m thick) immediately overlies the Jagger coal. Above this mudstone is a sequence of laminated siltstone and shale containing very fine-grained sandstone laminations and interbeds. This, in turn, is overlain by very fine- to fine-grained laminated sandstone. The entire interval ranges from 2 to 13 m in thickness (fig. VI-6) and generally coarsens upward.

Primary sedimentary structures in the laminated siltstone and sandstone include: (1) starved or incipient ripples; (2) drainage runnels and scoured surfaces with shale-chip conglomerates; (3) wave ripples with mud drapes; (4) raindrop imprints and desiccation cracks; and (5) tool marks. Soft-sediment deformation features (low-angle slumping and flowage structures) are also present. Current directions measured from cross bedding were to the south while those from current lineations, tool marks, and slumps were to the northwest.

Bedding within the laminated siltstone/sandstone facies is cyclic. Coarser, sandy sets of laminations/interbeds (3 to 5 cm thick) are separated by finer units (2 to 3 cm thick). The sandstone bodies that top the interval are typically thin (1 to 3 m), broad (tens to hundreds of meters) channel forms. These channels show evidence of scouring and have a basal lag of imbricated, sideritic shale-chip pebbles and coalified logs.

Fossils in the interval are limited to plant debris including coalified compressions and casts of allochthonous lycophyte, calamite and seed fern leaf, stem, and trunk material. Autochthonous, cast lycophyte and calamite trunks are rooted at or near the top of the underlying Jagger coal. The top of the sandstone in the upper portion of the interval is moderately rootworked and preserves abundant *Stigmaria* axes and "rootlets" (appendages).

Trace fossils from the Jagger to Blue Creek coal interval are abundant, diverse, and exceptionally well preserved. Traces include burrows (*Palaeophycus, Treptichnus, Rosselia, Lingulichnus*), surface trails (*Haplotichnus, Kouphichnium,* arthropod and vertebrate trackways), resting traces of arthropods and bivalves, network burrows, and grazing traces (see Rindsberg, this guidebook; Rindsberg and others, 1989).

The depositional environments of this interval are interpreted to have been clastic swamps, tidally influenced mud flats, and associated tidal creeks or channels. The fossiliferous mudstone above the Jagger coal contains abundant lycophyte leaf and trunk material in addition to erect, *in situ* lycophyte and calamite trunks, and *Stigmaria* axes and rootlets. These autochthonous plant fossil horizons are indicative of clastic swamp forest-floor litter horizons (Gastaldo and others, 1989).

Bedding within the laminated siltstone/sandstone facies exhibits pronounced cyclicity. Coarser, sandy sets of laminations or interbeds (3 to 5 cm thick) are separated by finer units (2 to 3 cm thick). These alternating beds and laminations may record cyclic tidal deposition on a mud or mixed mud and sand flat (Demko and Gastaldo, 1989a). The presence of erect lycophyte trunks, albeit very rare, indicate that these tide-influenced flats were sparsely vegetated.

The preservation of tidal sequences in coal-bearing strata may be the result of the early compaction of buried coastal peat bodies. Early compaction of the underlying Jagger peat body enhanced the preservation potential of the strata recording tidal cyclicity. This compaction allowed quick, localized subsidence and accommodation of tide-influenced sedimentation. Cessation of this compaction allowed filling of these local depocenters, and a return to forested, terrestrial conditions (represented by the Blue Creek paleosol), and the resumption of peat accumulation (represented by the Blue Creek coal).

BLUE CREEK COAL

The Blue Creek coal overlies a root-worked horizon in the sandy channel fills of the tide-influenced interval below. The Blue Creek is a persistent coal throughout the basin. It is thin, but consistent, over the entire study area, never varying much from 0.3 to 0.5 m (fig. VI-8). This coal is very low in sulfur (0.6 to 0.7 percent) and moderate in ash content (13 to 14 percent) (Barnett, 1986). Erect trunks (predominantly lycophytes) are cast in mudstone immediately above the coal (see Gastaldo, this guidebook).

The environment of deposition of the Blue Creek coal is interpreted to have been an autochthonous peat body deposited in a coastal swamp. The erect trees rooted in the top of the Blue Creek "peat" represent the last arborescent elements of the peat forest (Gastaldo and others, in press).

BLUE CREEK COAL TO MARY LEE COAL INTERVAL

The interval between the Blue Creek coal and the Mary Lee coal (4 to 6 m) (fig. VI-9) is typically mudstone, but rarely can be a coarsening upward sequence of mudstone, siltstone, and very fine-grained sandstone. The interval is characterized by multiple, stacked, fossil plant horizons (fig. VI-10). Fossil plants are autochthonous. There are three to five principle fossil plant horizons preserved between the Blue Creek and Mary Lee coals. The first is generally 1 to 2 m above the Blue Creek and the overlying horizons are generally 0.3 to 1.0 m apart. The sequence is capped by the Mary Lee coal. The depositional environments of the Blue Creek coal to Mary Lee coal interval are interpreted to have been a sequence of aggrading, alluvial swamps (Gastaldo and others, in press).

The cyclic alternation between peat-accumulating and clastic swamp environments, and the stacking of alluvial swamp horizons, is most striking in the Blue Creek coal to Mary Lee coal interval. The Blue Creek coal is interpreted to have been an autochthonous peat body formed in a near-coastal swamp environment. Although it has been proposed that many Carboniferous peat bodies were "domed" (Smith, 1962; McCabe, 1984, 1987; Cecil and

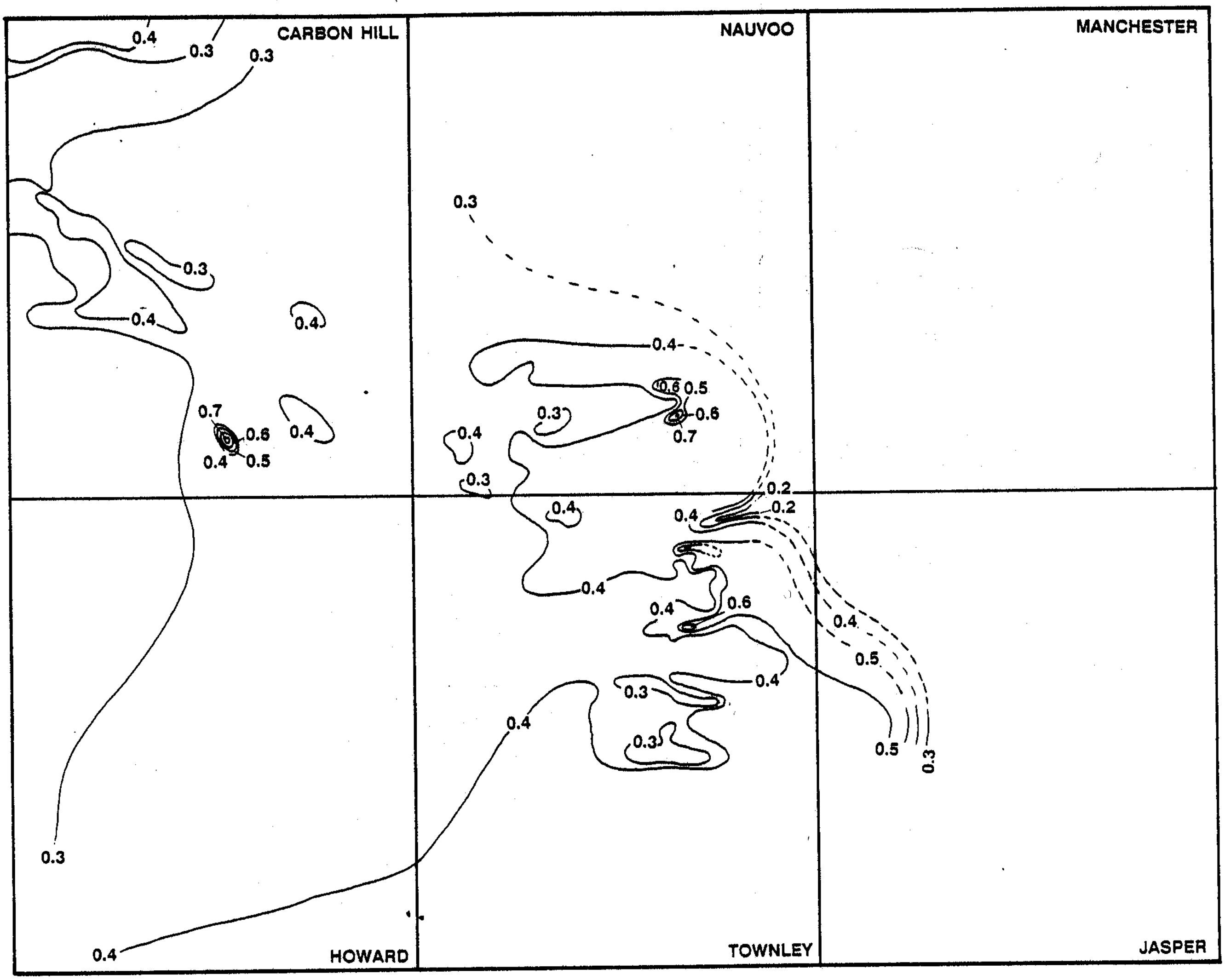

Figure VI-8.--Isopach of the Blue Creek coal. Data acquired from Ward (1986), Barnett (1986), open-file reports of the Geological Survey of Alabama, Gateway Malls, Inc., Drummond Company, Inc., open-permit files at Alabama Surface Mining Commission, and field data. Contour interval is 0.1 m.

others, 1985; Esterle and Ferm, 1986), the relatively thin, but consistent, thickness of the Blue Creek coal (averaging 35 cm) is evidence of a planar or slightly "domed" geomorphology.

The present thickness of the Blue Creek coal can be decompacted to reflect an original peat thickness. The coals in the Mary Lee coal zone consist predominantly of lycophyte trunks and rootlets (see Winston, this guidebook). Studies of plant parts in coal ball to coal transition in Carboniferous bituminous coals have shown that lycophyte trunks, composed principally of periderm (bark) tissues, have a compaction ratio that averages 13.5:1 (range 11.1:1 to 16:1; Winston, 1988). *Stigmaria* "rootlets" are composed of aerenchymatous tissues and compact more than periderm tissues. The average compaction ratio of these rootlets has been calculated to be 29:1 (range 21.1:1 to 40.1:1; Winston, 1988). Accurate decompaction of the coal necessitates the knowledge of the quantitative distribution of plant parts within the coal. These data presently are available for the Blue Creek coal outside of our study area (Richard Winston, written communication, July 1989). If we conservatively estimate the overall

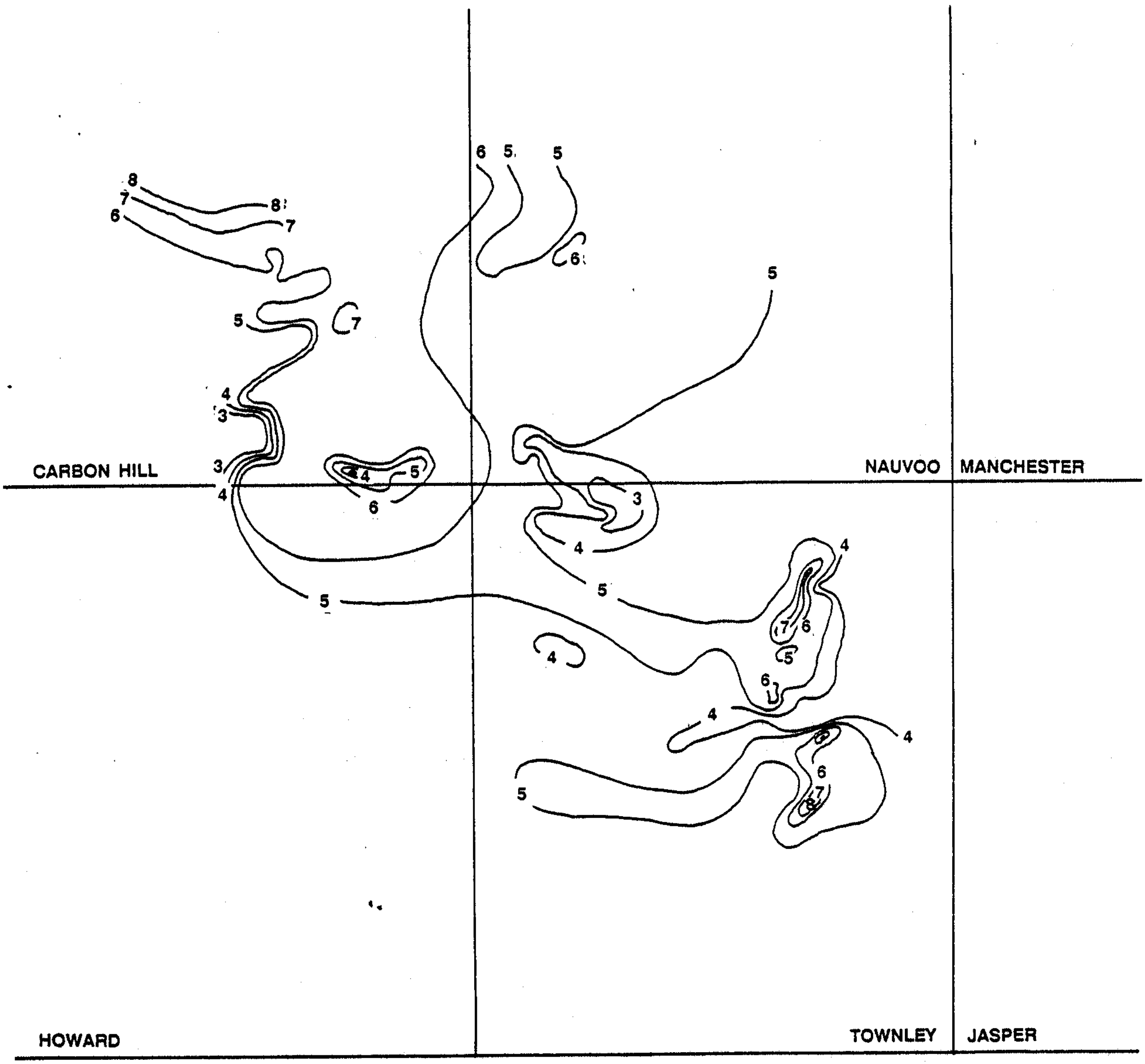

Figure VI-9.--Isopach of the Blue Creek to Mary Lee clastic interval. Data acquired from Ward (1986), Barnett (1986), open-file reports of the Geological Survey of Alabama, Gateway Malls, Inc., Drummond Company, Inc., open-permit files at Alabama Surface Mining Commission, and field data. Contour interval is 1 m.

compaction ratio of the Blue Creek "peat" to be 10:1, allowing for less compressible plant components (e.g., pteridosperms) and mineral matter, the original thickness of the peat would have ranged between 3 to 5 m.

The erect, *in situ* lycophyte trunks preserved immediately above the Blue Creek coal represent the last arborescent members of the peat swamp community. The trunks are preserved to heights of 2.5 m, surrounded and cast with gray mudstone. The first 0.1 to 0.5 m of mudstone above the coal preserves a concentrated accumulation of aerial canopy detritus, predominantly a lycophyte-pteridosperm mixture (see Gastaldo, this guidebook). These accumulations of autochthonous plant material mark the penultimate forest floor litter, a phase of senescence, and ultimate death of the peat swamp vegetation due to partial burial by terrigenous clastics. This initial incursion of clastic material into the peat swamps (largely

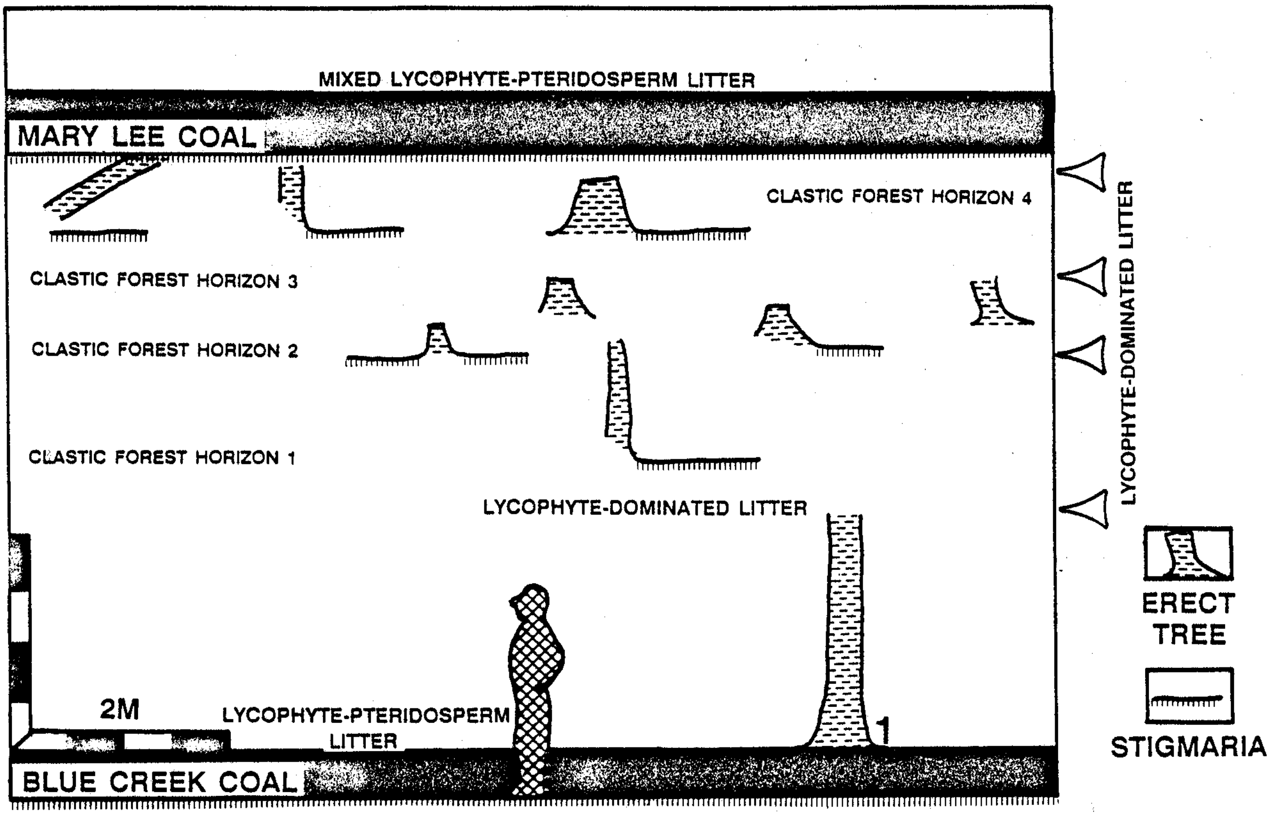

Figure VI-10.--Detailed highwall section of the Blue Creek coal to Mary Lee coal interval showing erect lycophyte trunks above the Blue Creek coal and at four clastic forest horizons. Illustration from photograph taken at Drummond Company, Inc. 2570 Pit, (sec. 12, T. 14 S., R. 9 W., Townley 7.5-Minute Quadrangle). Scale marked in 0.5 m intervals.

isolated from clastic deposition during peat accumulation) was probably due to a high magnitude, low frequency flood. This event not only buried and preserved the existing forest-floor litter (canopy parts and prostrate logs), but also put the standing vegetation under fatal clastic stress. The plant debris preserved immediately above the peat swamp forest floor is the product of abscission of aerial parts and decay of lycophyte trunks after death (see Gastaldo, this guidebook).

The catastrophic flood event was not the terminal phase of forest vegetation in the area. A few members of the peat swamp community appear to have been able to withstand the influx of sediment. *Calamites* not completely buried by the flood adapted to the stresses of burial. These plants developed adventitious rooting structures from the nodes of buried stems, and continued their growth (see Gastaldo, this guidebook). After the stabilization of the new sediment surface, the calamites were soon joined by other taxa adapted to life in clastic swamps (mineral soils). These plants included pteridosperms and clastic-tolerant lycophytes. In the Blue Creek coal to Mary Lee coal interval, criteria used to recognize these alluvial swamp horizons have been established by Demko and Gastaldo (1989b). These include: (1) erect, *in situ* lycophyte and calamite trunks; (2) pteridosperm- and lycophyte-dominated litter accumulations associated with the erect vegetation; (3) mud-cast prostrate logs; (4) paleosols with stigmarian root axes and other rooting structures; and (5) rhizoconcretions. It is important to note that these horizons represent well-developed, forested, clastic swamp communities (sensu Gastaldo, 1986) with accompanying forest-floor litters. They do not represent scattered, isolated trees, but may represent a single climax forest (Gastaldo and others, in press). They probably do not represent several forests on a single soil; root-working of the paleosols is moderate, and primary sedimentary structures remain discernible.

Even though arborescent vegetation flourished in these alluvial swamps, peat did not accumulate. Early and continued compaction of the buried peat body created an unstable platform. As the buried peat compacted, additional accommodation space developed, and a local depocenter was created. As a result, the alluvial swamps were susceptible to additional clastic influx. Subsequent catastrophic floods dumped more sediment into these depocenters, burying the swamp vegetation established in the mineral soil (see Gastaldo, this guidebook). This process of punctuated loading, continued compaction and subsidence, and the reestablishment of swamp vegetation resulted in a sequence of stacked, aggrading alluvial swamps (fig. VI-10). The time represented by each alluvial swamp horizon is problematic. The longevity of Carboniferous vegetation and the time required to establish swamp communities is not known. However, many of these plants probably did not expend much energy in production of hard tissue and most likely were not developmentally long-lived (DiMichele and others, 1986). Also, the presence of buried erect vegetation up to 3 m in height is evidence of quick, possibly catastrophic, and certainly geologically instantaneous, deposition by the burying mud. Examination of the infill structures of mud-cast, prostrate, hollowed logs present in fossil litter horizons can provide some idea of their residence time on the forest floor (Gastaldo and others, 1989). Partial infill can take hundreds of years, complete infill longer. Catastrophic burial of partially infilled logs resulted in casts, oval in cross section (previously interpreted as a compactional feature). Completely infilled logs remained circular. Both oval and circular cast aerial trunks and branches are found in the Blue Creek to Mary Lee interval. Circular cast logs are common. It is, therefore, probable that the paleosols and forest-floor litter horizons in the Blue Creek coal to Mary Lee coal interval represent more time than the deposition of the clastic material. The number of alluvial swamp horizons present is a function of the frequency of catastrophic floods and the accommodation space created by short-term compaction of the buried peat bodies. These factors are superimposed on a background of longer-term tectonic subsidence and eustatic base level change.

The sequence of stacked alluvial swamps is capped by the Mary Lee coal. The Mary Lee coal marks the resumption of peat accumulation. At this point, the compaction of the buried peat body had slowed considerably or stopped. A stable platform was created providing conditions amenable for peat accumulation. This was probably a transformation of the last alluvial swamp above the Blue Creek into a peat swamp. It is common to see erect lycophytes and calamites, representing the last alluvial swamp horizon, terminate in the bottom of the Mary Lee coal.

SUMMARY AND CONCLUSIONS

The vertical series of depositional environments in the lower part of the Mary Lee coal zone comprise an overall regressive sequence. The lowest unit described, the "Jagger bedrock," represents deposition in a nearshore/offshore zone, possibly an estuary. This environment was dominated by flood-tidal currents, and was notably deficient in muds and silts. Trough cross stratification, reactivation surfaces, ripples, and runnels may record neap-spring tidal cyclicity.

The Jagger coal seam is immediately above this sand body. The distribution of thick peat areas in the Jagger peat swamp complex was dependent on the paleotopography on top of the sand body—thickest in the paleo-lows and thinnest over the paleo-highs. The superposition of a terrestrial peat swamp body over an offshore sand body implies a regression and a hiatus in deposition between the two units.

The interval between the Jagger and Blue Creek coals contains tidally influenced mudflat and channel deposits. Pronounced cyclic bedding within the interlaminated shales, mudstones, siltstones, and sandstones may record the tidal cycles of the Westphalian epeiric sea (Demko and Gastaldo, 1989a). This type of preservation of tidal cyclicity may be common in coal-bearing sequences dominated by coastal deposition (Kvale and Archer, 1989; Breyer, 1987). The preservation of tidal cycles (possibly daily) was the result of quick accommodation caused by early compaction of the buried Jagger peat body. The tidal flat sequence was succeeded by peat clastic swamp deposition and eventually peat deposition in the Blue Creek peat swamp.

The Blue Creek coal to Mary Lee coal interval, in most cases a fossiliferous gray mudstone, contains a series of stacked alluvial swamp horizons. These horizons represent clastic swamp deposition in subsiding depocenters. This subsidence was also the result of early compaction, this time of the buried Blue Creek peat body. These horizons contain autochthonous plant fossils and have the pedogenic features of gleyed paleosols. The last clastic-dominated swamp in the series eventually may have been the progenitor-swamp of the Mary Lee peat swamp. This swamp and the fascinating sequence above is discussed elsewhere in this guidebook (see Liu, this guidebook).

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DEPOSITIONAL ENVIRONMENTS OF THE UPPER MARY LEE COAL ZONE, LOWER PENNSYLVANIAN "POTTSVILLE" FORMATION, NORTHWESTERN ALABAMA

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ABSTRACT

The upper Mary Lee coal zone of the Lower Pennsylvanian "Pottsville" Formation, northwestern Alabama, records a depositional history of transition from coastal terrestrial to nearshore and offshore environments. The coastal paleoenvironments were complicated by a westward progradation of a splay complex, resulting in two depositional areas. The western area is characterized by a vertical association of peat swamps, clastic swamps, and overbank lakes. The eastern area is represented by a sequence of peat swamps, a splay complex, peat and clastic swamps, and overbank lakes. The transgressive event recorded by a basal ravinement surface and marine fossil assemblages terminated the regressive deposition.

INTRODUCTION

Sedimentological studies of fine-grained overbank deposits have received much less attention than those of coarse-grained channel deposits (Bridge, 1984; Miall, 1987). Detailed investigations of modern floodplain environments are scattered and restricted to a few study sites (e.g., Farrell, 1987; Smith and others, 1989). Ancient overbank facies architecture comparable to modern analogs are even more limited (Bridge, 1984). Sedimentological characteristics of coal-bearing overbank facies may provide insights into the recognition of coal-forming conditions with regard to the raised mire or swamp concept (McCabe, 1984, 1987), but this aspect of studies has lagged behind event more. One of the major difficulties inherent in facies architecture studies of overbank deposits in coal-bearing strata is their poorly preserved, scattered exposure, resulting in an incomplete understanding of sedimentological control of peat swamp termination. Extensive surface mining in the study area has provided an excellent opportunity to carry out architectural studies of overbank facies in Pennsylvanian terrestrial deposits. The outcrops of the Mary Lee coal zone (Lyons and others, 1985) of the Lower Pennsylvanian "Pottsville" Formation laterally extend several hundreds or even thousands of meters, and are usually oriented in oblique or perpendicular directions to each other. This permits a three-dimensional view of the stratigraphic sequence and provides the exposure necessary to detail the architecture of the coal-bearing facies.

This report attempts to depict a sedimentological outline for the upper Mary Lee coal zone exposed in the study area. The interval under consideration begins from the paleosol beneath the Mary Lee coal, includes Newcastle coal and overlying ravinement surface, and ends at the marine zone above.

STUDY AREA AND METHODS

The study area is located within Walker County, northwestern Alabama, and includes the Carbon Hill, Nauvoo, Townley, Jasper and Cordova Quadrangles (USGS 7.5-minute) covering approximately 800 km^2 (fig. VI-11). Outcrops extending a linear distance of more than 65 km occur as surface mine highwalls, roadcuts, and natural exposures forming a broad east-west band of outcrops. The detailed field mapping was conducted with careful description of vertical sequences and lateral changes of facies relationships. A total of 58 sections was measured and relevant subsurface data were collected from various coal companies and the Geological Survey of Alabama. Interpretations of paleoenvironments of the upper Mary Lee coal zone have been made after the synthesis of the field and subsurface data.

Sedimentological characteristics identified in this study indicate two distinct attributes to the

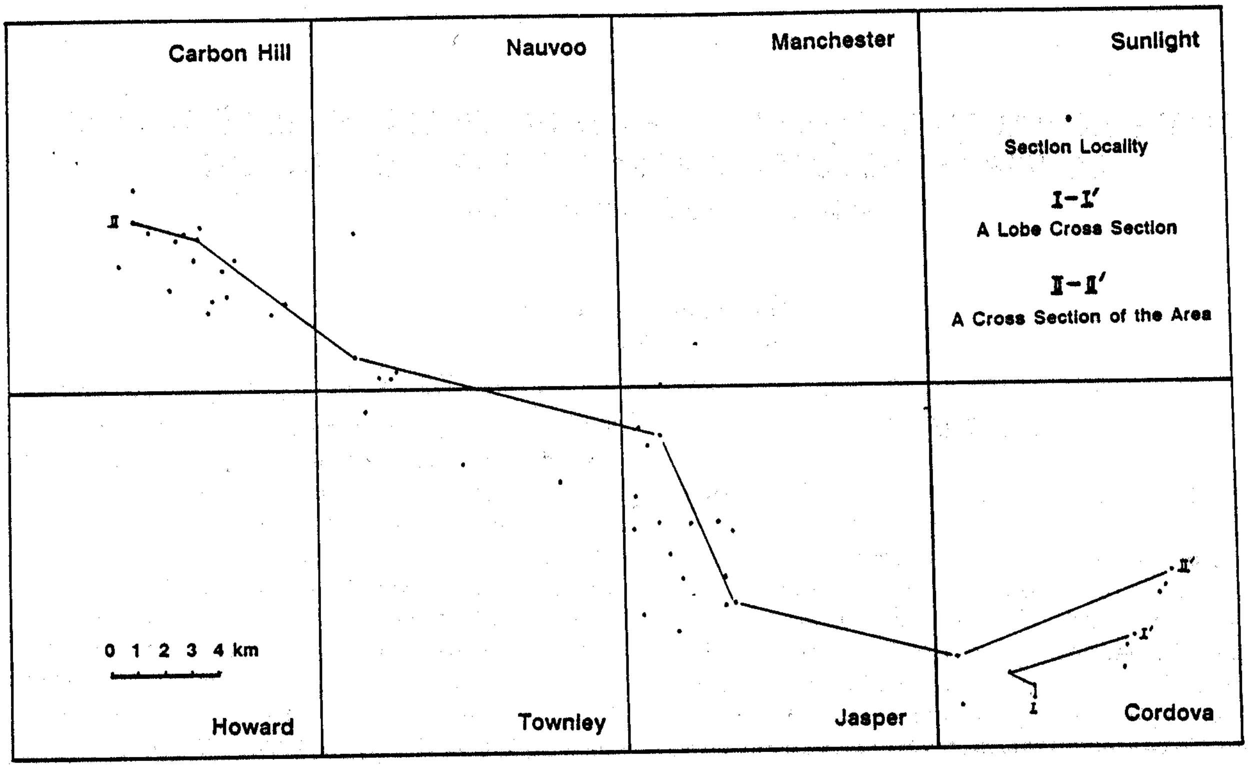

Figure VI-11.--Location map of the study area showing the localities of the measured sections and cross sections within 7.5-minute quadrangles.

deposits: temporal accumulation of the upper Mary Lee coal zone represents a depositional history of transition from nonmarine to marine deposits; the spatial distribution of the nonmarine deposits is related to two different depositional areas. The Carbon Hill Quadrangle differs from the rest of the area by the absence of both the Newcastle coal and significant flood deposits. The following description, therefore, reflects these natural differences. For convenience, the Carbon Hill Quadrangle and the remainder of the study area are distinguished as the western and eastern area in this report, respectively. A synthetic sedimentological outline will be made after correlation is made between the two areas.

SEDIMENTOLOGY OF TERRESTRIAL FACIES

FLUVIAL CHANNELS

There are two channel systems found in the study area. The first is a sandstone split interbedded between the upper and lower benches of the Mary Lee coal, and occupies an area whose northwest to southeast width was about 2 km in the Carbon Hill Quadrangle (fig. VI-12). The distribution of this channel belt may have been controlled by the sandstone body geometries of the underlying "Jagger bedrock" (see Demko, this guidebook). The second is a localized channel above the Mary Lee coal, and truncated by the overlying ravinement surface. These two channel systems can be seen in outcrops at Stop 2.

The sandstone split consists of medium-grained sandstone with minor amounts of mudstone. Its thickness ranges from 0.4 to 2.8 m. The most prominent feature of the channel is its multistoried internal sequences of cross stratification, and channel-form geometry. A typical internal sequence is illustrated in figure VI-13a. It consists of a basal erosional surface bounded by the underlying lower bench of the Mary Lee coal, and four depositional units of large- to small-scale trough cross stratification. Each unit is composed of vertically stacked

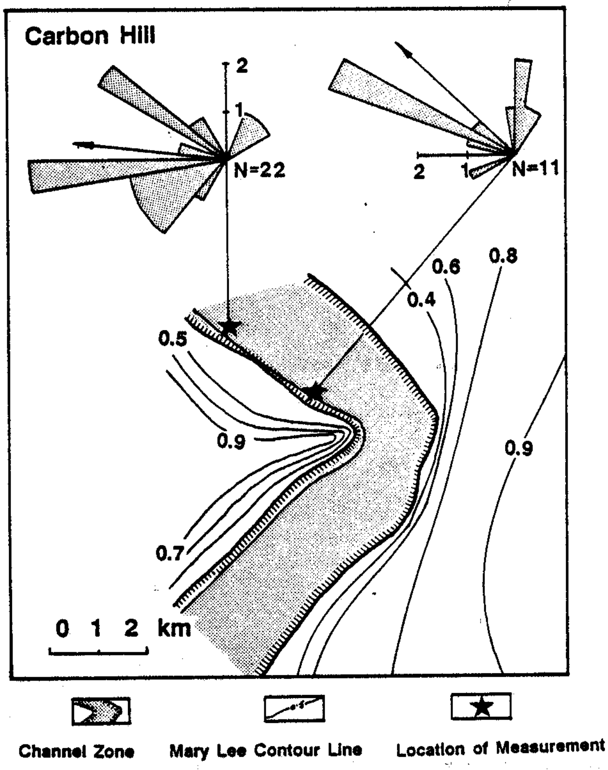

Figure VI-12.--Distribution map of the major channel zone in the western part of the study area (Carbon Hill area). The rose diagrams represent the measured current orientation. Contour interval is in meters.

trough stratification and bounded by a basal scour surface. The thickness of these units decreases vertically from about 0.5 to 0.2 m, which is accompanied by a slight decrease of grain size. Overlying these four units is a complete fining upwards unit consisting of a medium-grained sandstone bed, and a gravel-bearing layer which is, in turn, capped by the upper bench of the Mary Lee coal. The gravel-bearing layer is composed of alternating vitrain bands (coalified logs) and very fine- to fine-grained sand laminations. The gravel, ranging from pebble to boulder size, occurs either inside vitrinized logs or dispersed among them, and is believed to have been transported by floods from extrabasinal areas to the depositional site. This provides a reliable data set for the source area of the upper "Pottsville" Formation (Liu and Gastaldo, 1989).

The four depositional units were formed by the migration of lunate dunes in shallow water as indicated by thinness of the set thickness (Allen, 1982). The vertical gradual decrease in thickness of these units suggests that flow magnitude reduced with time. The fining upwards unit overlying the basal units represents a phase of channel abandonment. The vertical association of these five units is typical of a channel-fill element, reflecting progressive abandonment of the channel (Miall, 1985).

The channel cross section geometry is observable in highwall exposures. A typical channel cross-section is illustrated in figure VI-13b. It pinches out towards both ends and overlaps with adjacent channels. The width of the channel is approximately 380 m in the exposed direction, which is believed to be the minimum width in the study area. The overall channel zone is delimited by using field and drilling data (fig. VI-12). It is a 2-km-wide meandering channel zone in which the measured paleocurrent direction is estimated to have been northeastward then northwestward. In the northwest segment of the channel zone, the measured current orientation varies from 275° to 315°. When an average paleocurrent orientation in this segment is calculated to be 290°, the minimum width of a single channel in the direction perpendicular to the flow can be estimated. It is calculated that the minimum channel width is about 150 m. The maximum depth is about 3 m. This indicates that the overall channel-fill geometry is a broad channel-fill complex which may have been formed by lateral channel migration or switching related to lower rates of subsidence (Miall, 1985).

The sandstone channel, localized above the Mary Lee clastic swamp deposits and truncated by the overlying ravinement surface, is only found in one location at the Gateway Malls North Mine (Stop 2). This channel consists of fine-grained sandstone with small-scale cross stratification. The lenticular geometry is partially preserved due to the overlying transgressive erosion. The preserved maximum thickness is 1.5 m and the width is about 30 m. Overlying this fine-grained sandstone is a 0.5-m-thick layer of interbedded fine-grained sandstone and siltstone. The wedge-shaped geometry, dipping away from the channel sandstone, is observable in the outcrop. This layer is interpreted to represent a levee deposit overlying the fine-grained sandstone channel.

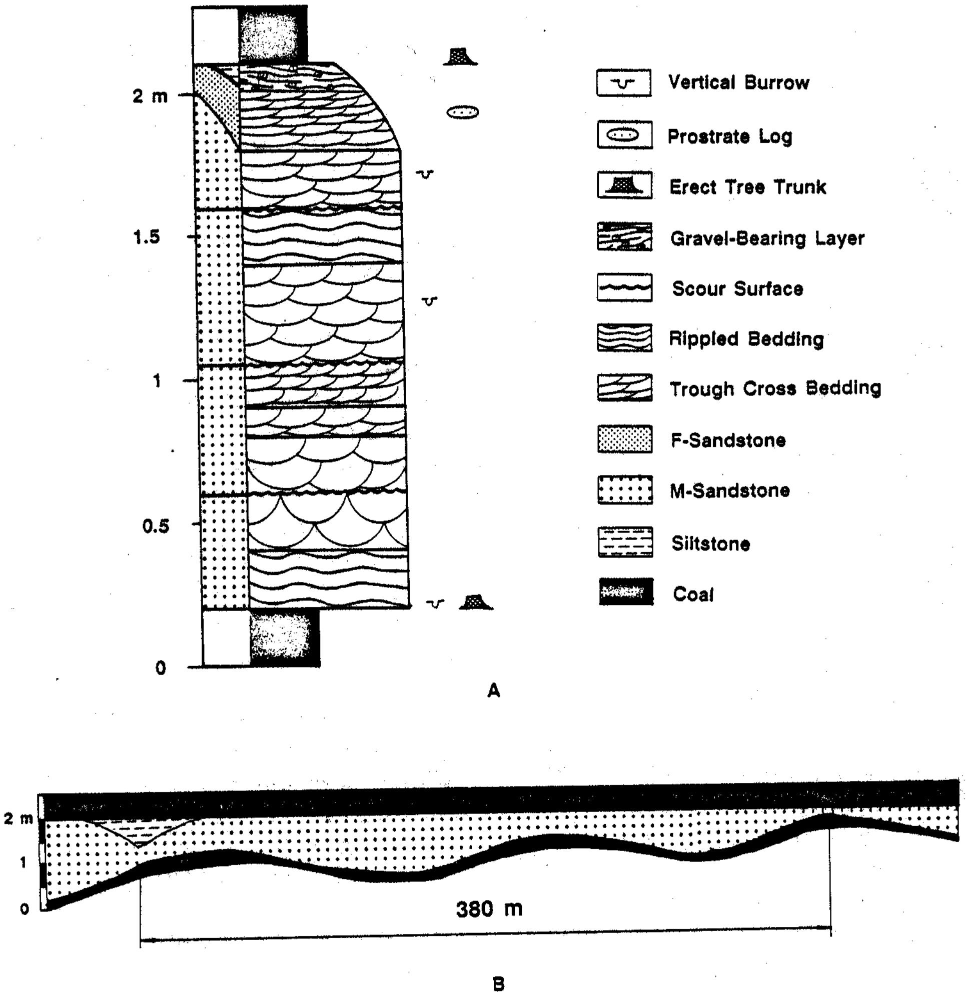

Figure VI-13.--Internal sequence and geometry of the major fluvial channel splitting the Mary Lee coal in the Carbon Hill area (Stop 2). Illustration from measured section and field illustrations in the Gateway Malls Hope Galloway mine. (a) A typical internal sequence of the channel. (b) A field illustration of a typical cross sectional view of the channel geometry.

CLASTIC SWAMPS

Clastic swamp deposits generally are found above the Mary Lee and Newcastle coal seams. The thickness varies from 1 to 5 m, showing a general trend of thickening eastward. In the western part of the study area it is usually less than or equal to 1 m thick, whereas in the eastern part it is variable but generally greater than 2 m.

These deposits are characterized by graded mudstone with multiple, autochthonous fossil plant horizons. A graded bed consists of a thin basal sandy or silty laminae gradational with an overlying mud layer. Each graded bed approaches a thickness of 1 to 2 cm. In thin section, a micro-scour surface can be seen to occur at the base of the sandy or silty laminae, and a great amount of mica is concentrated in the mud.

Erect tree trunks rooted in the underlying coal are usually encountered in the lower part of the deposit. These tree trunks were cast either by surrounding graded mudstone or by the overlying sandstone. The preserved heights of these trunks are up to 5 m with diameters ranging from 0.1 to 0.5 m. Accompanying these trunks are litter horizons and mud-cast logs in the first several centimeters above each coal seam.

Two or three horizons of *Stigmaria* axes or "rootlets" are vertically stacked in the upper portion of this deposit. This mudstone interval is in a gradual or sharp contact with the overlying sandstone units (Stops 3 and 7). A pronounced feature of this mudstone interval is its wedge-shaped geometry in highwall exposures (Stops 3 and 7). This is especially striking in the eastern study area. Wedges usually contact the underlying coal seam at angles of 5 to 10° (fig. VI-14a). The wedge dip orientation varies with locality. A rose diagram of pole trends for the measured wedge dip orientations shows a fan-shaped distribution with a circular mean orientation of 251° (fig. VI-14b). Although this does not represent a single fan-shaped geometry, it indicates the spatial distribution and major trend of the variable dip orientation.

It is apparent that these graded beds are formed by a two-stage sedimentary process: an early period of silt or sand deposition followed by a later period of mud deposition settling from suspension. The periodicity of this process can be related to floods developed in overbank environments (Hughes and Lewin, 1982). The wedge-shaped geometry indicates that these graded beds may have been deposited along the fronts of lobate flooding bodies, resulting in foreset beds (Harms et al., 1981). This interpretation is supported by the thickness isopach map constructed by considering the graded beds and the overlying sandstone bodies as a depositional system (fig. VI-17). The details of this system will be discussed below. The erect tree trunks and litter horizons preserved above the Mary Lee and Newcastle coal seams represent the last forestation of the peat swamp community. The death and subsequent preservation of this vegetation resulted from the quick accumulation of flood sediments. Re-establishment of the vegetation is evidenced by the *Stigmaria* "rooted" horizons in the upper portion of this interval and, hence, the colonization in a mineral soil (clastic swamp; Gastaldo, this guidebook).

Sedimentologically, clastic swamp deposits may be developed in three stages. An initial stage of high rates of deposition is characterized by wedge-shaped graded beds, and abundant, litter horizons and erect trunks. This may have resulted from a lobate flood accumulation in a low-lying area developed within the peat swamps in response to compaction of the underlying, highly porous peat and mud. A second stage of periodic but continued deposition is indicated by horizontally graded beds and few litter horizons. This may be the result of deposition on the foreset beds. Finally, a third stage of slow deposition is characterized by preserved paleosols in the upper part of the deposit, representing clastic swamp revegetation.

CREVASSE SPLAY COMPLEX

Traditional crevasse splays described by authors in modern deltaic and fluvial environments are small and simple lobate bodies formed by the initial breach of trunk channels (e.g., Coleman, 1969; Arndorfer, 1973; Elliott, 1974; O'Brien and Wells, 1986). These crevasse splays represent an early stage of splay evolution (Smith and others, 1989). Further development of these splay bodies may result in larger complexes consisting of a complicated lobate body network. The crevasse splay deposits in the entire eastern part of the study area may be one of the ancient examples of this type of crevasse splay complex.

SPLAY CHANNELS

Splay channel deposits consist mainly of medium-grained sandstone with a minor amount of mudstone. A typical internal sequence of cross stratification is illustrated in figure VI-15. It is characterized by six fining-upward units of deposition. Each unit is bounded by a broad basal scour surface with mud chips and large- to small-scale trough cross stratification. This is overlain by a thin, horizontally bedded shale or mudstone. The thickness of these units varies from 0.25 to 0.7 m. The number of units within the complex also varies with location. The measured current orientation ranges from 230° to 290°. Diagnostic features of the splay channel deposits are their thinness and indistinct channel geometry (Stops 3 and 5).

Each unit represents the deposition of the sandy bedform of a dune or sandwave in a shallow channel (Miall, 1985). This active channel may have undergone quick deposition (tens of years) and subsequent abandonment. Lateral quick changes of these stacked units indicate the mobility of shallow channel migration. These can be related to the periodical

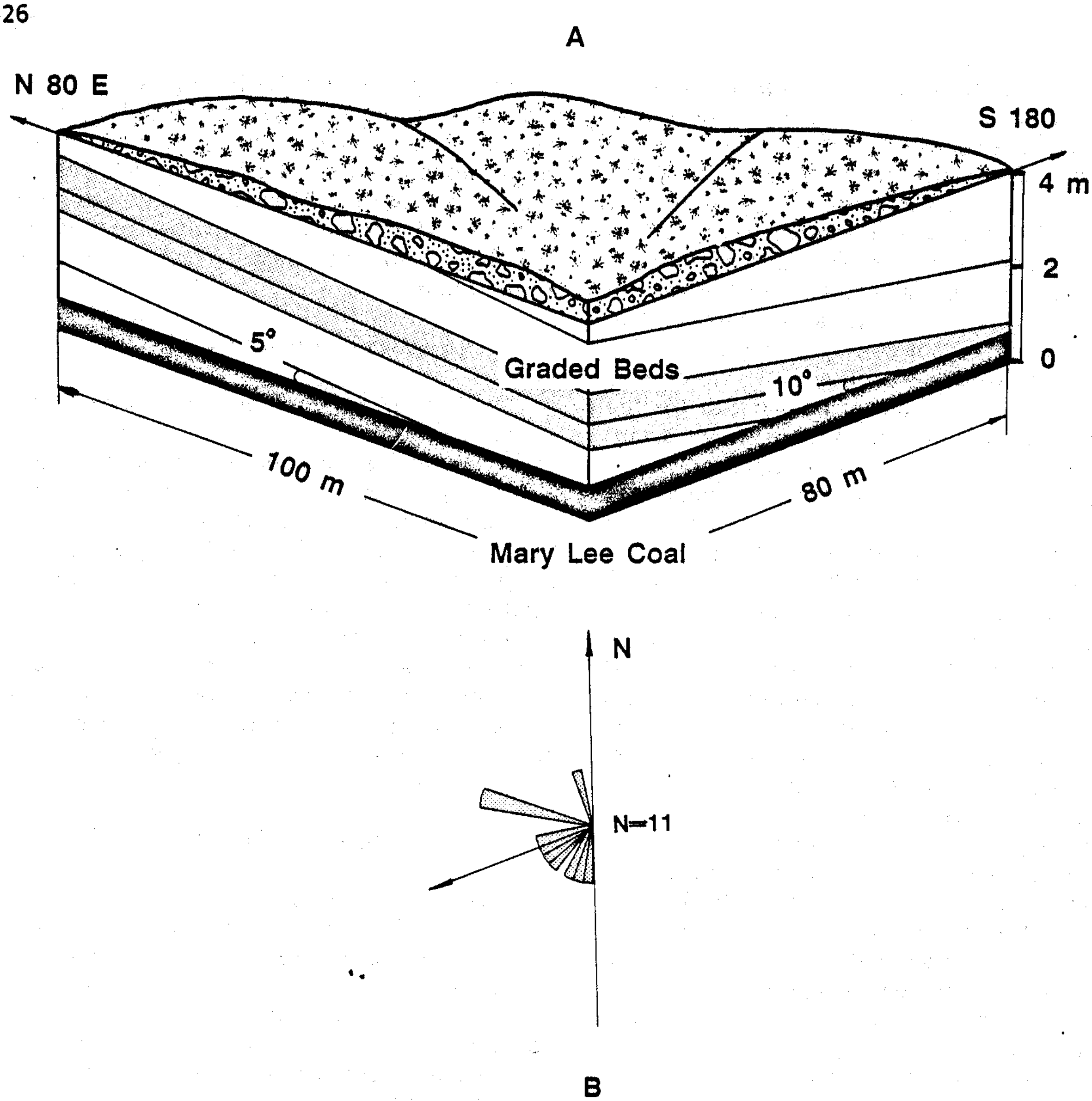

Figure VI-14.--A sketch of wedge-shaped mudstone deposits in the alluvial swamp sequence. Data from the Lost Creek mine (sec. 27, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle, Alabama). (a) Typical wedge-shaped geometry of the mudstone beds. (b) Rose diagram illustrating the fan-shaped orientation of these wedge-shaped deposits.

recharge of crevasse channels by floods in the overbank environments.

SPLAY SHEET SANDS

Splay sheet sands refer to the sandy deposits near active splay channels (Smith and others, 1989). They are the result of sediment deposition adjacent to the channels within the crevasse shield. These sheet deposits are characterized by a fine-grained sandstone with variable small-scale bedding structures. The thickness ranges from 0.5 to 2 m. Bedding structures include microcross and trough cross laminations, and ripple lamination. Trace fossils are preserved on bedding planes (see Rindsberg, this guidebook). Mud drapes are usually found on the bedding surfaces. Sheet sands usually rest on a flat scoured surface and may be traced laterally for more than 100 m. Laterally and/or vertically,

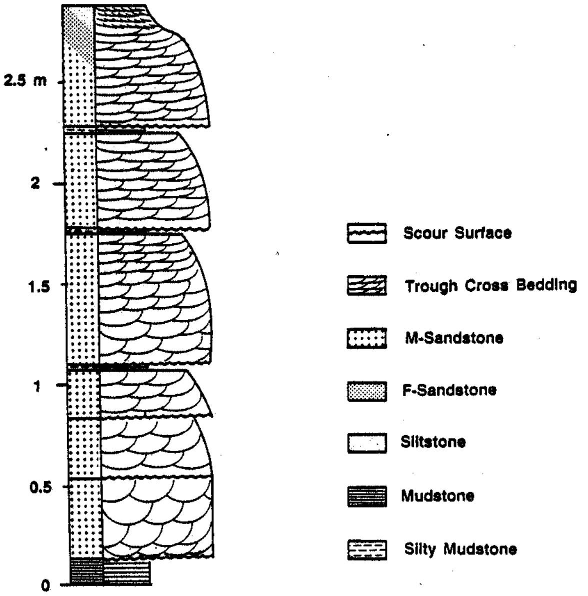

Figure VI-15.--An internal sequence of a splay channel deposit. Data from measured section in Drummond Company, Inc., Cedrum mine (Stop 3).

they are usually associated with the splay channels (Stop 5).

Sheet sand deposits were formed by the migration of ripples and dunes under a lower flow regime. The sheet geometry is indicative of deposition on unconfined surfaces. These characteristics indicate that they may have progressed toward lowland areas as a result of splay complex progradation.

SPLAY LOWLAND

A splay lowland refers to the area between splay channels. The area may include shallow lakes and other wetland settings receiving floodwater (Smith and others, 1989). The rocks of splay lowland deposits are characterized by interbedded fine-grained sandstone and mudstone. The fine-grained sandstone is generally 1 to 2 cm thick and exhibits various sedimentary structures. These include ripple laminations, microcross laminations, and lenticular bedding. The mudstone averages 3 mm in thickness and often is horizontally bedded. Individual splay lowland deposits vary from 0.5 to 2 m in thickness. A variation on this depositional scheme is an interbedding of siltstone and mudstone (Stop 5).

The alternation of sandstone and mudstone represents the deposition of sandy bedforms migrating under a lower flow regime. This was followed by vertical aggradation of mud from suspension. These facies are also indicative of a periodical influence of floods on the lowland area in the splay complex.

FACIES RELATIONSHIPS OF SPLAY COMPLEX

Facies relationships can be well defined by assessing their vertical associations and lateral changes. Vertically, splay facies may show a complicated association, but they generally follow a consistent pattern of splay lowland-sheet sands-channel-sheet sands/lowland deposits. This is reflected in a general coarsening upward then fining upward sequence. This vertical sequence represents splay progradation towards the lowland area and subsequent abandonment as a result of rising and waning flood stages (Bridge, 1984). Laterally, splay facies change sharply within 100 or 200 m. This change is well illustrated in a cross section constructed transversely across an individual splay lobe (fig. VI-16). The vertical sequences within this cross section differ from each other, but they show a general trend of associations. The sequence located in the center of the lobe is more complicated and thicker than those at the margin. This complexity is caused by several vertically stacked splay channels, resulting in a thicker splay deposit. These central thicker sequences can be used to delimit the major splay channel zones. The lateral sharp changes within these facies may represent the mobile features of splay deposition in response to attempts to reduce a regional gradient during splay progradation (Smith and others, 1989).

FACIES GEOMETRIES OF SPLAY COMPLEX

Facies geometries of this splay complex occurring in the entire eastern study area can be visualized using an isopach map of the interval between the Mary Lee and Newcastle coal (fig. VI-17). This map is constructed by using extensive field data and adequate subsurface information provided by the Geological Survey of Alabama and various coal companies. The clastic swamps overlying the Mary Lee coal are closely associated with these splay deposits and, thus, are treated sedimentologically as the product of the initial stage of splay "delta"

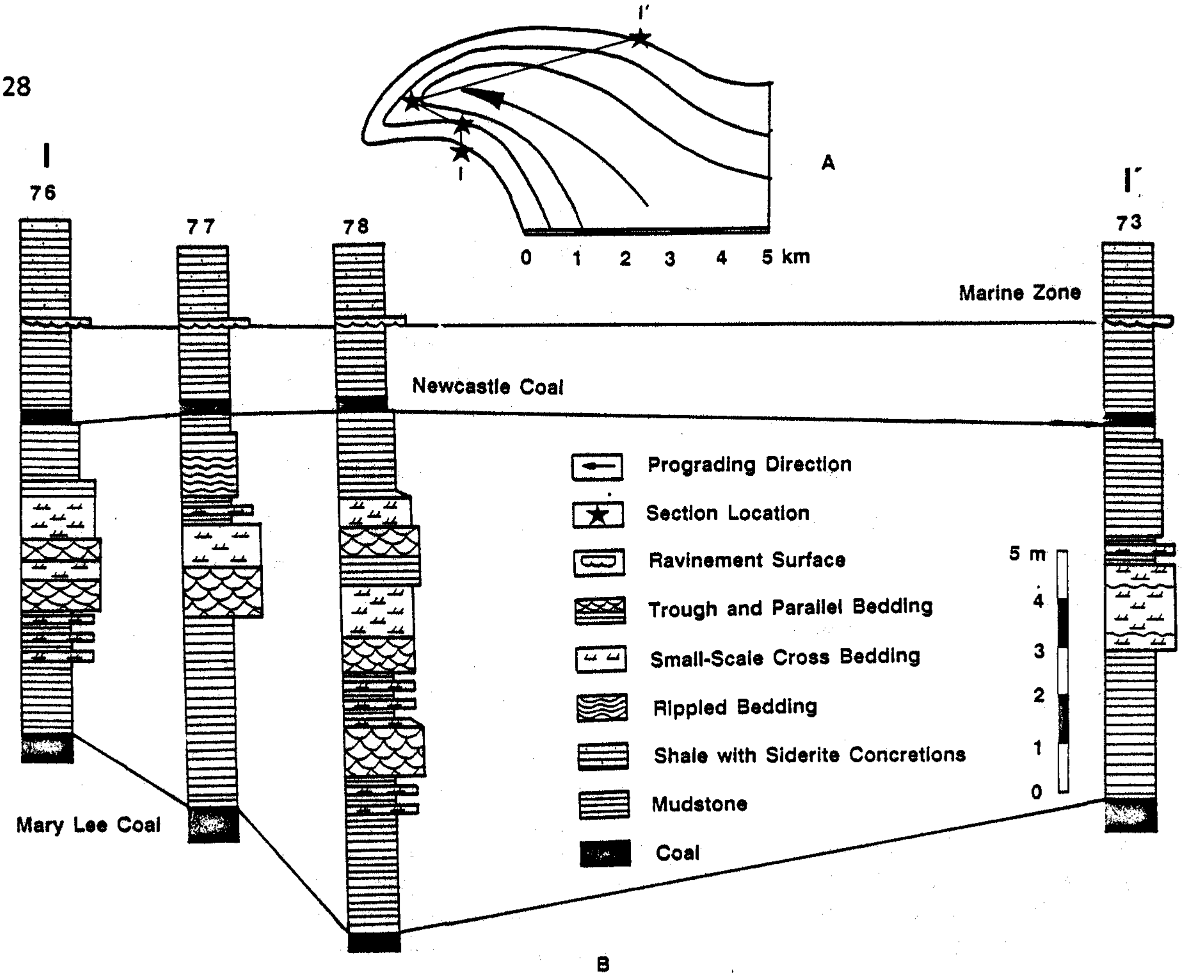

Figure VI-16.--A cross section of a lobate splay deposit showing vertical facies associations and their lateral changes (see locality in fig. VI-11).

deposition. This initial stage is analogous to the bottomset of a typical Gilbert delta, because crevasse splays and splay complexes are actually small-scale deltas. The isopach map for the entire interval, therefore, will represent the spatial distribution and the geometries of the splay complex. Two interlocked birdsfoot-like sand bodies are well defined in the isopach (fig. VI-17). Each of these bodies consists of four tongue-shaped lobes at the front margin. These lobes are oriented in a radial pattern and become thinner toward the direction of progradation. The major splay channels are interpreted to be within the centers of the lobes. These splay lobes developed as an interconnected splay complex (Smith and others, 1989). Two birdsfoot-like bodies coalesce at their front margins, oblique to their major prograding directions. This is indicative of a lateral merging of the splay complexes, the result of progradation. Although their geometries are not completely illustrated because of the limitation of the study area (about 600 km^2 exposed), their splay outlines are well represented in figure VI-17.

PEAT SWAMPS

The Mary Lee and Newcastle coal seams are immediately underlain by sandstone or mudstone with zones of *Stigmaria*, and overlain by fossil plant horizons with erect lycophyte and calamite trunks (see Gastaldo, this guidebook). These coal seams represent peat accumulations in coastal autochthonous peat swamps that vary in quality and distribution over the study area.

The Mary Lee coal seam is persistent over the entire study area. Its best quality (12 to 13 percent ash, 0.6 to 0.8 percent sulfur; Barnett, 1986) makes it an exploitable horizon in the basin. In the western study area the Mary Lee coal is separated by the 2-km-wide meandering channel zone into a thick upper bench (0.5 to 0.7 m) and a thin lower bench (0.2 to 0.3 m). Toward

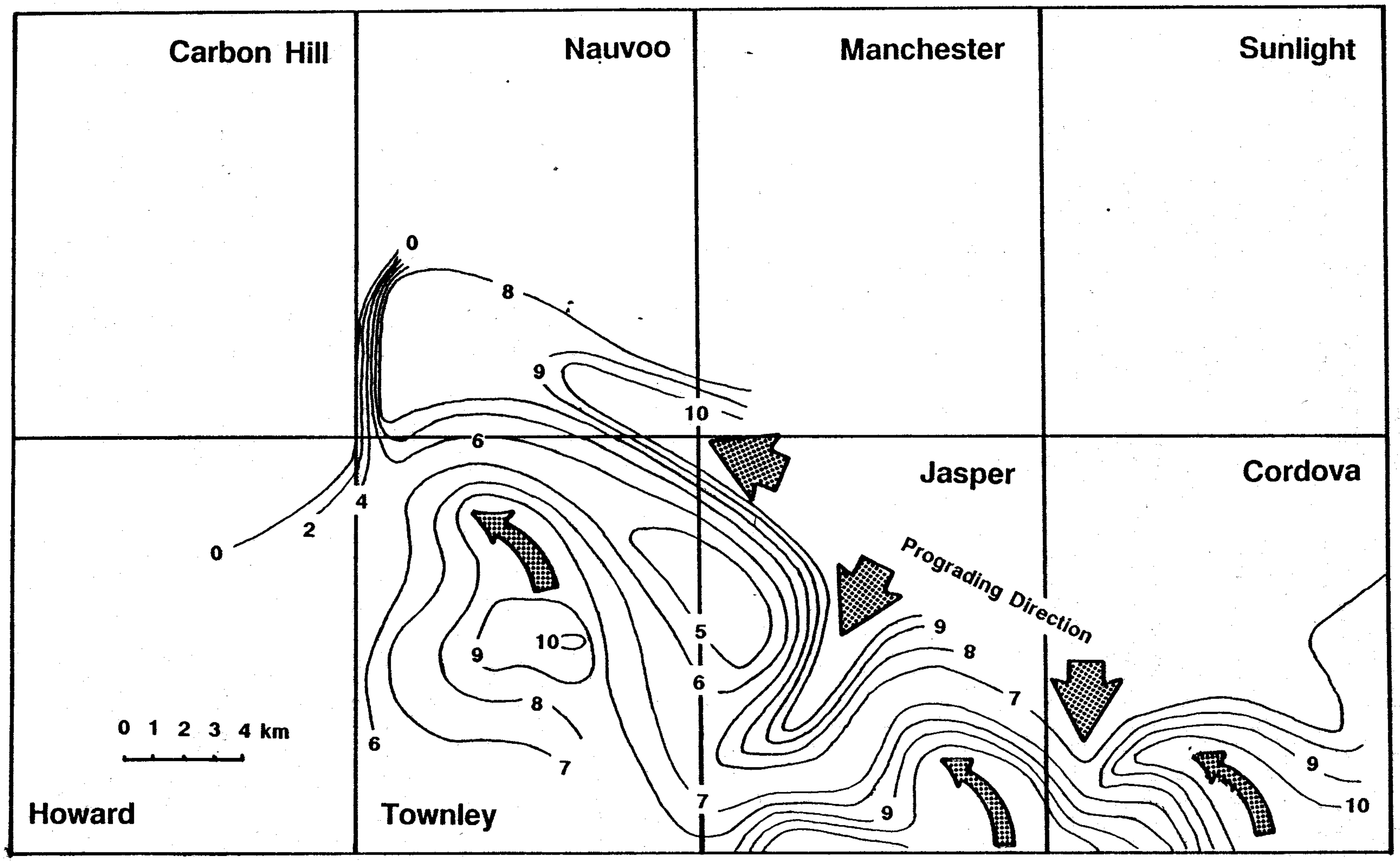

Figure VI-17.--An isopach map of the interval between the Mary Lee and Newcastle coal. Data acquired from surface and subsurface information at the Geological Survey of Alabama, various mining companies, and field records. Contour line is 1 m.

the eastern area it usually occurs as one bench with variable thickness. The isopach map (lower bench in the western area and one bench in the eastern area) indicates that the Mary Lee coal varies in thickness from 0.4 to 1.74 m (fig. VI-18). The coal body is oriented in an elongate or elliptical pattern with a topographical low in the center. This topographical thickness characteristic may reflect the preexisting depositional environments on which the peat swamp evolved; and these, in turn, may have controlled the subsequent deposition of the splay complex.

The Newcastle coal seam is a local split of the Mary Lee coal and is found only in the eastern study area. This coal maintains a constant thickness (never exceeding 0.5 m) and poor quality (15 to 20 percent ash, 1.5 to 5.0 percent sulfur; Barnett, 1986). The thickness isopach map is illustrated in figure VI-19. When compared to the Mary Lee coal, the distribution of the Newcastle coal exhibits a linearity in which a few local thick areas are arrayed in the center of the ridge. Because the Newcastle peat swamp developed over the underlying splay complexes, a comparison between these two isopach maps may provide a good chance to assess the depositional control on the accumulation of the peat swamp.

OVERBANK LAKES

Overbank lake deposits are usually found throughout the entire study area, but their occurrence varies in the two portions of the study area. In the western area, they occur as succeeding deposits of the Mary Lee clastic swamps, whereas in the eastern area they are located stratigraphically above the Newcastle clastic swamps (Alternative Stop 3).

These deposits are characterized by interbedded very fine-grained sandstone and mudstone. The sandstone shows rippled or lenticular bedding with set thicknesses approaching 1 cm. The mudstone exhibits horizontal lamination. Abundant leaf fragments and mica are distributed on the bedding surfaces. The thickness of this interval averages 1 m, but it shows an increase in thickness in the western part of the study area. Overbank lake deposits are usually found immediately above the clastic swamp deposits, representing the succeeding development of overbank standing waters from clastic swamps. This may be due to an increase of water depth in the clastic swamp as a result of the underlying compaction of mud and peat.

SEDIMENTOLOGY OF NEARSHORE AND OFFSHORE FACIES

The vertical stacking of the nonmarine coastal deposits, beginning with the Mary Lee coal through the clastic swamp and splay complex, and ending with the overbank fine-grained deposits above the Newcastle coal, represents a portion of a regressive sequence. This regressive sequence is the result of coastal progradation (a complete regressive sequence includes the interval between the Jagger and the Mary Lee coal seams; see Demko, this guidebook). This regressive sequence is finally truncated at the top by a transgressive event recorded by a ravinement surface at the base.

RAVINEMENT SURFACE

A ravinement surface is an erosional surface formed by the landward migration of a shoreface in response to sea level rise. It marks the stratigraphic position of the transgressive erosional surface (Swift, 1968). Recognition of a ravinement surface in the study area is of fundamental importance in understanding the sedimentological history of the upper "Pottsville" Formation. It also provides strong evidence for the argument that transgressive-regressive cycles may be the origin for the Pennsylvanian cyclothems in the Black Warrior basin (Wanless and others, 1970).

This ravinement surface occurs as a disconformable surface throughout the study area, separating the overlying marine rocks from the underlying nonmarine deposits (Stops 2, 4, and 6). In most localities the sediments above and below this surface are gray mudstone. In this case it is difficult to recognize the position of the ravinement surface in the field. The ravinement surface is most pronounced where underlying coastal channels are truncated by it (fig. VI-20). This condition provides unequivocal evidence for the presence of a ravinement surface. Unfortunately, these are localized occurrences and not often exposed. The most important criterion for the identification of the ravinement surface is the recognition of a ravinement bed deposited immediately above the ravinement surface.

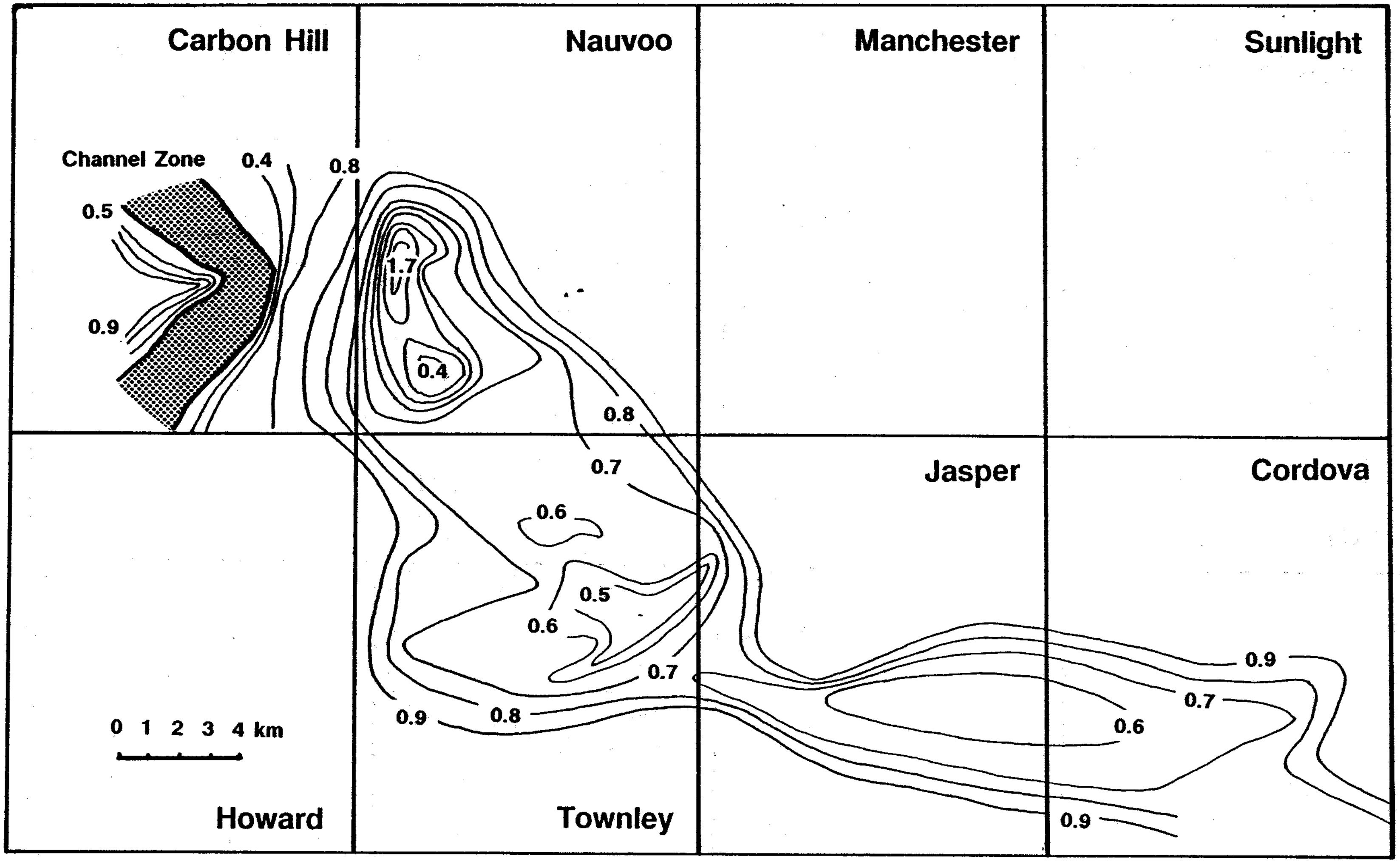

Figure VI-18.--An isopach map of the Mary Lee coal and the associated channel zone in the west. Contour line is in meters. Data acquired from surface and subsurface information at the Geological Survey of Alabama, various mining companies, and field records.

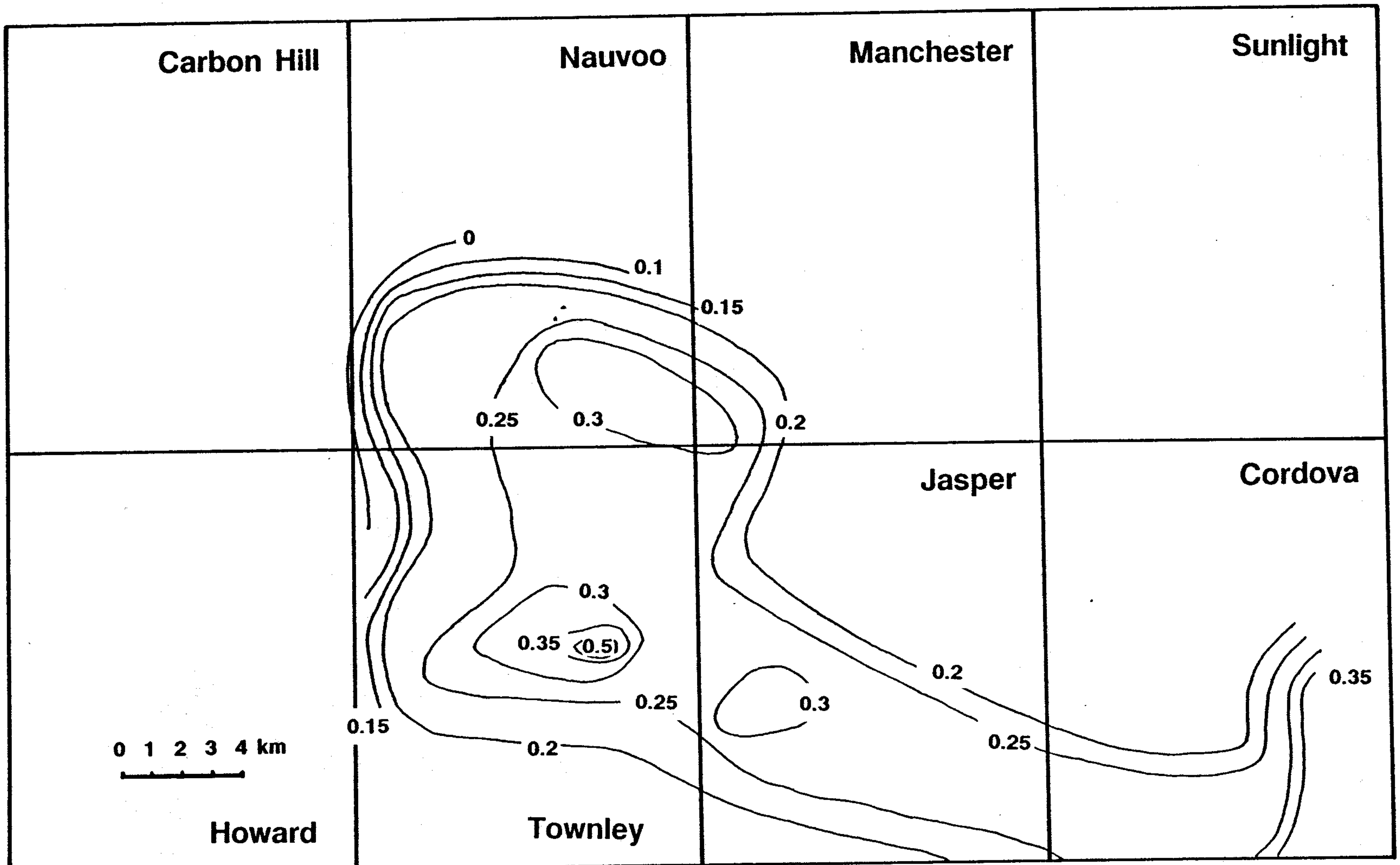

Figure VI-19.--An isopach map of the Newcastle coal in the eastern part of the study area. Contour interval is 0.05 m. Data acquired from surface and subsurface information at the Geological Survey of Alabama, various mining companies, and field records.

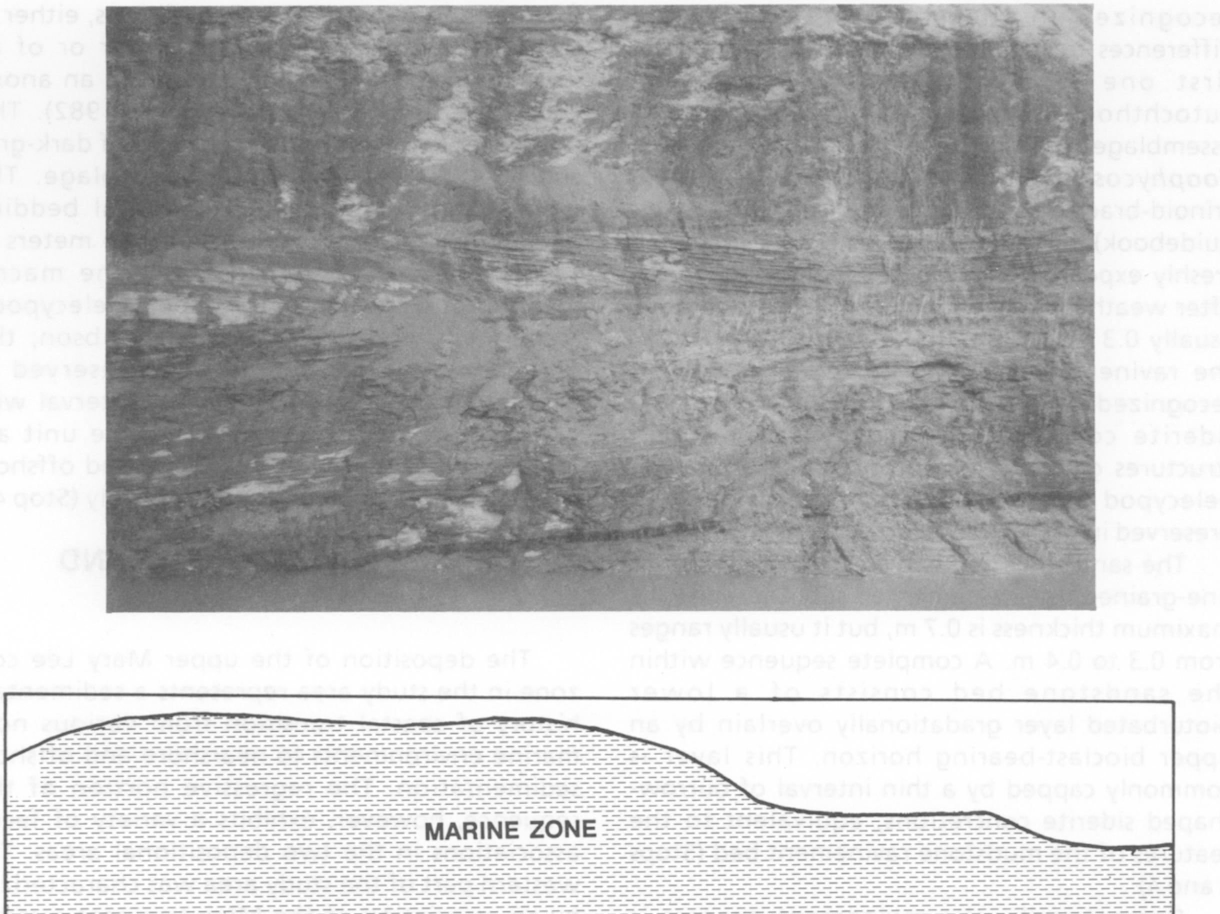

Figure VI-20.--Field occurrence of the ravinement surface at Stop 2. (a) Photograph of abandoned highwall in the Gateway Malls Hope Galloway mine in which the channel-form sandstone can be seen to be truncated by the ravinement surface. (b) Line illustration of photograph accentuating the terrestrial Blue Creek to Mary Lee coal interval, channel and levee sandstone deposits, ravinement surface, and overlying marine sequence of the Morris shale.

Two variations of the ravinement bed are recognized in the study area based on differences in lithology and macrofauna. The first one is a mudstone bed with an autochthonous pelecypod and brachiopod assemblage. The second is a sandstone bed with *Zoophycos* and an allochthonous trilobite-crinoid-brachiopod assemblage (see Gibson, this guidebook). The mudstone bed is dark gray on a freshly exposed surface and becomes light gray after weathering. It is persistent in its thickness, usually 0.3 m. Its basal bounding surface marks the ravinement surface. Its top boundary is recognized by a thin layer of burrow-shaped siderite concretions. Primary sedimentary structures generally are obscured by abundant pelecypod and brachiopod fossils, which are preserved in growth position (Stops 6 and 7).

The sandstone bed is typically a very fine to fine-grained, calcite-cemented sublitharenite. Its maximum thickness is 0.7 m, but it usually ranges from 0.3 to 0.4 m. A complete sequence within the sandstone bed consists of a lower bioturbated layer gradationally overlain by an upper bioclast-bearing horizon. This layer is commonly capped by a thin interval of burrow-shaped siderite concretions, equivalent to the features of the mudstone ravinement bed (Stops 3 and 4).

Geometrically, the ravinement process is controlled by the magnitude of an angle termed a "climbing angle", which is formed by an imaginary line connecting the top points of the migrating shoreface (fig. VI-21). Under sub-critical conditions, where the shoreface angle is greater than the climbing angle, the shoreface retreat landward produces two genetic consequences. The first is the formation of a ravinement surface consisting of a series of erosional surfaces. The second is the deposition of ravinement beds whose sediments are controlled by the properties of the eroded shoreline. The detailed discussion of this ravinement process will be presented elsewhere.

NEARSHORE AND OFFSHORE FACIES

Overlying the ravinement bed is an interval of gray to black shale with intercalated sideritic concretions and/or beds. The average thickness is 3 m. This interval is characterized by distinct horizontal bedding without a preserved macrofaunal assemblage throughout most of the study area. The intercalated sideritic concretions or beds may represent periodic fluctuations of geochemical conditions, either as a result of the influx of freshwater or of an increase in organic carbon content in an anoxic condition (Berner, 1981; Maynard, 1982). This interval is, in turn, overlain by a unit of dark-gray shale with a marine faunal assemblage. The marine unit is typified by horizontal bedding and varies in its thickness from a few meters to tens of meters. The enclosed marine macro-invertebrates include brachiopods, pelecypods, scaphopods, and gastropods (see Gibson, this guidebook). These are usually preserved as articulated body fossils. The shale interval with sideritic concretions and marine shale unit are interpreted to represent nearshore and offshore depositional environments, respectively (Stop 4).

FACIES RELATIONSHIPS AND PALEOGEOGRAPHY

The deposition of the upper Mary Lee coal zone in the study area represents a sedimentary history of coastal transition from various non-marine environments to nearshore and offshore sedimentation. The regressive portion of this sequence, however, exhibits a variety of facies associations in the two depositional areas. The western part of the study area was characterized by an association of the Mary Lee peat swamp, clastic swamps, and overbank lake deposits. The Mary Lee peat accumulation was locally interrupted by the inundation of a 2-km-wide meandering channel zone. Subsequent to the abandonment of this channel zone, peat accumulation resumed resulting in the upper bench of the Mary Lee coal. A localized channel fill was also found above the clastic swamp deposits where it was truncated by the overlying ravinement surface. This channel fill was stratigraphically equivalent to the overbank lake deposits.

The terrestrial sequence in the eastern part of the study area consists of the Mary Lee peat swamp, followed by a crevasse splay complex, the Newcastle peat swamp, and clastic swamp/overbank lake deposits. The inundation by the splay complex was responsible for the termination of the Mary Lee peat swamp. The subsequent abandonment of this complex resulted in the reestablishment of a new peat swamp in the area, forming the Newcastle coal.

A better understanding of the paleo-geography during the accumulation of the

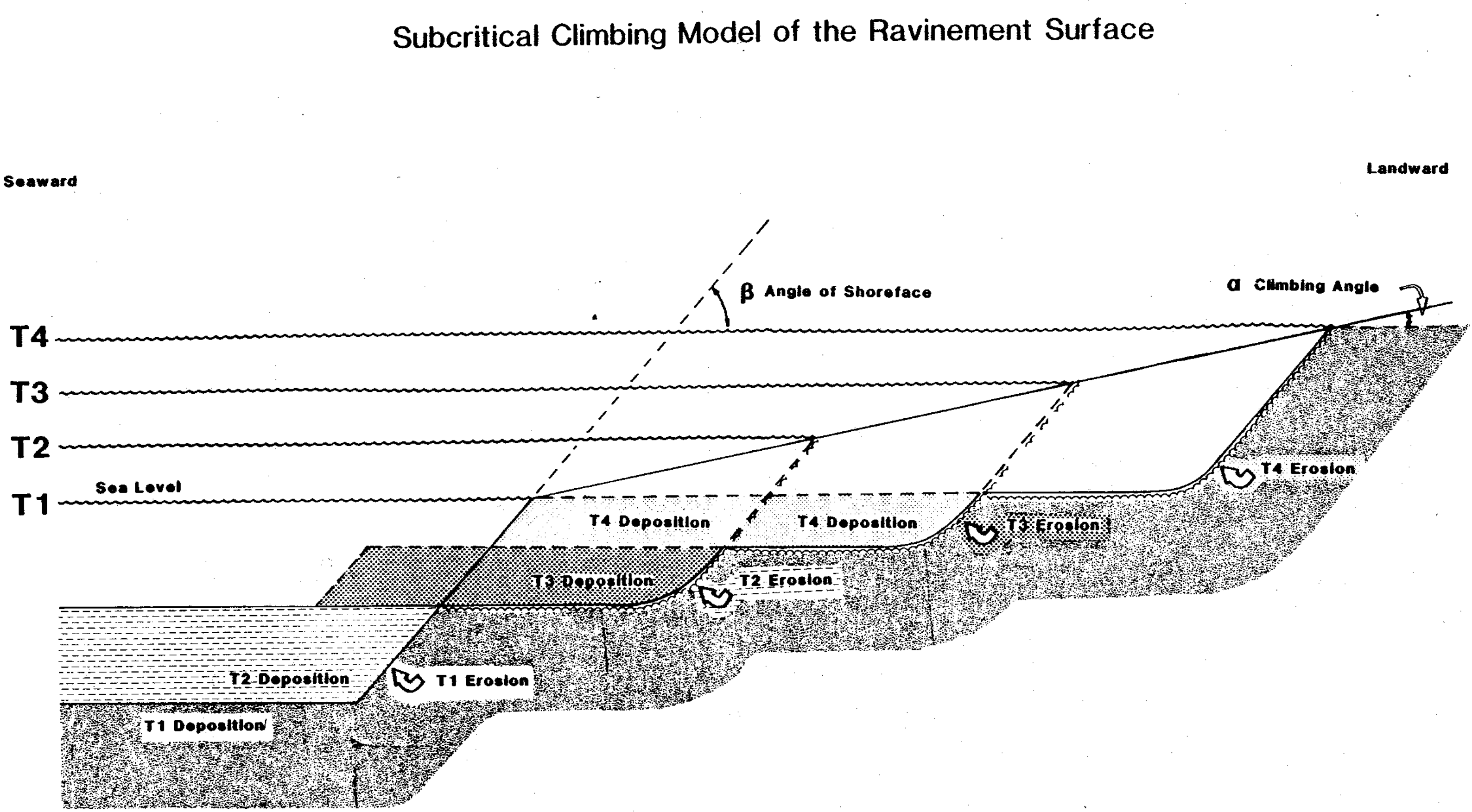

Figure VI-21.--Geometrical model of the ravinement surface and bed. When climbing angle is less than the shoreface angle, transgression results in the erosion of the shoreface (T1 erosion) and offshore deposition of this sediment (T1 deposition). As sea level continues to rise, erosion of the shoreface continues (T2 erosion) and this sediment is deposited over the former erosional surface (T2 deposition). A ravinement bed is formed.

upper Mary Lee coal zone is dependent on the stratigraphic correlation between these two depositional areas. Two reliable stratigraphical markers can be used to serve this purpose. One is the ravinement surface which marks the beginning of the transgression. It serves as the top bounding surface for the genetic stratigraphical sequence of the Mary Lee coal zone (Galloway, 1989). The other is the Newcastle coal seam which is a split of the Mary Lee coal. It restricts the time required for deposition of the splay complex. A cross-section over the entire study area is illustrated in figure VI-22 in which the rocks are correlated with these two markers. Because the interval between the Mary Lee and Newcastle coal seams (including these two coal seams) in the eastern study area can be correlated with the Mary Lee coal in the western part, the time required for the development of the Mary Lee peat swamp in the western area is equal to that for the accumulation of the Mary Lee and Newcastle peat plus the intervening splay complex. It is important to recognize this fact because it provides a time constraint for the numerous lateral changes of fluvial splay facies and the basis for a paleogeographical interpretation.

The Mary Lee peat swamp developed initially from the underlying clastic swamp (see Demko, this guidebook) over the entire study area. A westward progradation of the crevasse splays invaded and occupied the eastern part of the study area, smothering and terminating the Mary Lee peat swamp. This inundation of the splay complex may have been the combined result of compaction within the underlying highly porous mud and peat, and an avulsion of trunk channels probably located to the east of the study area. A large channel sandstone sequence has been found immediately outside the study area across the Black Warrior River (sec. 36, T. 14 S., R. 6 W.). During this active stage of clastic deposition in the eastern area, the western part continued peat accumulation in the Mary Lee peat swamp. This indicates that a low rate of peat accumulation and rapid clastic deposition developed simultaneously in the coastal regime during this time. Final abandonment of the splay complexes resulted in revegetation and subsequent development of the Newcastle peat swamp. At this time, the Mary Lee peat swamp in the west may expand eastward, resulting in the Newcastle coal as a localized split of the Mary Lee coal.

The western Mary Lee peat accumulation was also locally terminated by the development of the meandering channel zone. This channel zone may represent the magnitude and geometries of a trunk channel system developed in this coastal regime. Development of the channel system was probably earlier than the inundation of the splay complex. This is because the Mary Lee lower bench separated by this channel system is much thinner than one bench of the Mary Lee in the eastern area. Further clastic incursion over the Mary Lee and Newcastle peat swamps resulted in the termination of the peat accumulation and subsequent deposition of clastic swamps and/or overbank lakes. These terrestrial deposits were finally truncated by a transgressive event recorded by the ravinement surface and overlying mudstone and shale with marine fossil assemblages.

In summary, the sedimentary rocks reported in this study record two paleogeographical settings: a coastal regime of nonmarine deposition and an area covered by shallow marine sedimentation. A northeast-southwest oriented shoreline at the time of the initial transgression was probably located in the northern part of the Carbon Hill Quadrangle. This is interpreted by using the seaward pinch-out of the Mary Lee coal (Rahmani and Flores, 1984) and the possible absence of the ravinement surface in that area (sec. 3, T. 13 S., R. 10 W.). A southern Appalachian provenance for this part of the upper "Pottsville" Formation has also been interpreted by using the log-transported gravels preserved in the top of the channel sandstone sequence that splits the Mary Lee coal in the western part of the study area (Liu and Gastaldo, 1989).

CONCLUSIONS

Sedimentological characteristics identified in this study indicate two distinct attributes to the deposits. Temporal accumulation of the upper Mary Lee coal zone represents a depositional history of transition from coastal terrestrial to nearshore and offshore environments. The spatial distribution of the nonmarine deposits is related to two different depositional areas. The Carbon Hill Quadrangle differs from the rest of the area by the absence of both the Newcastle coal and significant flood deposits.

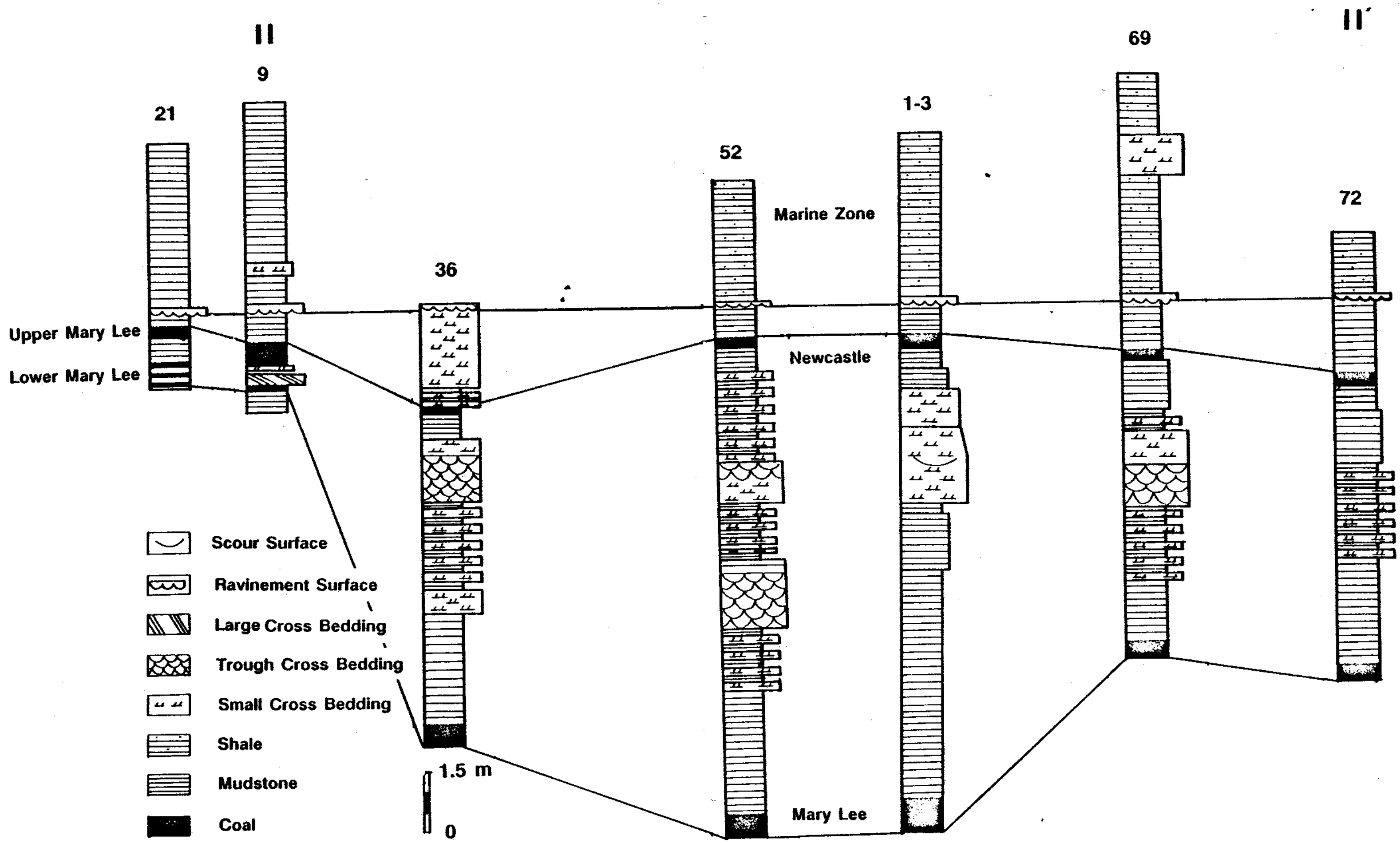

Figure VI-22.--A cross section of the study area showing the stratigraphic correlation between the two depositional areas (see locality in fig. VI-11).

The western part of the study area was characterized by an association of Mary Lee peat swamp, clastic swamps, and overbank lake deposits. The Mary Lee peat accumulation was locally interrupted by inundation of a 2-km-wide meandering channel zone. The terrestrial sequence in the eastern area consists of the Mary Lee peat swamp, followed by development of a splay complex, the Newcastle peat swamp, and clastic swamp and overbank lake deposits. The Mary Lee peat accumulation in the western area is synchronous with that of the Mary Lee and Newcastle peat, and the splay complex deposits in the eastern area. The broad channel-fill complex interbedded between the upper and lower benches of the Mary Lee coal in the western area may represent the magnitude and geometry of a major fluvial system in the coastal regime.

The geometry of the splay complex is characterized by two interlocked birdsfoot-like sand bodies, each consisting of several marginal lobes oriented in a radial pattern. The splay complex sequence consists of three depositional units. The lower mudstone unit is characterized by graded beds and a wedge-shaped geometry with autochthonous fossil plant horizons. The middle sandstone unit is characterized by the association of splay channel fill, sheet sands, and lowland deposits. The upper siltstone and.or mudstone unit is characterized by *Stigmaria* rooted horizons.

ACKNOWLEDGMENTS

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EARLY PENNSYLVANIAN SWAMP FORESTS IN THE MARY LEE COAL ZONE, WARRIOR BASIN, ALABAMA

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ABSTRACT

Fossil forests are a common feature of the Pennsylvanian rocks of the Black Warrior basin. These forests are preserved in their original growth site (autochthonous) and are composed of erect and prostrate elements. The preservation of each forest is the result of low-frequency, high-magnitude floods that buried the vegetation. Each flood event preserves the original forest litter at the bottom, and at the top, forest litter generated after the death of the canopy. The forests that represent the final peat accumulating communities are composed of a higher diversity vegetation, whereas those communities representing intervening clastic swamps preserve a lower diversity. The differences in preserved diversity may be the result of taphonomic biases and residence time of macrodetritus on the forest floor. Peat swamp communities are heterogeneous and composed of at least a three tiered guild. Lycophytes are the sole canopy plants. They may have developed a closed or partially closed canopy over an understory of pteridosperms. A third, lowest tier, is believed to have been dominated by scrambling plants, the most common of which is *Sphenopteris pottsvillea*.

INTRODUCTION

The preservation of autochthonous forests (preserved in their site of growth) in Carboniferous coastal lowlands of Euramerica is a more common feature than previously recognized. This vegetation may be preserved either as coalified compression assemblages, as cast erect (*in situ*) plants, or as a combination of preservational modes. The distribution of such forest litters may be found beneath coals in the seat earth (gleyed paleosol; e.g., Wnuk, 1989), at the top of seams rooted either in the coal (DiMichele and DeMaris, 1987; DiMichele and Nelson, 1989; Gastaldo and others, in press) or in the rocks above (Gastaldo, 1986a, 1987), or within the terrestrial clastics between coals (Dilcher and Pheifer, 1974; Cobb and others, 1981; Gastaldo and others, in press). These fossil Lagerstätten may represent either the terminal phase of forestation in organic (peat) soils or various developmental phases within inorganic mineral soils. The stage of forest development can be inferred from its taphonomic characteristics and preserved position within the stratigraphic sequence.

The sedimentological conditions under which the terrestrial portions of the "Pottsville" Formation, Black Warrior basin, Alabama, were deposited resulted in the preservation of multiple forests representing both peat swamp and clastic swamp vegetation. Examples of autochthonous forests occur within each recognized coal zone (after Lyons and others, 1985). The most common occurrence is that of mud-cast stigmarian "rooting" structures permeating underclays of coal seams (Rheams and Benson, 1982; Raymond and others, 1988). Probably as common an occurrence is the preservation of standing forests above the coals. These occur in geographically localized areas, although the areal extent of the preserved forest may be tens to hundreds of km^2. As significant, but generally overlooked, are the multiple stacked forests preserved in the terrestrial clastics between major coals (Gastaldo and others, in press). These exceptional conditions provide a unique opportunity to assess Late Carboniferous coastal plain communities.

Exposures of the Mary Lee Coal zone uncovered in strip mines of Walker County allow for a characterization of Early Pennsylvanian (Westphalian A equivalence) clastic swamp and peat swamp communities. Autochthonous erect trees are preserved above, as well as between, the Jagger, Blue Creek, Mary Lee, and Newcastle coals. Understory vegetation that was not prone to preservation in an erect position is preserved either prostrate on, or partially transecting, bedding. The litters of these forests occur as mixed taphocoenoses of coalified compression-impressions and casts. This manuscript will provide an overview of the processes responsible for the development and preservation of these fossil Lagerstätten, and the community structure they represent.

LOCALITIES

The Mary Lee Coal zone is buried shallowly in northwestern Alabama and exposures occur as surface mine highwalls, roadcuts, and natural outcrops. It is possible to trace the coal zone over 1,000 km^2 throughout Walker County. Individual surface mine highwalls may extend for several km with preserved fossilized forests. Transects detailing the distribution of erect vegetation throughout the study area have been conducted principally above the Blue Creek and Mary Lee coals. This is due to mining practices. The Jagger coal is discontinuous in its distribution (see Demko, this guidebook), and the thickest areas were originally deep mined during the early twentieth century. Exploitation of the remaining coal occurs where thick underground coal pillars remain. Exposure of the Jagger coal is sporadic and localized. Although erect vegetation is preserved above this coal, it is not possible to document the relationships between standing vegetation over long distances. The thin Newcastle coal is found in the eastern part of the study area (see Liu, this guidebook). It is often quickly mined. Although it can be seen in most highwalls within the surface mine operations, it is inaccessible.

The best preserved forests have been documented in several mining operations in which the Blue Creek (BC) and Mary Lee (ML) coals are exploited. These include the Hope Galloway Mine (BC to ML interval; highwall running from SW¼SW¼ sec. 12 to SW¼NE¼ sec. 13, T. 13 S., R. 10 W., Carbon Hill 7.5-Minute Quadrangle), Prospect mine (BC to ML interval; NE¼SE¼ sec. 9, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle), Cedrum mine (BC to above ML; highwall running from NE¼NW¼ sec. 12, T. 14 S., R. 9 W., to SE¼SE¼ sec. 33, T. 13 S., R. 9 W., Townley 7.5-Minute Quadrangle), and the Lost Creek mine (BC to above ML; SW¼ sec. 27, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle). Trees may be found rooted in the coals and within the terrestrial clastics between coals. Individual erect trees are preserved above the Jagger coal (Hope Galloway mine; IMAC; Carbon Hill outcrop NE¼ sec. 25, T. 13 S., R. 10 W., Carbon Hill 7.5-Minute Quadrangle) and the Newcastle coal (Prospect mine; Cordova NW¼ sec. 27, T. 14 S., R. 6 W., Cordova 7.5-Minute Quadrangle). In the cases where trees are preserved along with the Jagger, trees are either rooted in the top of the coal or within the clastics of the first 0.5 m above the coal. In the documented cases above the Newcastle, all vegetation is rooted in the top of the coal.

METHODOLOGY

Mud and sand-cast erect trees were identified in the highwalls above and between coals. Measurements included height to which the tree was preserved (a variable parameter depending upon the surface mine cut), diameter of each tree at approximate DBH (Diameter Breast Height), and distance to next tree. Each tree was identified to major plant group (lycophytes, sphenophytes, pteridophytes, pteridospermophytes, and cordaites), if possible. Additionally, the position and presence of prostrate cast and compressed canopy detritus were noted within the clastics between coals. Where possible, quantification of this detritus was attempted using a modified technique proposed by Pfefferkorn and others (1975). A 10 cm^2 quadrat of clear Plexiglas was placed onto the surface of recovered rock preserving forest floor litter. Each different plant within the quadrat was identified to genus and noted. After 100 plants had been identified, the frequency of occurrence of major plant groups was determined and expressed as a percentage. This provides a rough approximation of the contribution of vegetation at that particular site.

RESULTS

The distribution of erect vegetation in the terminal phase of peat accumulation of the Blue Creek coal and its systematic affinities are illustrated in figure VI-23. Morphometric data are presented in table VI-2. Erect trees are normally encased in mudstone and also cast in mudstone. In specific localities, erect trees may be encased and cast by sandstone, or encased in mudstone and cast by sandstone derived from an overlying facies. The standing trees are preserved to heights up to 3.1 m above the contact of the mudstone and coal. The maximum height

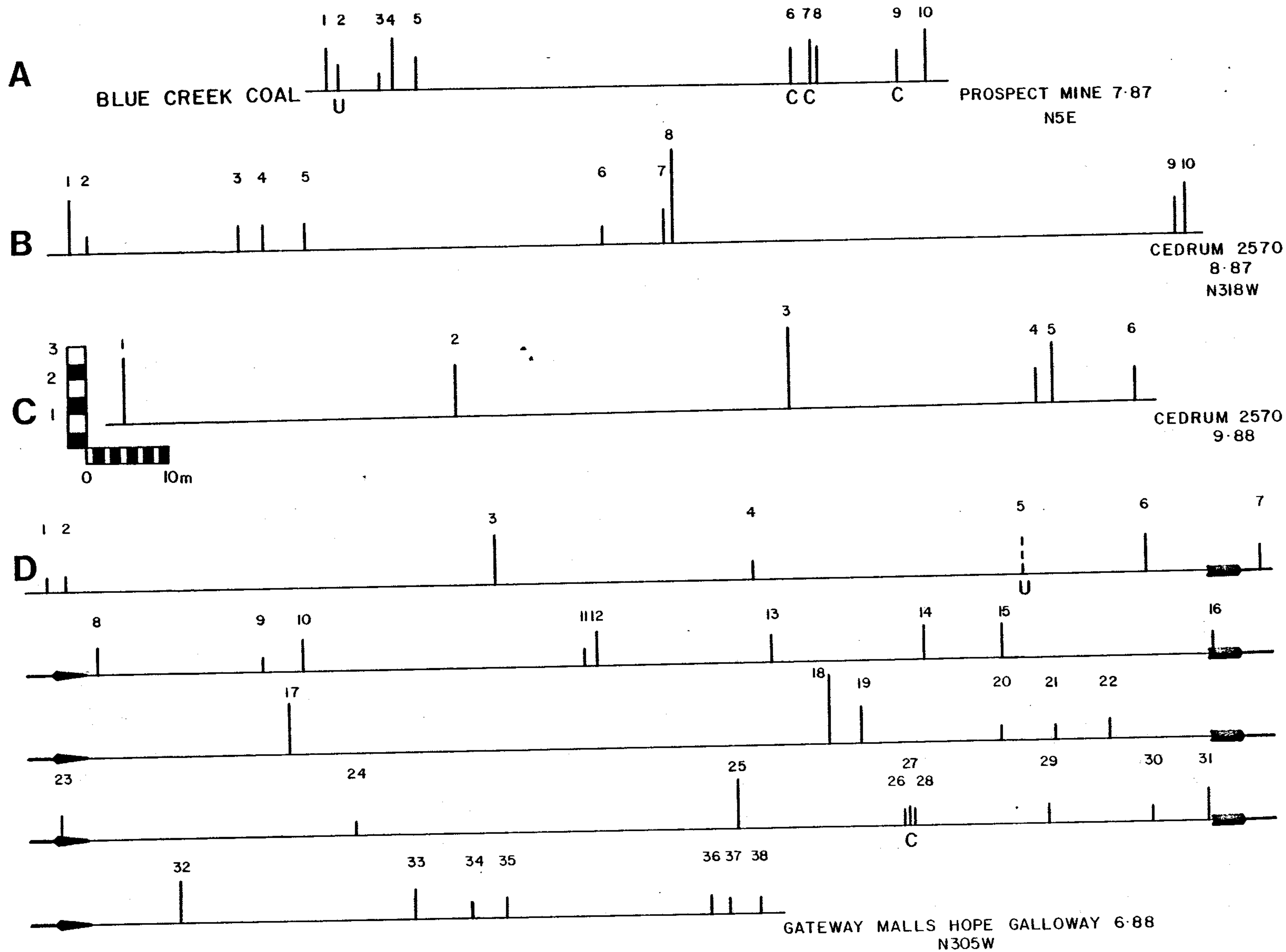

Figure VI-23.--Distribution and density of terminal peat swamps preserved erect above the Blue Creek coal in mine highwall transects located in the study area. All erect vegetation is assigned to the lycophytes except those labeled with a C (*Calamites*) and U (unknown identity). Unknowns are some type of lycophyte, but due to the lack of morphological characters in these specimens, it is impossible to assign them to a morphotype. Morphometric data is provided in table VI-2. Scales in meters, and orientation of highwall is given.

Table VI- 2.--Autochthonous erect vegetation rooted in Blue Creek coal

Prospect Mine 7-87

Sample number	Systematic affinity	Height in highwall (meters)	Width of specimen (meters)	Distance to next (meters)
1	Lycophyte	1.25	0.40	1.40
2	Unknown	.65	N/R	5.0
3	Lycophyte	.45	.30	1.5
4	Lycophyte	1.5	.33	2.7
5	Lycophyte	1.0	.20	45.2
6	Calamite	1.1	.05	2.3
7	Calamite	1.1	.10	.9
8	Lycophyte	1.0	.60	9.7
9	Calamite	1.0	.06	3.6
10	Lycophyte	1.7	.38	--

Cedrum 2570 Mine 8-87

Sample number	Systematic affinity	Height in highwall (meters)	Width of specimen (meters)	Distance to next (meters)
1	Lycophyte	1.6	0.45	2.0
2	Lycophyte	.36	.55	17.90
3	Lycophyte	.65	.21	2.9
4	Lycophyte	.70	.65	4.8
5	Lycophyte	.65	.20	36.2
6	Lycophyte	.50	.10	7.7
7	Lycophyte	1.0	.35	.8
8	Lycophyte	3.1	.30	59.8
9	Lycophyte	1.1	.47	1.5
10	Lycophyte	1.5	.60	--

Cedrum 2570 Mine 9-88

Sample number	Systematic affinity	Height in highwall (meters)	Width of specimen (meters)	Distance to next (meters)
1	Lycophyte	2.0	0.40	40.0
2	Lycophyte	1.3	.95	40.0
3	Lycophyte	2.0	.35	30.0
4	Lycophyte	1.0	.25	2.0
5	Lycophyte	.7	.60	10.0
6	Lycophyte	.9	.25	--

Table VI-2.--Autochthonous erect vegetation rooted in Blue Creek coal–Continued

Gateway Malls Hope Galloway Mine 6-88

Sample number	Systematic affinity	Height in highwall (meters)	Width of specimen (meters)	Distance to next (meters)
1	Lycophyte	0.65	0.80	2.0
2	Lycophyte	.6	.60	32.5
3	Lycophyte	.8	.40	20.0
4	Lycophyte	.5	.50	19.8
5	Unknown	1.4	.46	9.8
6	Lycophyte	.6	N/R	9.0
7	Lycophyte	.5	N/R	6.5
8	Lycophyte	1.0	.55	14.7
9	Lycophyte	.65	.40	3.8
10	Lycophyte	.75	.60	21.0
11	Lycophyte	.4	N/R	1.3
12	Lycophyte	.9	.5	13.6
13	Lycophyte	.5	.25	12.0
14	Lycophyte	1.0	.45	6.5
15	Lycophyte	.8	.5	18.3
16	Lycophyte	1.1	.6	25.0
17	Lycophyte	1.1	.6	38.0
18	Lycophyte	.7	.8	3.5
19	Lycophyte	1.6	.5	11.0
20	Lycophyte	2.0	.6	4.0
21	Lycophyte	1.0	.4	4.5
22	Lycophyte	.4	.4	16.0
23	Lycophyte	.55	.7	22.5
24	Lycophyte	.55	.5	29.0
25	Lycophyte	.65	.7	16.5
26	Lycophyte	.3	.3	1.0
27	Lycophyte	1.4	.55	1.0
28	Calamite	.45	.05	16.5
29	Lycophyte	.5	.2	12.5
30	Lycophyte	.45	.5	6.5
31	Lycophyte	.9*	.04	24.0
32	Lycophyte	1.25	.55	28.0
33	Lycophyte	.8	.55	7.0
34	Lycophyte	.3	.4	4.0
35	Lycophyte	.6	.4	24.3
36	Lycophyte	.55	.3	1.9
37	Lycophyte	.4	.4	3.6
38	Lycophyte	.4	.3	--

recorded at any particular mine represents the height to which all living vegetation was preserved in that site. The recorded preserved heights (table 2) represent the height of each tree in the highwall after exposure. In most cases, the trees are not preserved perpendicularly, but rather are at some slight angle from vertical. Therefore, when uncovered, the tree may be oriented either into or away from the face of the highwall. Those oriented away from the mine face have been partially destroyed and removed by mining. It is common to find these casts in the spoils. It is difficult to determine whether or not a cast trunk represents an already dead and decayed stump residing in the forest before encasement and casting by the matrix because of these post-exposure conditions.

Lycophytes dominate the standing forests; 91 percent of standing biomass is attributable to this group. In most instances, the preserved basal trees do not exhibit morphological characters that would allow a systematic assignment of the specimen to genus. Most trees are typified by a vertical fissuring of the bark, indicative of periderm (bark) sloughing during diameter increase. Identifiable periderm recovered from the forest litter horizons are assignable to either *Lepidophloios* or *Lepidodendron*. To date, rare specimens of *Sigillaria* have been recovered from the compression litters. The diameters (DBH) of the trees vary throughout the transect with those presumably less mature represented by trees less than 0.3 m DBH, and those more mature by trees greater than 0.3 m DBH. The greatest tree diameter recorded in the study area is 0.95 m, with an average per tree diameter of 0.53 m. This figure is representative of those trees considered as more mature. Canopy-derived litters are found to occur within the first 0.2 m of mudstone above the coal and at the level of termination of the highest preserved cast tree (fig. VI-10; Demko, this guidebook).

Where *Calamites* occur, these trees are found either isolated or in small clusters. The casts are oriented at an angle up to 45° from vertical. Each specimen represents the internal hollow pith which displays the node-internode relationships characteristic of the sphenophytes. In addition to these features, helically arranged and geopetally oriented rootlets originate from the nodes. The roots crosscut bedding structures. The diameters of the pith casts remain constant from the base to the top of each specimen. The maximum diameter of any pith cast recorded is 0.2 m. Neither lateral branch scars on pith casts nor branches in the surrounding matrix have been observed in the specimens.

Coalified compression assemblages are recovered from forest floor litters preserved between erect vegetation. These compression-impression taphocoenoses occur directly above the coal, generally within the first 0.2 m. Relative abundances of major systematic groups are presented in table 3. In contrast to the dominance of lycophytes in the erect vegetation, the prostrate debris provides an insight into the composition of the understory. Lycophyte and sphenophyte canopy detritus accounts for a small portion of the autochthonous coalified-compression tapho-assemblage. The canopy parts are restricted to terminal branchlets with leaves or isolated leaves (*Cyperites*). Occasionally, lateral branches with leaf cushions (representing sites of abscised leaves) are encountered. Pteridosperms (gymnosperms commonly termed "seed ferns") and pteridophytes (true ferns) comprise the majority of recoverable macrodetritus. These parts include prostrate stems, adventitious roots (*Pinnularia*), entire and partial leaves (rachial and laminar parts), and reproductive organs (pteridospermous seeds and pollen organs). Plants that can be definitely assigned to pteridosperms (*Neuropteris, Neuralethopteris, Alethopteris*, and *Lyginopteris*) and those that may be either pteridosperms or pteridophytes (i.e. *Sphenopteris*) are common. The diversity of pteridosperms recovered, to date, is low, whereas the diversity of *Sphenopteris* is variable with collection site.

Compression-impression and cast autochthonous macrodetritus also occur in the terrestrial clastics between coals. Two taphocoenoses are identified. The first is a rooting assemblage (rhizocoenosis) composed exclusively of *Stigmaria* axes and erect tree stumps (fig. VI-10; Demko, this guidebook). *Stigmaria* are oriented either horizontally or on a slight angle to bedding. Helically arranged stigmarian appendages ("rootlets") are common and permeate the sequence. This is the only bioturbation noted to occur in the gleyed mudstone. Rhizoconcretions of siderite may occur either adjacent and parallel to the principal *Stigmaria* axis or surrounding stigmarian appendages. *Stigmaria* may be found isolated in the highwall or attached to erect

Table VI-3.--Autochthonous forest floor litter recovered between erect vegetation

	Gateway Malls Hole Galloway Mine July 24, 1987 n-100	Gateway Malls Hope Galloway Mine July 24, 1987 n-100
Lycophytes	22	1
Sphenophytes	10	11
Pteidophytes/pteridosperm	65	82
Pteridosperms[1]	43	68
Cordaites	0	0
Unidentified	3	6

Blue Creek coal

	Gateway Malls Hole Galloway Mine July 24, 1987 n-100	Gateway Malls Hope Galloway Mine July 24, 1987 n-100
Lycophytes	29	5
Sphenophytes	2	1
Pteridophytes/pteridosperm	63	71
Pteridosperms[1]	44	62
Cordaites	0	0
Unidentified	7	13

[1]Note: Pteridosperm detritus is represented with the omission of *Sphenopteris*, a genus of ambiguous affinity.

basal lycophyte trunks; the isolated *Stigmaria* probably occur distal to the main trunk and principal dichotomies of the underground axes. The second consists of lycophyte-exclusive canopy detritus (xylophyllocoenosis) that occurs at the same level as the height to which erect trees are preserved (fig. VI-10; Demko, this guidebook). Coalified compression-impression and mud-cast trunks and canopy branches, some with leaves and reproductive strobili, are found in the litters. Often the litters are identified only by the presence of mud-cast logs with surrounding coalified periderm tissues.

DISCUSSION

BIOSTRATINOMIC PROCESSES FOR THE DEVELOPMENT OF AUTOCHTHONOUS FORESTS

The mechanisms responsible for the preservation of these *in situ* forests involve the periodic catastrophic introduction of suspension-load clastics into the swamps via floods. Liu (this guidebook) and Liu and Gastaldo (1989) provide evidence for the presence of high magnitude low frequency flood events in the Mary Lee coal zone. These overbank deposits blanket geographically large areas, burying the vegetation in its site of growth. This results in several processes operating simultaneously for the preservation of the vegetation.

The accumulation in the site of growth of aerial and canopy parts of any forest results from physiological or traumatic processes (Gastaldo, 1988a). Physiological mechanisms that are responsible for the production of potentially preservable macrodetritus include the abscission of assimilating leaves and shoots, loss of lateral and annual branches, bark shedding resulting from volumetric growth, and dispersal of reproductive structures. Traumatic-induced loss, in contrast, may provide high quantities of biomass in geologically instantaneous events. Although canopy litter is continuously generated, the development of forest floor litters does not guarantee fossilization. Rather, the probability is extremely high that generated canopy litter will undergo decomposition (through bacterial, fungal, and detritivore activity). The rate of decomposition is dependent upon climatic as well as internal and external chemical parameters.

The litter that was amassed during peat accumulation was principally that of physiological loss (fig. VI-24) probably at accumulation rates similar to modern peat accumulating environments (McCabe, 1984). In most instances, less resistant canopy detritus (e.g., laminar portions of leaves, reproductive parts) underwent decomposition and were converted into the precursors of the vitrinite matrix. The more resistant woody and bark tissues had a higher probability of partial preservation. Winston (Alabama Geological Survey, written communication 1989), utilizing etched coal samples, has studied the preserved plant parts in the Newcastle coal outside our study area. He has found that lycophyte canopy detritus (comprised primarily of periderm) dominates the coal, accounting for up to 80 percent of the identifiable components in some zones. Lycophyte aerial parts are often found in association with resistant pteridosperm and fern parts, these being rachial fragments. Sphenophytes (*Calamites*) are infrequently encountered, and cordaitaleans are absent. Laminar portions of leaves are not recognizable in the coal samples.

The residence time on the forest floor before complete degradation processes removed the less resistant canopy detritus was probably similar to modern ecosystems. In montane rain forests in Puerto Rico, for example, La Caro and Rudd (1985) demonstrated that although litter decay rates of successional taxa differ after an initial rapid decay, only 10 to 20 percent of the composite litter remained after 16 weeks (113 days) of exposure. Therefore, under normal conditions, the less resistant components of the forest litter at the surface of the peat swamps would quickly become unrecognizable. Yet, the recovered coalified compression-impression assemblages at the contact between the coal and the overlying mudstone are exquisite in their preservational state. This points to extremely rapid inundation and burial to a depth where the organic material was isolated from biological decay processes. These conditions are necessary to preserve the litter where it fell.

The high magnitude flood events that were responsible for the burial of these forests altered the erect position of standing vegetation in two ways. Lycophytes possess underground axial systems that develop radially from the base of the tree, extending for distances up to 13 m. These plants that were well rooted in the peat substrate were slightly deflected from their upright position (fig. VI-24b; Gastaldo, 1986b). This accounts for the nonvertical orientation of cast lycophytes above coals in the study area. Sphenophytes (*Calamites*) may either be solitary or clustered due to their propagation through a subterranean rhizome. These plants were also deflected from a vertical position during the emplacement of the clastics. Pteridosperms, on the other hand, do not appear to have had significant underground rooting structures. Rather, they developed adventitious aerial roots (*Pinnularia*) assisting in upright stabilization of the plant. In some pteridosperm taxa, plants grew in clusters with intertwining individuals responsible for maintaining an upright habit of the clump (Wnuk and Pfefferkorn, 1984). These plants were easily pushed down during the high magnitude flood, and incorporated within the initial sedimentation. Occasionally, pteridosperm stems are encountered crosscutting the basal mudstone, but most often they are found prostrate within this fossiliferous interval.

The burial of the peat forest to depths of 3 m put most of the standing vegetation under fatal clastic stress. As noted above, *Calamites* appear to have had the potential to develop new roots from buried vertical axes. Depending upon the maturity of the standing lycophyte, the plant may have been forced into a phase of reproduction before death. Death of the erect forest ensued shortly after burial. Canopy

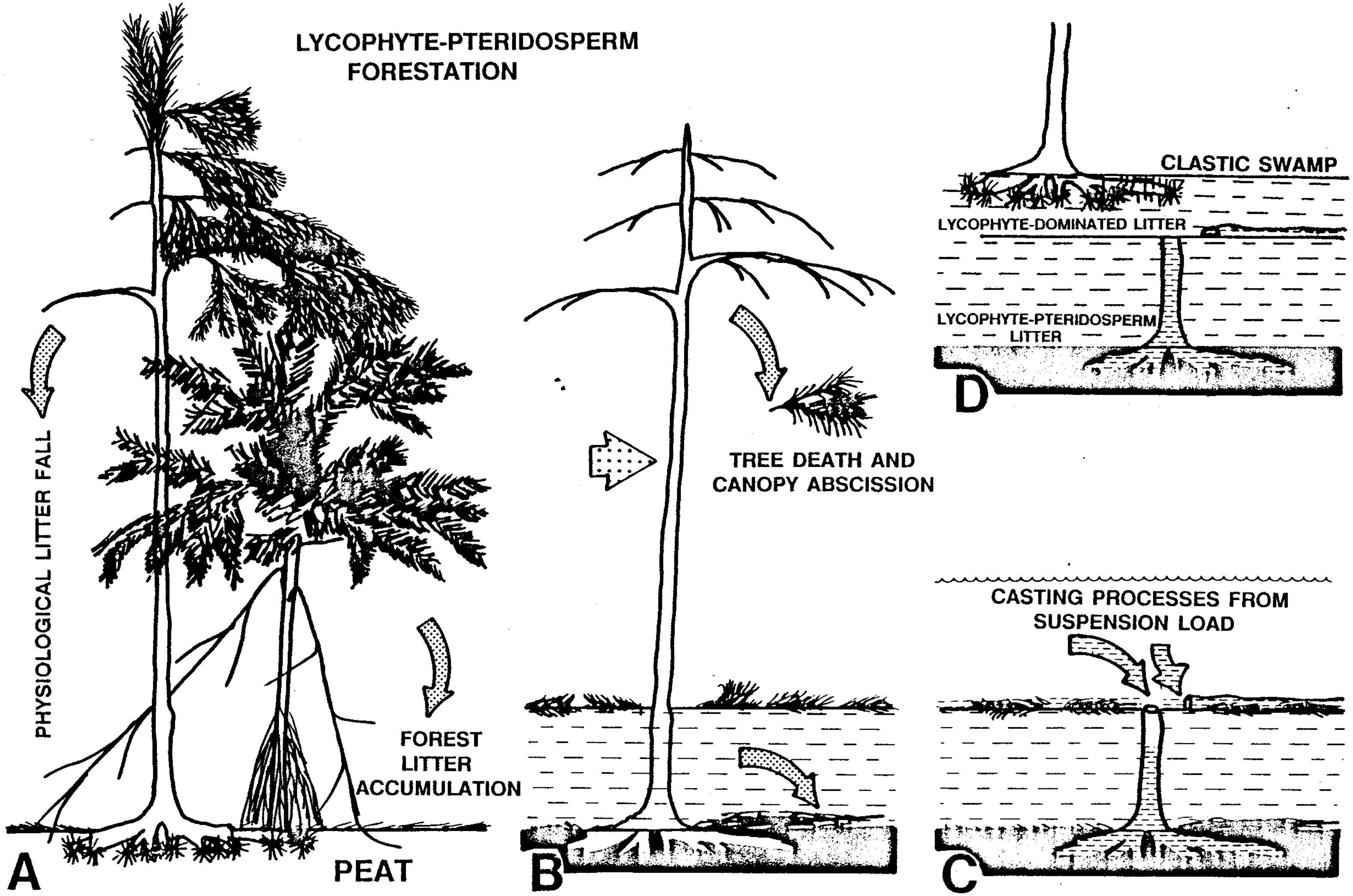

Figure VI-24.--Diagrammatic representation of processes responsible for the preservation of the terminal peat forests in the Mary Lee coal zone. (a) Ultimate community before inundation comprised of lycophytes in the canopy and a pteridosperm-dominated understory. (b) Low-frequency high-magnitude flood alters the erect position of the lycophytes and pushes the understory vegetation down. Burial follows as the flood peaks and wanes. Tree death ensues, and canopy parts accumulate on the surface of the flood deposit. (c) Dead lycophytes rot. Trunks break and fall onto the flood deposit surface. Subsequent low magnitude floods infill the hollow erect and prostrate trunks (see Gastaldo and others, 1989). (d) Burial of the lycophyte-dominated litter horizon occurs by another high magnitude flood. The pioneering lycophytes become reestablished in the clastic soil resulting in the development of a clastic swamp vegetation.

branches with and without leaves fell to the surface of the flood deposit. Rotting of the tree trunks eventually resulted in their breakage at or near the level of burial. The aerial part of the tree was emplaced in a prostrate position on the surface of the deposit. Lycophytes underwent selective degradation of internal tissues (DiMichele, 1981; Gastaldo, 1986b). This resulted in the maintenance of trunk integrity even when centrally hollowed. Subsequent small-scale flood events provided the sediment necessary to infill the hollow prostrate logs (Gastaldo and others, 1989) and erect trunk bases. If decay had proceeded to a stage where the underground *Stigmaria* were hollowed before the first clastic sediments were introduced into the trunk void, these subterranean axial systems were also cast. Their mud-cast remains occur in the upper parts of the coals (fig. VI-24c).

Continued sedimentation from various-scaled flood events eventually covered the lycophyte-dominated litters. Most often only prostrate mud-cast logs mark the horizon at which the litter accumulated and remained resident before final burial. The processes of infilling may be complex. Sediment-laden water flowing through the hollowed log may respond similarly to a pipe with rough boundaries. The irregular interior surface of the log will provide resistance to water flow thereby reducing velocity within the cavity. A reduction in flow velocity will affect the vertical velocity, resulting in an increased settling velocity. Deposition will ensue, and the result will be a single bed. As is the case with the prostrate cast lycophyte trunks, many beds (layers) of mud can be identified in transverse and longitudinal sections. Each identifiable bedding (layering) feature represents a single flood event. Multiple flood events, then, infill the cavity over time (see below). Gastaldo and others (1989) have documented in a modern analog the processes responsible for development of these lycophyte casts. They estimate that hollowed prostrate lycophyte trunks could remain in the swamp mud for several hundred years before being either completely or partially infilled before final burial. In some localities, other canopy litter can be recovered indicating that the time between death of the tree, emplacement of the canopy litter on the surface of the flood deposit, and burial was relatively short.

Recolonization of this flood deposit occurred when conditions were amenable for lycophyte germination and growth (fig. VI-24d). Lycophytes appear to be the pioneering plants in coastal lowlands of the Carboniferous (Gastaldo, 1986a). This is evidenced by the establishment of lycophyte-exclusive swamps of the intervening terrestrial clastic sequence between peat bodies (see Demko, this guidebook). In the Mary Lee coal zone, up to five levels of clastic swamps are preserved locally between the Mary Lee and Blue Creek coals. This reestablishment of vegetation in clastic substrates signals that conditions were not amenable to the accumulation of peat. Rather, continued clastic influx occurred. This accelerated the preservational processes found in clastic swamp environments resulting in the casting of hollowed erect and prostrate trees and compression (impression) of forest floor litter. Additionally, gleyed paleosols are permeated with preserved stigmarian appendages helically arranged around stigmarian axes. When localized subsidence slowed due to maximized peat compaction and stabilization of the coastal area occurred, conditions were favorable for the accumulation of canopy detritus as peat (Gastaldo and others, in press). Peat accumulation was again punctuated by anomalous flooding, initiating a new cycle.

COMMUNITY STRUCTURE IN EARLY PENNSYLVANIAN PEAT SWAMPS

Various techniques, based upon the preservational state of the plant community, have been used to assess the vegetational structure of Carboniferous peat swamps. The most successful results, to date, have been obtained from the systematic collection and analyses of permineralized coals in vertical profile (coal balls; e.g., DiMichele and Phillips, 1988). Recent advances in coal etching techniques can provide data comparable to coal ball studies (e.g., Winston, 1988), particularly where peat permineralizations are not known to occur. This is the case in the Warrior basin, and preliminary studies by Winston (this guidebook) have provided tantalizing data relative to community heterogeneity. Both of these techniques, though, generally are restricted to the assessment of those resistant plant parts found in the peat. Palynological data, collected from vertical channel samples, provides an independent test of the community constituents. These data may yield information not only on the dominant plants, but also on those that are not readily preserved due to rapid degradation of less resistant organs or architectures (see Eble, this guidebook). With the recognition of the biostratinomic processes responsible for the preservation of standing forests above coal seams, and the fact that the coalified compression assemblages preserved between erect vegetation represent the final peat swamp plant community, these "roof shale" floras take on a whole new significance relative to their use in community analysis. These autochthonous assemblages are truly fossil Lagerstätten. They not only provide information on the most resistant plant parts, but also on the most delicate. Because they represent the forest floor litter and the understory, these data can be used to reconstruct community guild organization and spatial patterning of vegetation.

The interpretations that follow, relative to these terminal peat communities, are a first attempt at integrating the data. These interpretations are based on the collected diversity and distribution data of canopy and subcanopy plants, and field observations. Continued data collection in restricted geographic areas will be the basis for further refinement of these generalities.

The dominant canopy vegetation in the buried stage of peat swamp development is undoubtedly lycophyte. The principal genera recovered and identified, to date, are *Lepidophloios* and *Diaphorodendron* (as identified by the absence of infrafoliar parichnos on the leaf cushion), although localized specimens of *Sigillaria* and *Lepidodendron* have been collected. Most lycophyte compressions are unidentifiable to genus due either to the development of vertical fissuring of the bark during growth, or coalification of the bark after burial. This correlates well with palynological data (see Eble, this guidebook). Sphenophytes (*Calamites*) are found infrequently either isolated or clustered in small groups. They do not appear to play a significant role as a member of the forest canopy, if it is assumed that they grew to such heights.

One characteristic of the canopy vegetation that is interesting concerns the diameters of the lycophyte trees relative to their spacing along any transect. Most trees are relatively small (average of 0.53 m for those trees believed more mature), yet the distance between trees may be great (fig. VI-23; table 2). This may be explained by several working hypotheses. Although the average tree diameter is relatively small (as compared to known lycophyte tree diameters exceeding 1 m), the vegetative crown may have been extensive covering tens of square meters. Competition for light and nutrients may have necessitated successful trees to be spaced appropriately on such a linear scale. It must be remembered that we do not have data on the disposition of trees in the third dimension relative to the transects. Based on data collected in the Plateau coal field, Gastaldo (1986a) demonstrated that erect trees occurred in successive mine cuts where there was an absence of erect trees in the previous highwall. It is likely that this condition may also prevail in the peat swamps. With such a spatial distribution of trees, the canopy probably would have covered the understory.

Another consideration might be related to the development and thickening of the accumulated peat in the swamp. In modern peat swamps of southeastern Asia and Indonesia, the size of individual trees of the same species is related to the availability of nutrients in the substrate (see Anderson, 1964). Where clastic influx rejuvenates the available minerals necessary for growth, plants respond by developing to a maximum potential. Once peat has accumulated to thicknesses that are infrequently inundated by flood-derived clastics, available nutrients in the peat soil have diminished and growth of the plant becomes stunted. The dominant forest tree in the peat swamps of Sarawak and Brunei, *Shorea albida*, grows to a robust size where there is a high available nutrient supply. Towards the thickest peat accumulation as one approaches the center of localized domes, *Shorea albida* becomes a small diameter tree. Stands of these plants are locally known as pole forests. In the center of the domed accumulation, where nutrient supply is extremely poor, *Shorea albida* develops as a dwarfed plant. Such a change in growth stature may have occurred with the lycophytes. The relatively smaller diameter of these trees living in a peat substrate away from the margin of the swamp (see Demko, this guidebook, fig. VI-8; Liu, this guidebook, fig. VI-18) may be the result of a decrease in available nutrients during the development of localized thicker peat accumulations.

A third hypothesis may be relevant to the discussion, and that relates to the dynamic character of the ecosystem. It is apparent that the peat swamp forest is not an even-aged stand of trees, as is often the case in some clastic swamp communities where standing water may prevail for up to nine months (see Gastaldo, 1989). The differences in recorded lycophyte tree diameters documented herein and in the Plateau coal field (Gastaldo, 1986a) suggest that there is a continued regeneration of the forest. This regeneration normally occurs when there is the death of a mature tree, allowing for an opening in the canopy. This permits an increased amount of light to penetrate to the forest floor, and intense competition to fill the space. The distances of tens of meters between trees may be the function of such openings in the canopy. A detailed evaluation of the compression floras within these large gaps would provide the data for interpreting the level of community development in these sites. It must be recognized that the preserved forest provides the viewer with an instantaneous glimpse in time. It is difficult to ascertain exactly the condition of the biocoenosis at the instant the "polaroid picture" was taken without intensive and systematic sampling. To date, field conditions have hindered such data gathering.

The composition of the understory vegetation is quite diverse and heterogeneous in its distribution. There may be two tiers of understory that developed beneath the lycophyte-dominated canopy. The pteridospermous elements probably dominate both tiers, as their vegetative and reproductive remains are the most commonly encountered fossils. Medullosan stems with lateral leaves are a typical component of the taphocoenosis in all collection sites. The parts may dominate the woody fraction particularly in those sites near the edge of the peat body (see Demko, this guidebook, fig. VI-8; Liu, this guidebook, fig. VI-18). In association with these trunks are large leaves (> 3 m in length) of *Neuropteris* (*N. schlehani, N. gigantea*), *Neuralethopteris* (*N. pocahontas, N. smithsii*), and *Alethopteris* (*A. decurrens, A. lonchitica*), pollen organs of the *Whittleysia*-type, and trigonocarpalean seeds. As discussed by Wnuk and Pfefferkorn (1984) and reconstructed by Pfefferkorn and others (1984), such plants were probably large shrubs (as delimited by a height <6 m) or small trees. These were probably the principal components of the second tier in the forest. The *Calamites* that are preserved erect in the flood deposits probably were also components of this primary understory tier.

The most frequently encountered and abundant plant is *Sphenopteris pottsvillea* (Gastaldo and Boersma, 1983; Gastaldo, 1988b). Bipartite leaves of this taxon are ubiquitous throughout the study area and appear to be endemic to the Appalachians. Where leaves have been found attached to apparently parental stems, they are widely spaced along stems that are small in diameter (1 to 2 cm). Individual leaves may be as long as 1.5 to 2 m. The characteristics of a large leaf, the structural integrity of which appears to be extremely good (see Gastaldo, 1988b, fig. 2), developing from a small diameter stem can be used to interpret the habit of this plant. It is quite possible that *Sphenopteris pottsvillea* was a ground creeper with the stem growing either along the surface of the peat or intertwining with other erect vegetation above the surface of the peat. This plant, and other vine-like plants, would constitute the lowest tier of the forest.

It is difficult at this time to ascertain the relative tier position(s) for the remainder of the forest elements. Most compressions are of leaf parts and these are not found attached to a parental plant axis. This may be due to the leaf's dehiscence after becoming nonfunctional, incomplete recovery of the fossil due to fracture of the rock during mining operations, or the present lack of recognition of the types of axes from which these leaves developed. Plants that are included within this category include a diverse assemblage of bipartite and planated leaves such as *Sphenopteris* (sensu latu), *Palmatopteris, Eusphenopteris, Eremopteris,* and *Lyginopteris*. It is most likely that these plants played a role in the understory tiers, as they have not been collected, to date, from the lycophyte-dominated assemblages that accumulated after burial of the forest (fig. VI-24).

CONCLUSIONS

The erect plants that occur directly above each of the coals in the Mary Lee coal zone represent the peat-accumulating swamp forest at the time of catastrophic burial. The burial process involved high-magnitude low-frequency floods that inundated vast tracts of the coastal lowland. These floods altered the erect positions of the canopy lycophytes and pushed over the pteridosperm-dominated understory. The compression assemblages found at the contact between the coal and the overlying mud represent the forest floor litter resident on the surface of the peat swamp prior to burial. The diverse compression assemblages recovered from the first 0.5 m of mudstone above the coal represent the drowned understory vegetation. Burial of the forests resulted in the death of the canopy vegetation. Aerial plant parts of this vegetation accumulated on the surface of the flood deposit. These compression assemblages are monodominant. The most commonly encountered elements in the clastic sequence are mud-cast prostrate logs, representing each forest surface.

Peat swamp forests were a heterogeneous mixture of plants of various growth architectures and habits. The canopy tier was dominated exclusively by lycophytes. It is not known whether the lycophytes comprised a closed or partially open forest canopy. Because forests are dynamic ecosystems, this condition most likely fluctuated as edaphic conditions were altered and death of canopy trees occurred. The understory tier was comprised of a mixture of pteridospermous and sphenophytalean elements, the former being dominant. It is believed that the most ubiquitous plant, ***Sphenopteris pottsvillea***, may have occupied the lowest tier in the forest. The additional pteridospermous and pteridophyllous plants recovered in these taphocoenoses were components of either, or both, lowest tiers. The distribution of plants within the peat swamps differs from that documented by Gastaldo (1987) in clastic swamps of the same age in the southern Appalachians.

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COAL-PALEOBOTANY OF THE MARY LEE COAL BED OF THE PENNSYLVANIAN "POTTSVILLE" FORMATION NEAR CARBON HILL, WALKER COUNTY, ALABAMA

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ABSTRACT

Coal-paleobotany is here defined as the study of plant megafossils in non-permineralized coal by means of their anatomy and morphology. Four samples of the Mary Lee coal bed of the Pennsylvanian "Pottsville" Formation near a paleochannel area in Walker County were selected for the first coal-paleobotanical analysis of Alabama coal. The floral assemblage of each sample has been quantified by identifying the most abundant plant type in each 1-mm increment of the coal bed using etched, polished coal blocks. The coal floral assemblage is dominated by lycopods (59 to 80 percent), with pteridosperms and possibly ferns as subdominants. Pteridosperms are most common in coal layers with abundant sandstone interbeds. Ferns appear to be most abundant in zones lacking sandstone interbeds. Calamiteans are rare. Cordaiteans have not been observed in any of the Alabama samples. By comparison, lycopods, a group especially favored by wet conditions, are generally not as abundant (45 to 60 percent) in other Alabama coals, suggesting that proximity to the paleochannel resulted in a wetter local environment. One of the Mary Lee samples contains the highest abundance of pteridosperms so far observed in an Alabama coal bed.

INTRODUCTION

Coal-paleobotany is here defined as the study of plant megafossils in non-permineralized coal by means of their anatomy and morphology. That the anatomy of plants is still preserved in coal might seem surprising, but it has long been known—if little publicized (Thiessen and Sprunk, 1942). In modern coal petrology, the polished coal surface is usually examined using oil-immersion objectives. Plant anatomy usually cannot be seen using this technique, but if the coal is etched or if thin sections are employed, the anatomy becomes readily apparent. By tracing plants from coal balls (permineralized peat) to coal, it has been possible to identify major plant taxa in coal (Winston, 1986, 1989; Lapo and Drozdova, 1989) and to quantify the abundances of these taxa in coal (Winston, 1988).

In this study, abundances of major plant taxa are quantified in several samples of the Mary Lee coal bed of the Pennsylvanian "Pottsville" Formation in or near a channel deposit (Liu, this guidebook) near Carbon Hill, Walker County, Alabama. The results from these samples are then compared to the results from other Alabama coal samples ranging from the Black Creek to the Cobb coal groups. Coal-paleobotany has not yet been applied to samples of the Mary Lee coal bed away from the paleochannel area, so comparisons with other Mary Lee samples cannot be made at this time.

MATERIALS

Four samples of the Mary Lee coal bed of the "Pottsville" Formation were collected at sites indicated in figure VI-25. Samples 16 and 81 through 83 represent the Mary Lee coal bed. Samples of other coal beds in the "Pottsville" Formation provide a basis of comparison. The localities of all the samples are listed in table 4. Sample 16 comes from stop 1A of the field trip (unit 12 of Raymond and others, 1988, p. 336). All the samples are on file at the Geological Survey of Alabama.

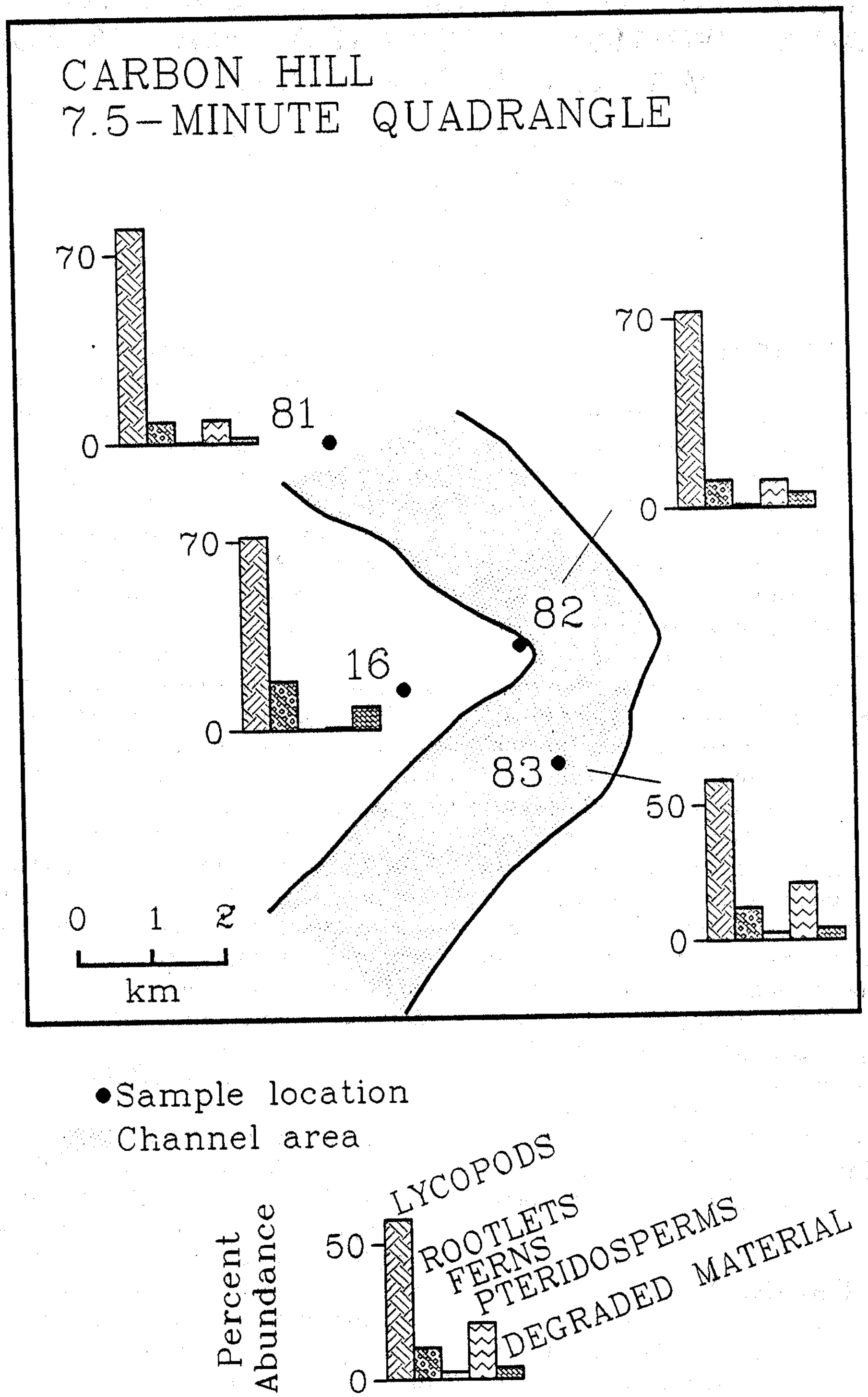


Figure VI-25.--Sample localities in the Mary Lee coal bed (channel area from Liu, this guidebook) with plant fossil abundances at each locality.

Table VI-4.--Localities of coal beds sampled for this study

Sample number (RBW)	Coal bed	Locality
16	Mary Lee	SE¼ sec. 15, T. 13 S., R. 10 W.
81	Mary Lee	E½SW¼ sec. 3, T. 13 S., R. 10 W.
82	Mary Lee	SE¼NE¼ sec. 14, T. 13 S., R. 10 W.
83	Mary Lee	SE¼NW¼ sec. 24, T. 13 S., R. 10 W.
8	M	NE¼SW¼ sec. 36, T. 18 S., R. 5 W.
14	Black Creek?	Sec. 15, T. 14 S., R. 5 W.
12	Jefferson	NW¼ sec. 17, T. 12 S., R. 11 W.
15	Jefferson	NE¼SE¼NW¼ sec. 16, T. 14 S., R. 5 W.
17	Jagger	SE¼ sec. 15, T. 13 S., R. 10 W.
19	Blue Creek	SW¼ sec. 10, T. 13 S., R. 10 W.
11	New Castle	NW¼NE¼ sec. 33, T. 14 S., R. 6 W.
9	American	NE¼ sec. 35, T. 16 s., R. 6 W.
4	Pratt	SE¼NE¼ sec. 23, T. 14 S., R. 11 W.
3	lower(?) Cobb	NW¼NE¼ sec. 36, T. 15 S., R. 9 W.

METHODS

The techniques of preparing and quantifying samples for coal-paleobotany have been reported previously (Winston, 1986, 1988) so they will be only outlined here. Oriented blocks of coal representing the entire, stratigraphic thickness of the coal bed are collected and embedded in plastic. Surfaces perpendicular to bedding are polished and etched. Etching can be accomplished best with a low-temperature, plasma asher. Chemical methods as described by Stach and others (1982) also can be used, but chemical methods are less easily controlled and result in more preferential etching of scratches.

The most abundant plant type in each 1-mm increment of the etched coal is identified under the microscope and recorded. Plant fossils thickness greater than 1 mm is measured to the nearest millimeter.

To display the data, each profile is divided into more or less homogeneous zones using a computerized trial-and-error method. The difference in plant fossil abundance between adjacent zones is maximized. No zone, however, is allowed to be less than 5 cm thick. Zone averages are plotted.

Another method of displaying the data makes use of plotting averages of overlapping 5-cm-thick increments. This method is similar to data representation on a geophysical log of an oil well. Logging tools may measure the average properties of rock sections up to 3 m thick. Despite this, they provide a continuous output rather than providing only one measurement for each 3-m increment. Thus, adjacent points on the log cover overlapping increments. For the plant fossil abundances, measurements of plant abundance are made every 1 cm in overlapping increments of coal 5 cm thick (fig. VI-26). This is a technique for smoothing the data.

No polished blocks of the sandstone partings in sample 83 have been prepared. Instead, their thicknesses have been measured and they have been assumed to be entirely sandstone.

Plant taxa present (fig. VI-27) include lycopods, ferns, calamiteans (also known as sphenopsids), pteridosperms, and cordaiteans (Winston, 1986, 1989). Two genera of lycopods, *Diaphorodendron* and *Sigillaria*, were identified (Winston, 1986, 1989). A third identifiable genus, *Lepidophloios*, was not observed; however, this is not conclusive evidence of its absence. Most lycopod specimens cannot be identified to genus. Even specimens of *Lepidophloios, Diaphorodendron*, and *Sigillaria*, can rarely be identified. The rootlets of lycopods and ferns cannot be distinguished from one another in coal and are recorded as a separate category as are degraded material, shale, sandstone, and other mineral matter.

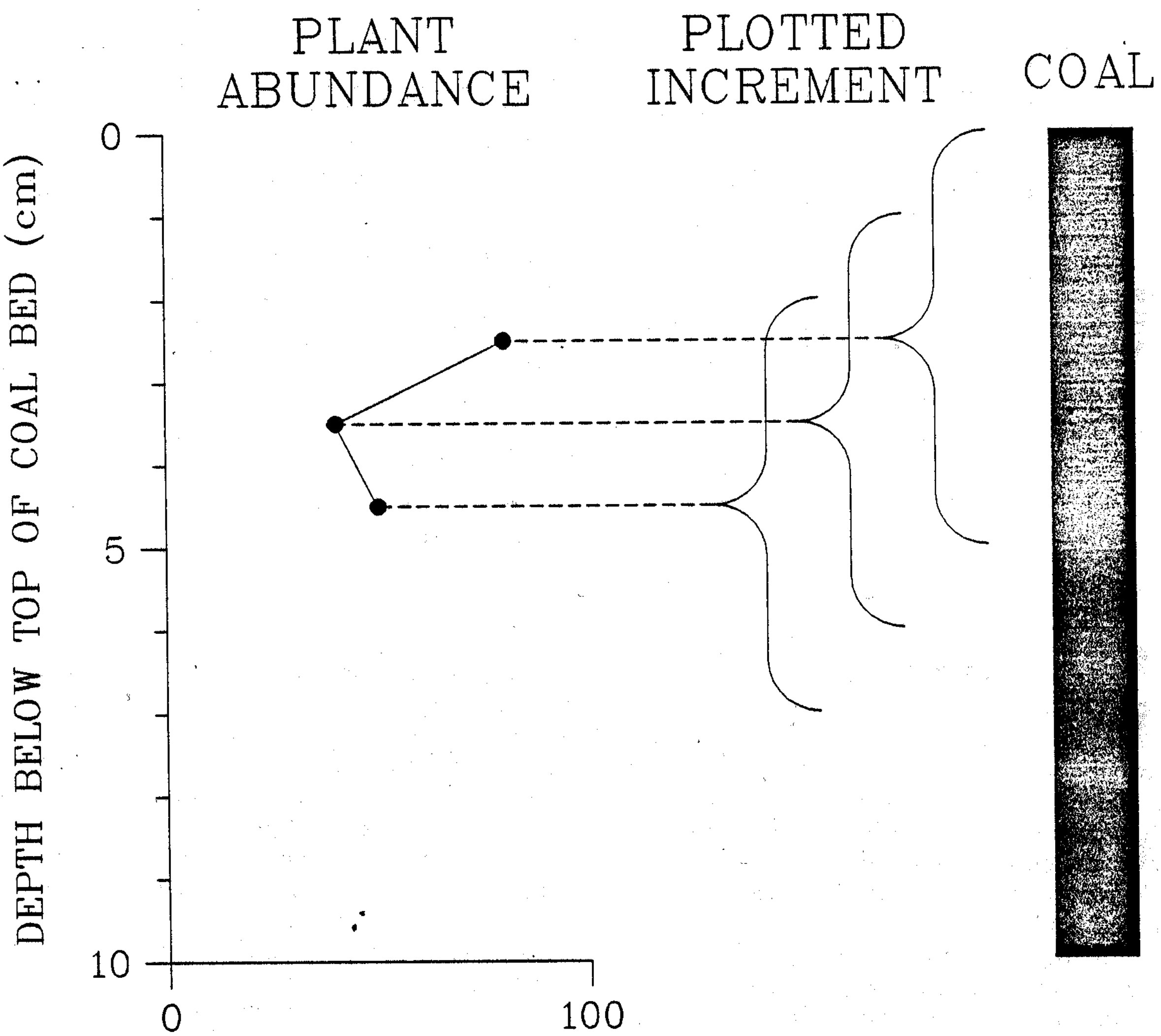


Figure VI-26.--Plot of plant abundance in overlapping increments of coal.

"Degraded material" comprises small pieces of organic matter lacking diagnostic, taxonomic characteristics. Desmocollinite, vitrodetrinite, isolated pieces of corpocollinite, and similar materials are the most common types of degraded material. Mineral matter is excluded when computing the abundance of the organic constituents and when dividing the coal beds into zones. Thick sandstone and shale partings (samples 16 and 83) are manually separated into zones once other zone boundaries have been picked using the plant abundance data (figs. VI-28 and VI-30).

RESULTS

In three of the Mary Lee samples (16, 81, and 82) (figs. VI-28 through VI-29), lycopods represent over 70 percent of the preserved megafossils (fig. VI-25, table VI-5). This contrasts greatly with their abundance in other Alabama coal beds in which typical lycopod abundances range from 45 to 60 percent (table VI-5). In the other Mary Lee sample (sample 83, figs. VI-25, VI-30), lycopods represent 59 percent of the preserved megafossils. Rootlet abundance ranges from 8 to 18 percent in the Mary Lee

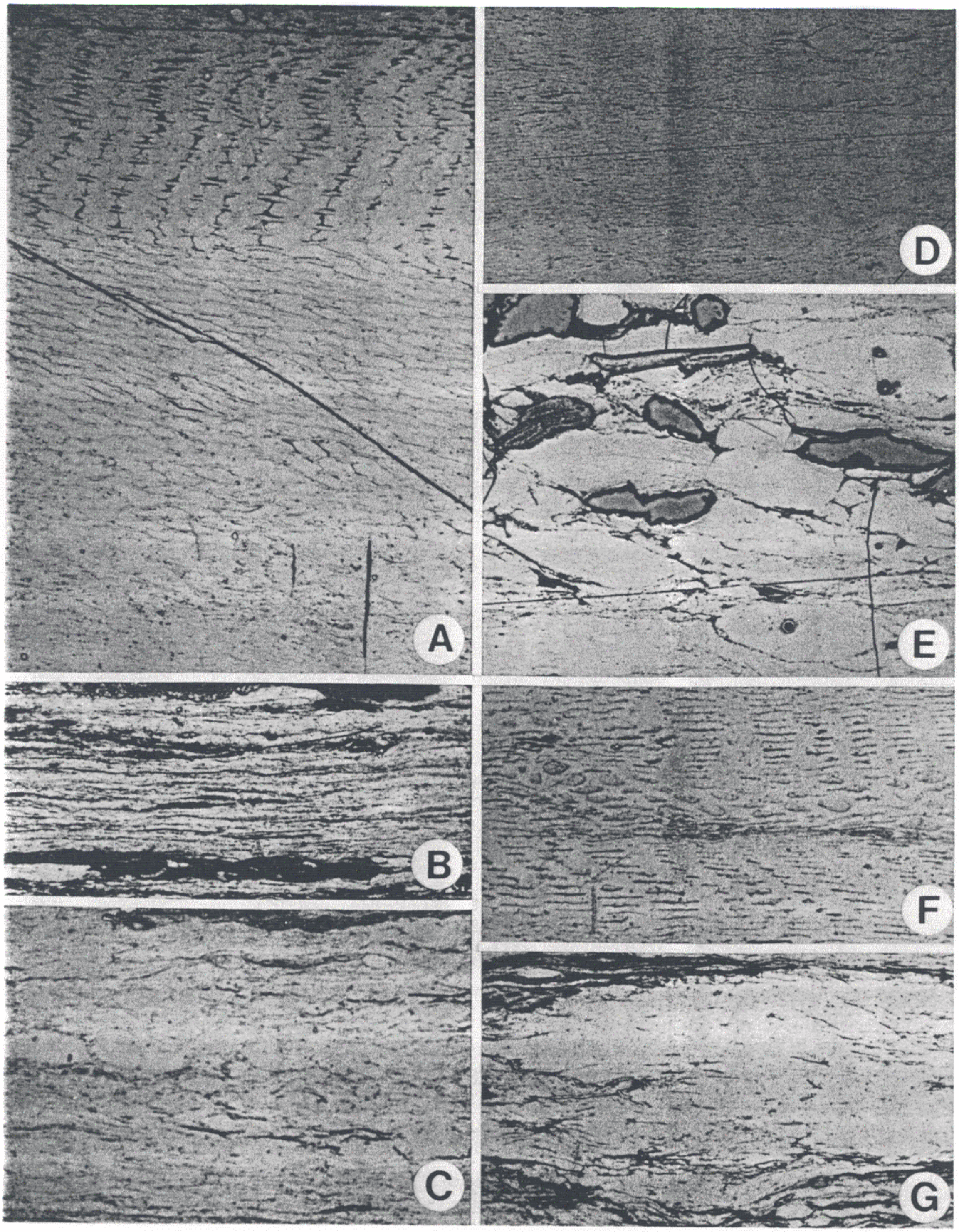
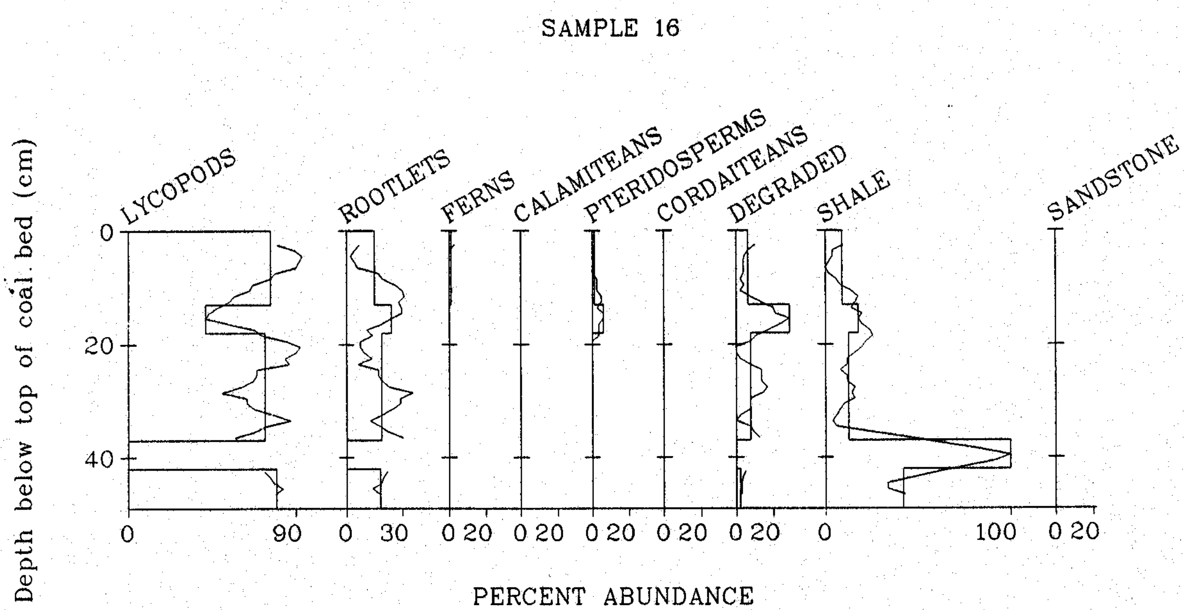


Figure VI-27.--Examples of plant fossils in coal. Magnification = 274x unless otherwise noted. (a) lycopod, (b) rootlet, (c) fern, magnification = 545x, (d) calamitean, (e) pteridosperm (dark bodies are sand grains), (f) *Diaphorodendron, G. Sigillaris.*



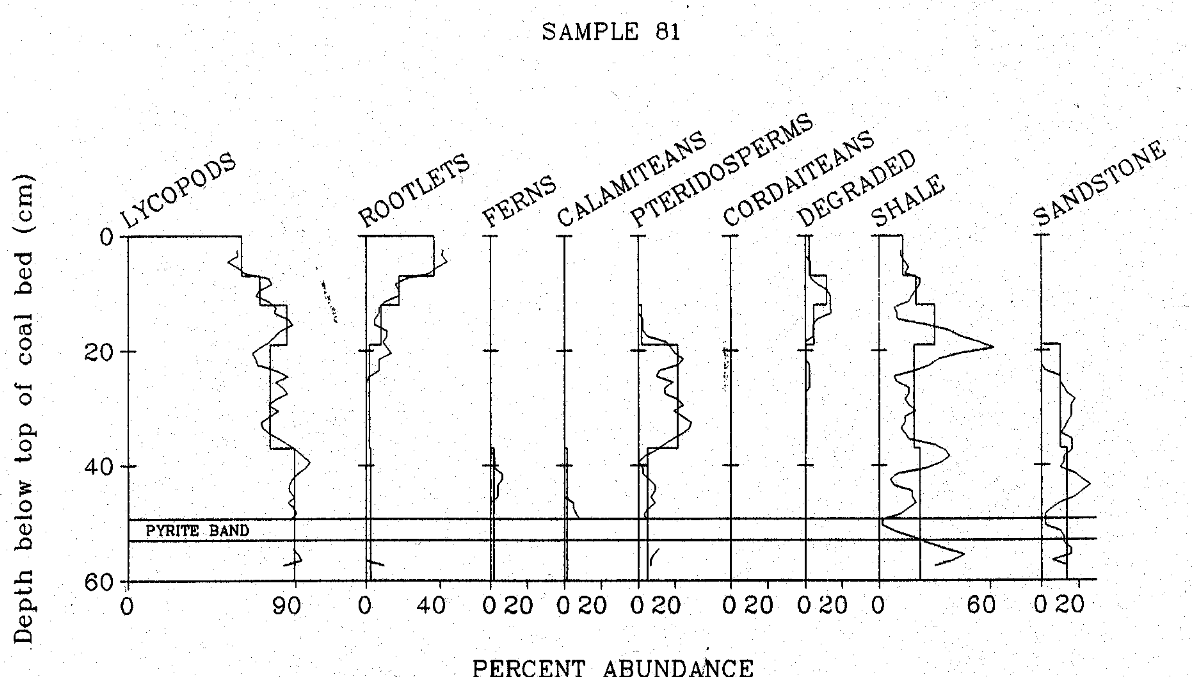


Figure VI-28.--Vertical distribution of plant groups in samples 16 and 81.

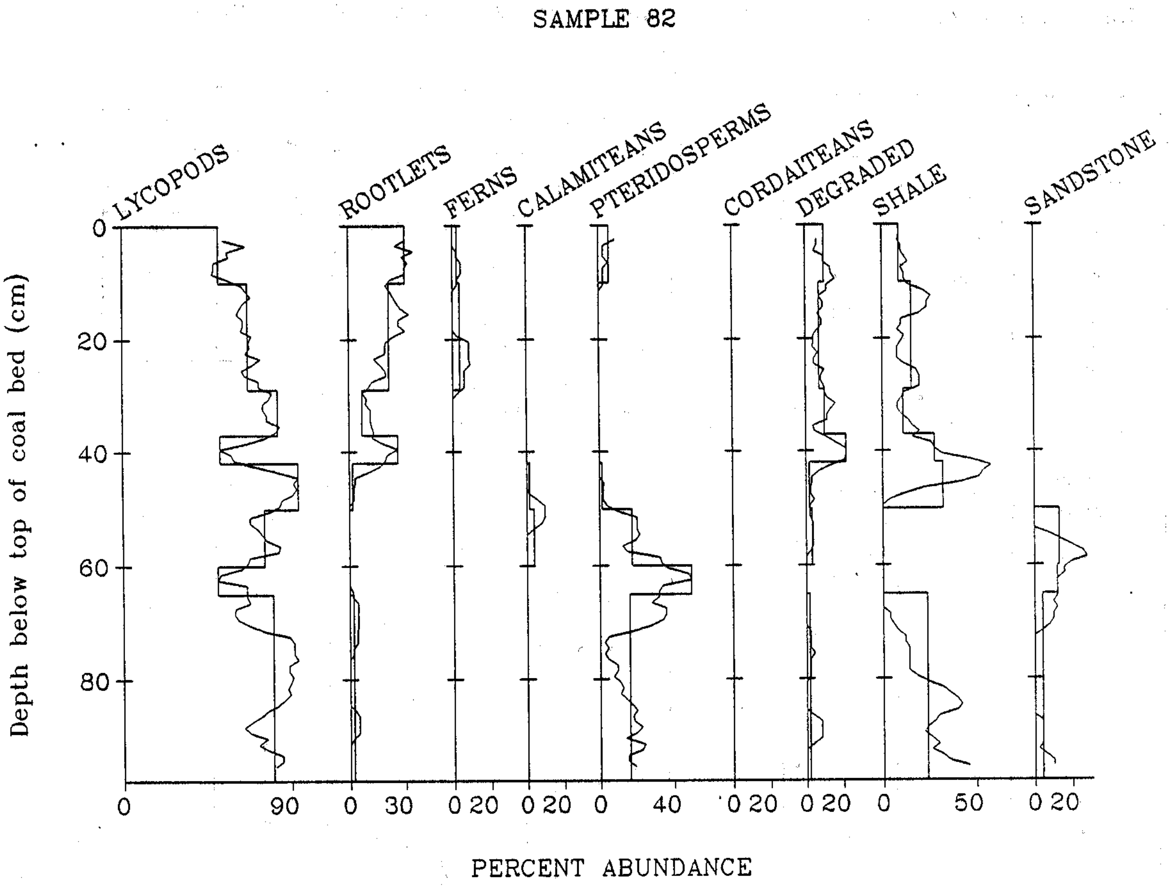


Figure VI-29.--Vertical distribution of plant groups in sample 82.

samples whereas in other coal beds rootlets typically comprise 20 to 40 percent of the coal (fig. VI-25, table VI-5). Preserved ferns and calamiteans are scarce in the Mary Lee samples (0 to 3 percent). Cordaiteans have not been observed in any of the Mary Lee samples. Samples of other Alabama coal beds give similar results for ferns, calamiteans, and cordaiteans (table 5). Pteridosperms range in abundance from 1 to 21 percent in the Mary Lee samples (fig. VI-25, table VI-5). In other Alabama samples they range from 1 to 13 percent. The highest abundance of pteridosperms in the Mary Lee samples is in the sample where sandstone is most common while the lowest abundance occurs where sandstone is absent from the coal. Sample 83 has the highest abundance of pteridosperms yet recorded for an Alabama coal. Degraded material comprises 2 to 7 percent of the coal, similar to results from many other Alabama coal beds (table VI-5). *Diaphorodendron* occurs in samples 82 and 83. *Sigillaria* occurs in sample 82. In both samples 82 and 83, *Diaphorodendron* and *Sigillaria* each comprise less than 3 percent of the coal.

Within individual samples, the abundance of degraded material parallels rootlet abundance in all the Mary Lee samples especially samples 16 and 83 (figs. VI-20 through VI-30). Ferns are more abundant in zones where degraded material and rootlets are more abundant in samples 82 and 83 (figs. VI-29, VI-30). Ferns are rare in all parts of samples 16 and 81 (fig. VI-28). Rootlets, degraded material, and ferns are scarce or absent in zones where sandstone is present such as in the upper part of sample 83 (fig. VI-30).

Pteridosperms tend to be most abundant in zones with abundant sandstone (for example, in the upper part of sample 83 and the middle of sample 81) (figs. VI-28, VI-30). Pteridosperms decrease in abundance upsection below the

Table VI-5.--Taxonomic composition of samples of Alabama coal beds for this study

Mary Lee samples

Sample number	Plant taxa[1]							
	Lyc	Rl	Fe	Cal	Pt	Cord	Deg	Min
16	72	18	0	0	1	0	7	25
81	80	8	1	<1	9	0	2	38
82	72	10	1	1	10	0	6	20
83	50	12	3	0	21	0	3	42

Samples from other Alabama coal beds

Sample number	Plant taxa[1]							
	Lyc	Rl	Fe	Cal	Pt	Cord	Deg	Min
8	46	40	3	0	5	0	6	0
14	46	25	6	0	8	0	14	14
12	58	9	2	0	1	0	29	0
15[2]	27	46	0	0	12	0	14	6
17	56	28	0	0	13	0	2	24
19	49	36	5	0	9	0	2	21
11	55	21	5	0	8	0	12	2
9	48	36	3	0	7	0	6	4
4	55	28	13	0	2	0	3	1
3	49	29	8	0	3	0	10	2

[1] Lyc = lycopods, Rl = rootlets, Fe = ferns, Cal = calamiteans, Pt = pteridosperms, Cord = cordaiteans, Deg = degraded material, Min = minerals.
[2] Only the upper bench is reported. The lower bench is a thick, local deposit of sapropelic coal.

upper parting in sample 83 (fig. VI-30). Above the upper parting, however, pteridosperms are abundant (fig. VI-30).

Lycopods decrease in abundance upsection in samples 81 and 82 where they are replaced by rootlets (figs. VI-29, VI-29). In sample 83, lycopods instead increase in abundance upsection (fig. VI-30).

DISCUSSION AND CONCLUSION

Certain taphonomic biases must be considered when interpreting these results. Comparison of palynological (C. F. Eble, personal communication, 1989) and coal-paleobotanical (R. B. Winston, unpublished) data from the same localities in the central Appalachian basin suggest that fern tissues decay preferentially relative to other plant groups so that much of the degraded material in coal-paleobotany may be derived from ferns. Assuming that degraded material is from ferns, then relative to coal-paleobotany, ferns are over-represented in palynological data by about 3:1 compared to lycopods. This does not mean that coal-paleobotany is more accurate than palynology; since we can know only the composition of the fossil assemblages and not the true makeup of the original vegetation, we cannot determine whether coal-paleobotany or palynology is more accurate. With respect to pteridosperms, however, coal-paleobotany does provide some information not generally provided by palynology. *Zonalosporites* (= *Monoletes*), the pollen of the pteridosperm *Medullosa*, is frequently very large (Stewart, 1983, p. 265) and is often screened out during routine, palynological sample preparation. Palynology

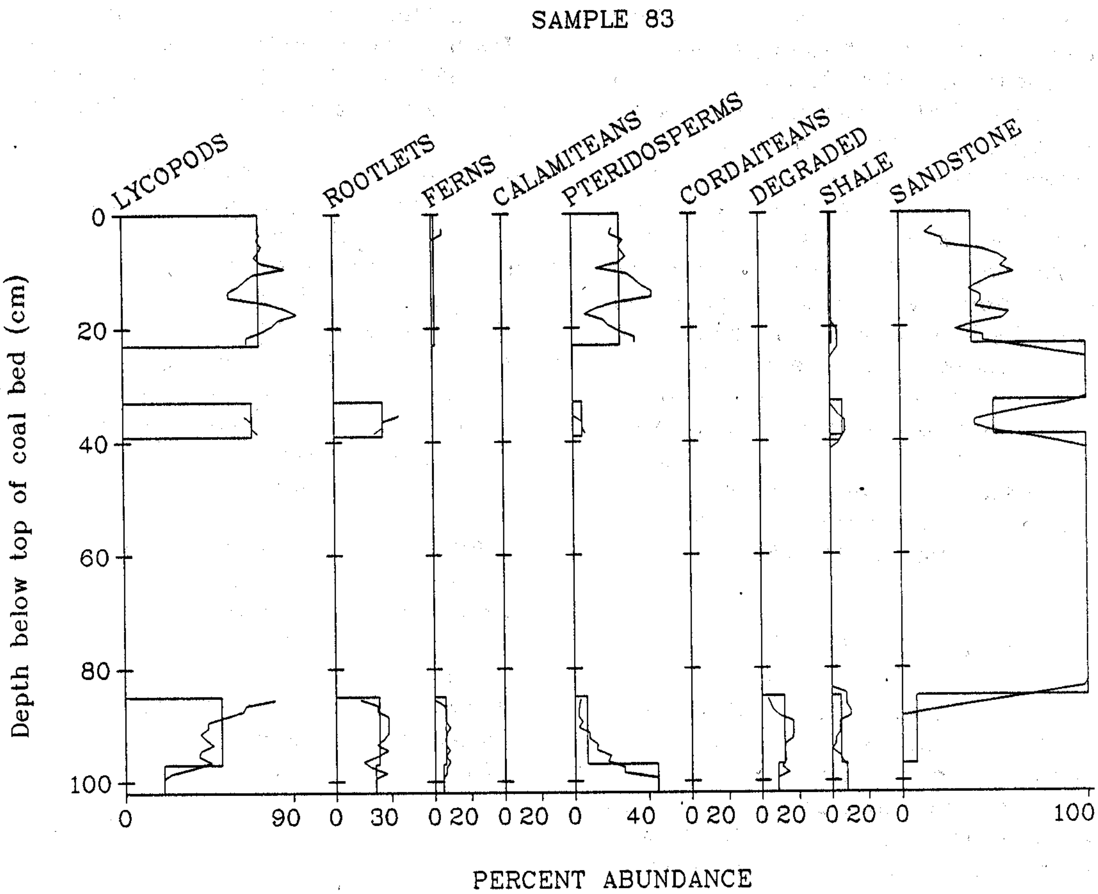


Figure VI-30.--Vertical distribution of plant groups in sample 83.

and coal-paleobotany combined probably provide a more complete understanding of the original vegetation than either does alone.

The high abundance of lycopods in the study area indicates that they were the dominant plant group in the local paleoenvironment. Pteridosperms were also important at least in some places. Similar trends in the abundance of ferns, rootlets, and degraded material suggest that ferns were more abundant in the original vegetation than in the coal. This is because preferential decay of ferns would have increased the amount of degraded material, and ferns would have been an added source of rootlets. If this interpretation is correct, then the relative abundance of ferns increased through time at the localities represented by samples 81 and 82, but decreased in abundance at the locality represented by sample 83. At the locality represented by sample 16, ferns appear to have been an important constituent throughout the time of peat accumulation. The low abundance of rootlets, degraded material, and fern material in zones containing sandstone suggests that the conditions responsible for sandstone deposition were unfavorable for fern growth. Another possibility is that fern decay was especially efficient in the channel area so that no degraded material remained. Pteridosperms tend to be most common in intervals containing sandstone suggesting that environmental conditions responsible for sandstone deposition were favorable for their growth.

The presence of numerous sandstone partings indicates that sand was introduced into the swamp many times. Sand could have been introduced into the peat-forming environment by flooding, by being blown from nearby levies, and by reworking of underlying sand layers by root throws.

The overall distribution pattern of plant taxa in the Mary Lee coal bed in the study area is one of lycopod dominance with pteridosperms and ferns as subdominants. Pteridosperms were associated with sand deposition while ferns were probably most common in areas of peat formation without sand deposition. Lycopods are generally more common in the study area of the Mary Lee coal bed than in other Alabama coal beds. Lycopods are favored by wetter conditions so the high lycopod abundance may reflect a locally wetter environment. In the Mary Lee sample that does not have unusually abundant lycopods, pteridosperms are more common than in other Alabama coal beds. It remains to be seen whether the high lycopod and pteridosperm abundances reflect local conditions or are typical of the Mary Lee coal bed.

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A PALYNOLOGICAL TRANSECT, SWAMP INTERIOR TO SWAMP MARGIN, IN THE MARY LEE COAL BED, WARRIOR BASIN, ALABAMA

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ABSTRACT

Incremental samples of the Mary Lee coal bed, collected along a proximal—distal swamp margin transect, were studied palynologically to determine if any vertical or lateral changes in swamp vegetation could be detected. Results show the Mary Lee palynoflora to be dominated by *Lycospora* spp. (arborescent lycopods), with other lycopod affiliated genera, *Crassispora* (*Sigillaria*) and *Densosporites* (small lycopods), occurring less frequently. Commonly encountered fern/pteridosperm allied miospore genera include *Leiotriletes, Granulatisporites, Lophotriletes* and *Schulzospora*. *Calamospora*, representing calamites, and *Florinites*, representing cordaites, are minor constituents of the overall palynoflora.

Both vertical and lateral palynofloral changes occur along the studied transect. Physical lateral changes include the occurrence of inorganic partings and high ash coal layers containing poorly preserved miospore assemblages at proximal swamp margin locations, in contrast to parting-free coal containing well-preserved assemblages at swamp interior locations. Lateral palynofloral changes, in a distal—proximal direction, include an increase in *Lycospora pusilla* (*Lepidodendron*) over *Lycospora pellucida* (*Lepidophloios*) and an increase in ferns, calamites, and cordaites. Vertical changes were also noted. At swamp interior locations basal coal layers contain either an arborescent lycopod dominant assemblage with abundant *Lepidodendron*, or a lycopod—fern/pteridosperm co-dominant assemblage. This flora grades upward into a *Lepidophloios*-dominant flora in middle layers and ultimately into a flora containing an abundant fern/pteridosperm element.

This vertical change is probably a response to changing edaphic conditions during peat accumulation. A decreased availability of super-saturated substrates, due to doming of the peat surface, may have been a controlling factor on arborescent lycopod development and expansion, with ferns/pteridosperms occupying more domed areas. An influx of more nutrient-rich, sediment laden (?) waters, on the other hand, might allow for increased pteridosperm development towards the top of the bed, in response to a drowning of the swamp. In both cases, the palynological signatures would be the same. Ash yield and sulfur content data should help discern which interpretation is more parsimonious.

INTRODUCTION

In the Warrior coal field of northwestern Alabama the Mary Lee coal bed occurs in the middle part of the Pennsylvanian "Pottsville" Formation. It is generally the thickest and most economically important coal bed in the Mary Lee coal group which includes, in descending order, the Newcastle, Mary Lee, Blue Creek and (in places) the Jagger coal beds (fig. VI-2; Demko, this guidebook). The Mary Lee is late Early Pennsylvanian in age and equivalent to the Westphalian A of western Europe (Cropp, 1960; Upshaw, 1967; Woerner, 1981; Gastaldo, 1982; Eble and others, 1985; Eble and Gillespie, 1989). This study is a palynological investigation of the Mary Lee coal bed to see if any vertical and/or lateral changes in the swamp flora can be detected by palynological indices along a traverse from "swamp interior" to "swamp margin". Pennsylvanian miospore analyses have been useful in reconstructing the paleoecology of ancient coal-forming swamps primarily for two reasons: (1) the pollen rain in large, modern swamps, thought to be good analogues for Pennsylvanian swamps, is largely autochthonous and therefore represents the local, contemporaneous flora (Anderson and Muller, 1975); and (2) the major palynomorph taxa recovered from Pennsylvanian coal beds have now been affiliated with their parent plant types (see Ravn, 1986 and Eble, 1988 for comprehensive reviews). However, because the quantities of spores and pollen produced by Pennsylvanian plants is unknown the possibility exists that some plants in the local vegetation were either over or under represented by their spore and pollen record. Therefore, changes in parent vegetation, based on changes recorded in the miospore flora, must be considered in relative, and not absolute terms.

PREVIOUS WORK

Cropp (1960) and Upshaw (1967) were the first to study Warrior coal field palynofloras. Woerner (1981) examined miospore assemblages of the Mary Lee and Blue Creek coal beds in order to reconstruct their paleoecology. He found the Mary Lee coal bed to contain a greater diversity and abundance of lycopod miospores than the Blue Creek coal bed, which contained more pteridosperm and fern related palynomorphs. On this basis, Woerner (1981) inferred that the ancient Mary Lee paleoswamp developed under wetter conditions than did the underlying, older Blue Creek paleoswamp.

MATERIALS AND METHODS

Vertically continuous, one-tenth meter increments of the Mary Lee coal bed were sampled from six locations in active and abandoned surface mines in Walker County, Alabama (fig. VI-31). The sampling scheme represents a traverse from distal parts of the swamp to the proximal swamp margin (Demko, 1989). This traverse essentially runs parallel to U.S. Route 78 (fig. VI-31). Sixty-two increment samples of coal and included clastic partings (shale, sandstone) were used in this study.

All samples were mechanically crushed to -18 mesh (1 mm) size, riffled and split to obtain a representative sample of 50 grams. Five grams were subsequently removed for palynological maceration. Palynomorph preparation procedures followed those outlined by Doher (1981) with minor modifications to achieve best results. Coal samples were oxidized in Schultze's solution (nitric acid saturated with potassium chlorate), digested in five percent potassium hydroxide, screened with a -60 mesh (250 µm) sieve to isolate the miospore fraction, and concentrated in a zinc chloride solution (specific gravity 1.9). Two hundred fifty miospores were counted from Canada Balsam mounts of each sample residue to determine relative abundances of spore taxa.

RESULTS

The overall miospore flora of the Mary Lee coal bed in the study area is dominated by *Lycospora* spp., representing arborescent lycopods (Andrews and Pannell, 1942; Felix, 1954). This corroborates the earlier findings of Woerner (1981). Other common lycopod miospore genera include *Crassispora*, representing *Sigillaria*, and *Densosporites* (and the related crassicingulate genera, *Cingulizonates* and *Cristatisporites*), which may have been produced by a small lycopod tree (Wagner, 1985, 1989). Sphaerotriangular miospore genera of fern (Mamay, 1950; Millay, 1979; Good, 1979, 1981) or pteridosperm (Millay and others, 1978; Brousmiche, 1983) affiliation, including *Leiotriletes, Granulatisporites* and *Lophotriletes* are common components of the Mary Lee coal bed palynoflora. *Schulzospora*, pteridosperm pre-pollen (Remy and Remy, 1955; Potonié, 1962), also occurs frequently. Other common accessory taxa include *Calamospora*, representing calamites (Arnold, 1944; Baxter, 1963; Gastaldo, 1981) and *Florinites*, representing cordaites (Delevoryas, 1953; Wilson, 1960; Brush and Barghoorn, 1962; Millay and Taylor, 1974, 1976) (figs. VI-32 and VI-33).

VERTICAL AND LATERAL MIOSPORE VARIATION

INTERIOR LOCATIONS

The three "swamp interior" sample sites, locations 073, 054 and 036 (fig. VI-31), display similar vertical miospore variation, even though the coal is twice as thick at location 054 (1.3 m) than at locations 073 (0.66 m) and 036 (0.67 m). All three locations display an upward increase in the amount of fern/pteridosperm related taxa (*Granulatisporites* + *Schulzospora*) over arborescent lycopod miospores (*Lycospora* spp.), which are abundant in the middle and basal portions of locations 036 and 054 (figs. VI-34 and VI-35). At location 073, the basal coal layers contain increased percentages of *Granulatisporites*. At all three locations the lycopod genera *Crassispora* and *Densosporites* are consistently represented, but in minor amounts. Likewise,

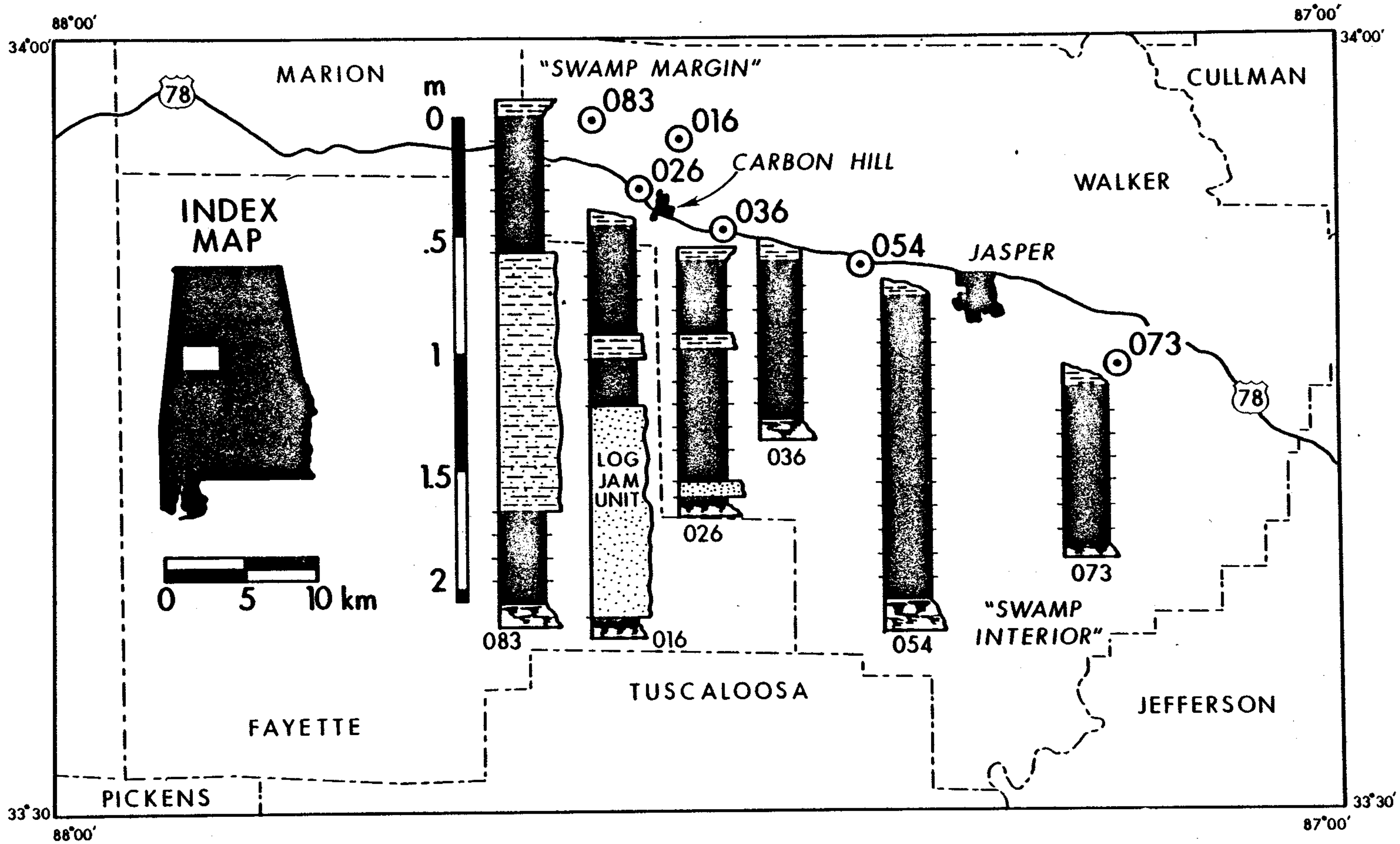

Figure VI-31.--Sample location map showing "swamp margin" and "swamp interior" areas in the Jasper, Alabama, 30 x 60-Minute Quadrangle.

Figure VI-32.--Common miospore taxa recovered from the Mary Lee coal bed (All photographs magnified 600X). **LYCOPODS**: 1) ***Lycospora pellucida*** (Wicher) Schopf, Wilson and Bentall, 40 µm. 2) ***Lycospora granulata*** Kosanke, 33µm. 3) ***Lycospora pusilla*** (Ibrahim) Schopf, Wilson and Bentall, 32 µm. 4) ***Lycospora pellucida*** (Wicher) Schopf, Wilson and Bentall, 41 µm. 5) ***Lycospora orbicula*** (Potonié and Kremp) Smith and Butterworth, 26 µm. 6) ***Lycospora micropapillata*** (Wilson and Coe) Schopf, Wilson and Bentall, 22 µm. 7) ***Crassispora kosankei*** (Potonié and Kremp) Bharadwaj emend. Smith and Butterworth, 69µm. 8) ***Anacanthotriletes spinosus*** (Kosanke) Ravn, 38 µm. 9) ***Densosporites duriti*** Potonié and Kremp, 70 µm. 10) ***Cingulizonates loricatus*** Dybova and Jachowicz emend. Butterworth, Jansonius, Smith and Staplin, 60 µm. 11) ***Cristatisporites indignabundus*** (Loose) Potonié and Kremp emend. Staplin and Jansonius, 66 µm. 12) ***Densosporites sphaerotriangularis*** Kosanke, 64µm. 13) ***Densosporites annulatus*** (Loose) Schopf, Wilson and Bentall, 40 µm. **FERNS/PTERIDOSPERMS**: 14) ***Punctatisporites minutus*** Kosanke emend. Peppers, 34 µm. 15) ***Schulzospora rara*** Kosanke, 88 µm.

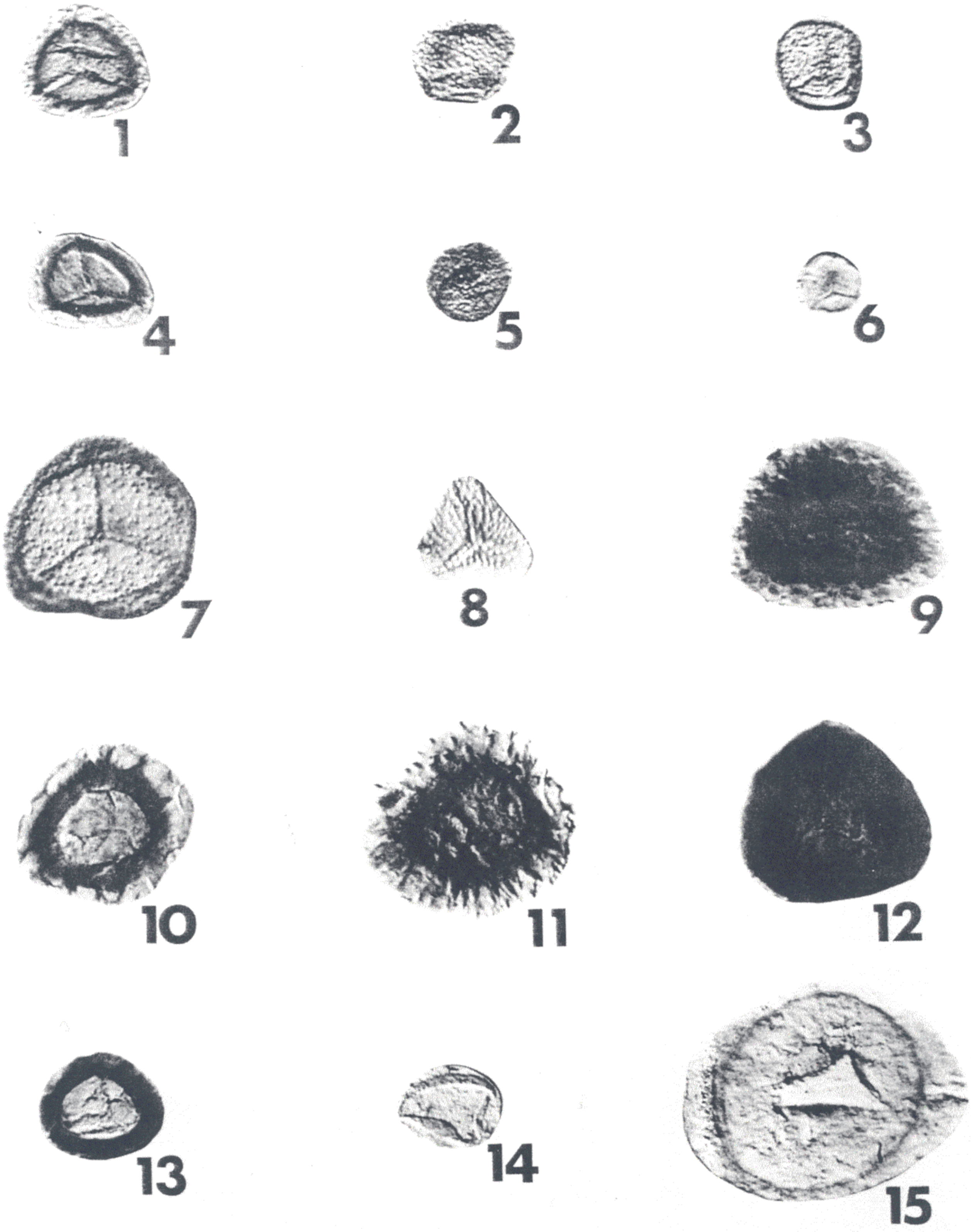
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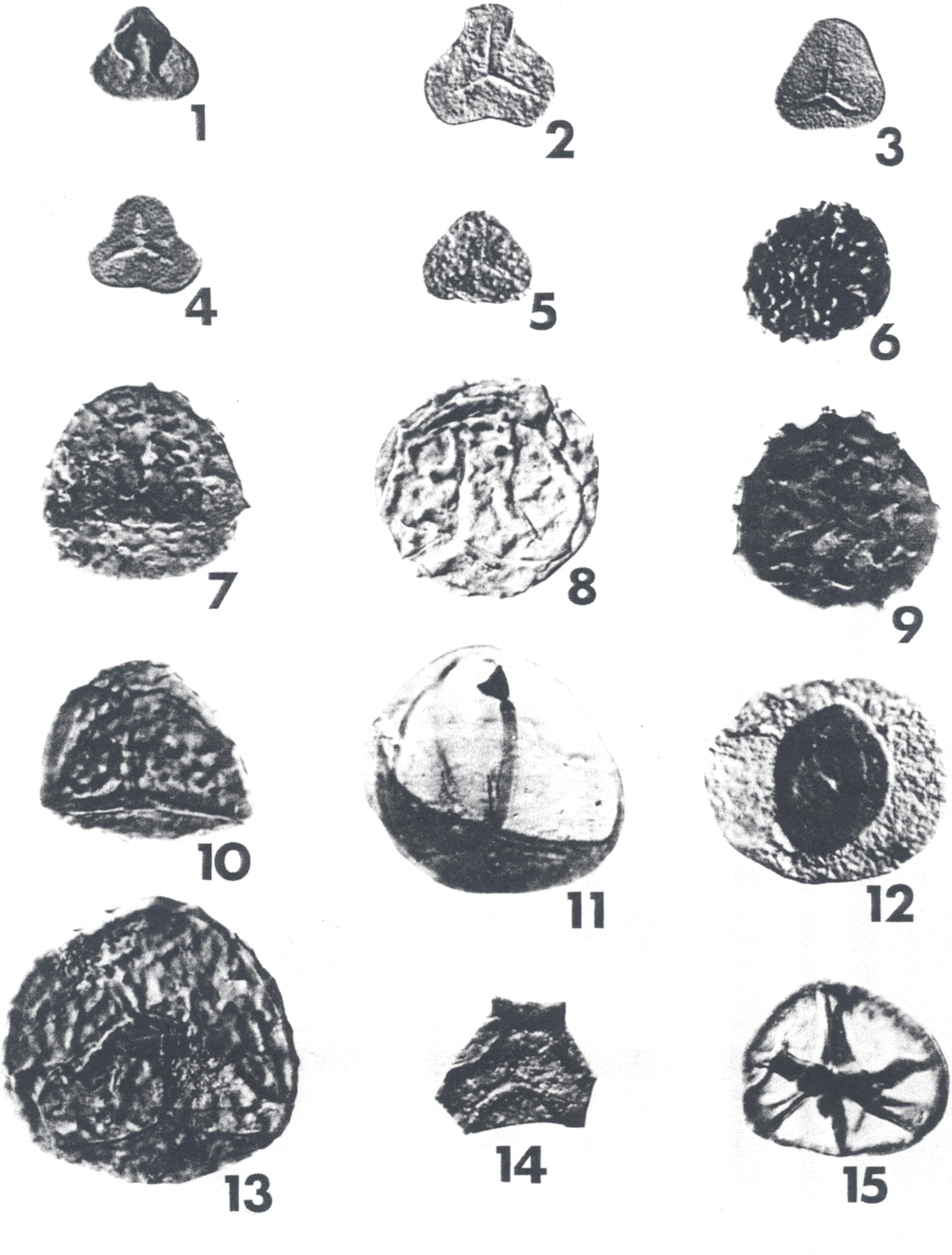
Figure VI-33.--Common miospore genera recovered from the Mary Lee coal bed (All photographs magnified 600X). **FERNS/PTERIDOSPERMS**: 1) *Leiotriletes priddyi* (Berry) Potonié and Kremp, 34 µm. 2) *Granulatisporites adnatoides* (Potonié and Kremp) Smith and Butterworth, 41 µm. 3) *Granulatisporites parvus* (Ibrahim) Potonié and Kremp, 36 µm. 4) *Granulatisporites piroformis* Loose, 34 µm. 5) *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp, 30 µm. 6) *Convolutispora florida* Hoffmeister, Staplin and Malloy, 50 µm. 7) *Camptotriletes bucculentus* (Loose) Potonié and Kremp, 63 µm. 8) *Camptotriletes corrugatus* (Ibrahim) Potonié and Kremp, 74 µm. 9) *Raistrickia grovensis* Schopf, Wilson and Bentall, 65 µm. 10) *Savitrisporites nux* (Butterworth and Williams) Sullivan emend. Smith and Butterworth, 69 µm. **CALAMITES**: 11) *Calamospora pedata* Kosanke, 85 µm. **CORDAITES**: 12) *Florinites mediapudens* (Loose) Potonié and Kremp, 79 µm. **UNKNOWN AFFINITY**: 13) *Grumosisporites varioreticulatus* (Neves) Smith and Butterworth, 97 µm. 14) *Ahrensisporites guerickei* (Horst) Potonié and Kremp ex. Horst, 62 µm. **FERNS**: 15) *Knoxisporites triradiatus* Hoffmeister, Staplin and Malloy, 70 µm.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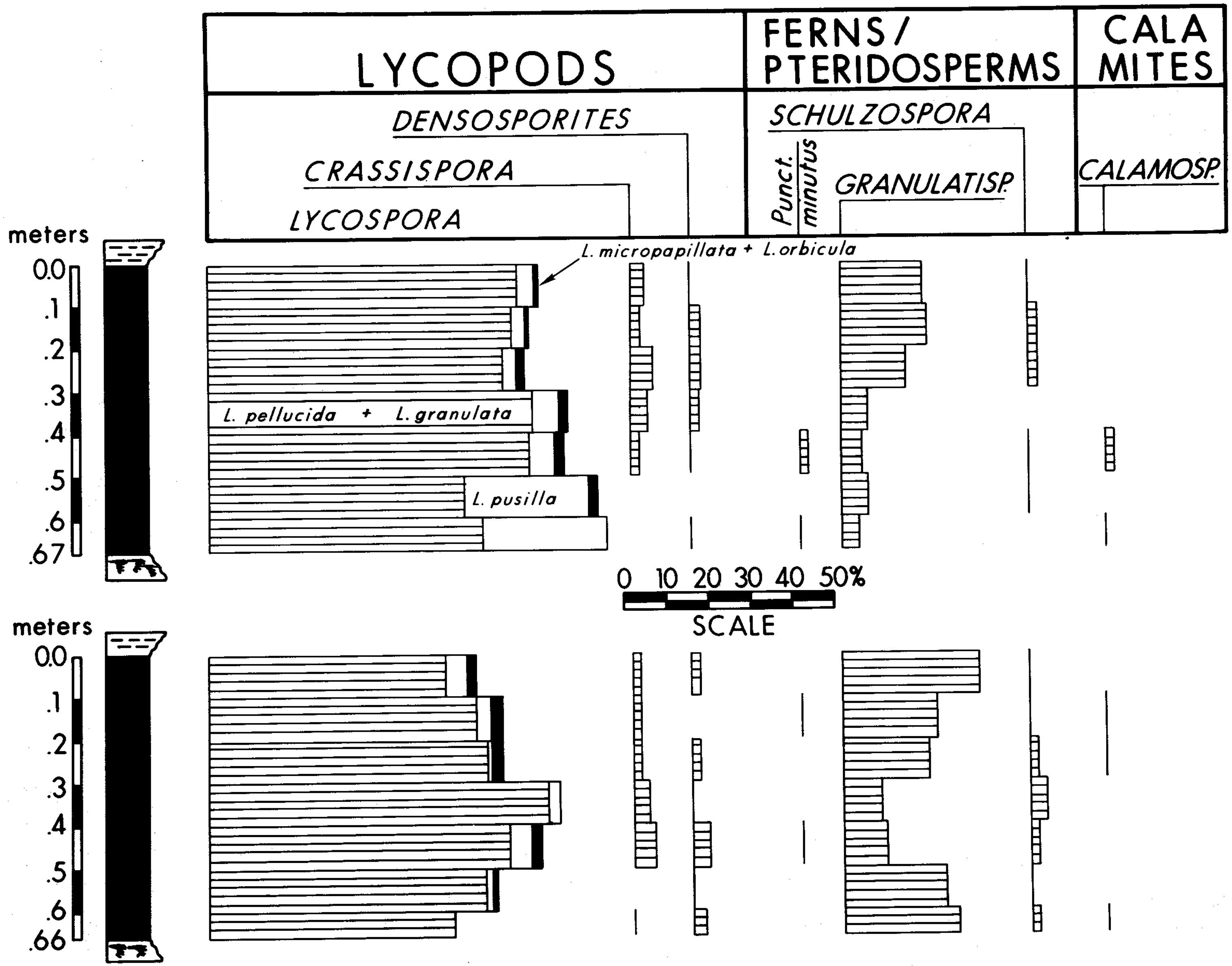

Figure VI-34.--Miospore distribution at sample locations 073 (bottom) and 036 (top).

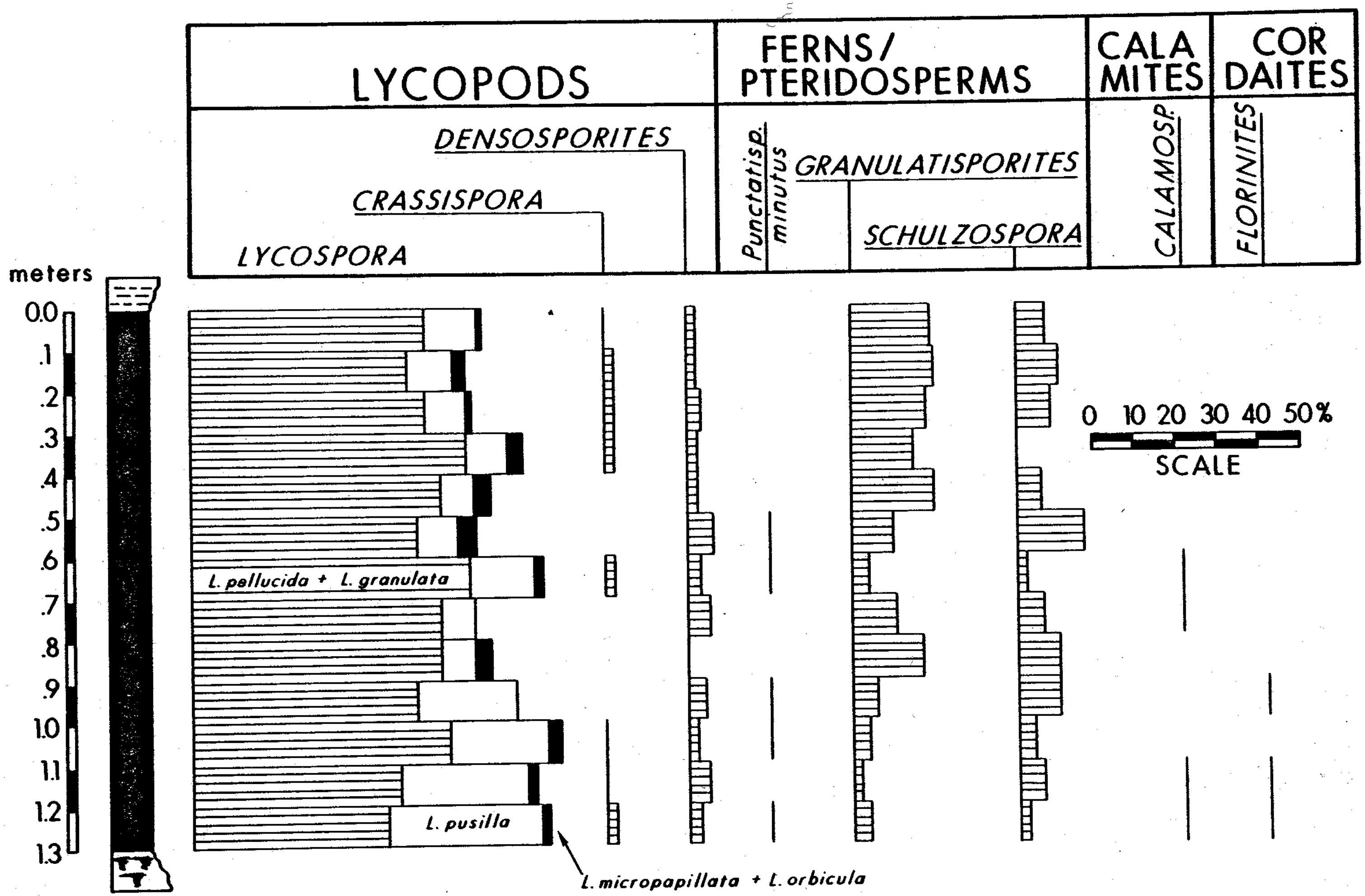

Figure VI-35.--Miospore distribution at location 054.

Calamospora and *Florinites* (location 054 only) occur in minor amounts also.

A vertical trend in species abundance of *Lycospora* occurs at locations 054 and 036. Basal layers contain more *Lycospora pusilla*, representing *Lepidodendron* (Willard, 1988), than do higher layers which are dominated by *L. pellucida* and to a lesser extent, *L. granulata*. Both of these latter species are allied with *Lepidophloios* (DiMichele and others, 1985; Willard, 1988). A third category of *Lycospora, L. micropapillata + L. orbicula*, represents *Paralycopodites* (DiMichele and Phillips, 1985; Willard, 1988). Miospores of this genus are poorly represented in the Mary Lee coal bed with no definite trends at the interior sample sites.

These data indicate that at the interior locations of the study area the Mary Lee swamp probably started out as an arborescent lycopod-dominant flora consisting of both *Lepidophloios* and *Lepidodendron*, though at location 073, pteridophytes/pteridosperms also appear to have been abundant. *Lepidophloios* has been suggested to have been the most water stress tolerant of the arborescent lycopods. It could form nearly monospecific stands, perhaps because of its aquatic adaptation, which would permit it to grow under conditions exclusive to other plant types (DiMichele and Phillips, 1985; Gastaldo, 1987). *Lepidodendron* was apparently less environmentally specific than *Lepidophloios* and may have flourished in areas that were better-drained (DiMichele and Phillips, 1985; Gastaldo, 1987). Therefore, the increased percentages of *Lycospora pusilla* observed in the basal layers of column 054 and 036 may be the result of an inconsistent water cover, which characterized the swamp during its early development. The occurrence of an abundant pteridophyte/pteridosperm element in the basal layers of location 073 would also be consistent with this interpretation as these plants could also flourish under conditions of fluctuating water cover (DiMichele and others, 1985).

All three columns show an increase in, and gradual domination of, *Lepidophloios* (*Lycospora pellucida + L. granulata*) towards the middle of the bed, perhaps indicating a stabilization of the local water table. This is followed by an increase in fern/pteridosperm allied miospore genera towards the top of the bed (figs. VI-34 and VI-35). The upward decrease of arborescent lycopods, especially *Lepidophloios*, may be reflecting a progressive loss of consistent water cover, allowing smaller-statured and perhaps edaphically less specific plants, such as ferns and pteridosperms, to proliferate. The cause of such a change is more difficult to establish with the available data. Doming of the swamp surface, in response to peat buildup in a very wet climate could potentially create a situation of fluctuating water cover, especially in higher domed areas (Anderson, 1964). Doming was invoked by Smith (1962) to explain similar vertical miospore variation in British coal beds of the same age. Likewise, Eble (1988) also incorporated a domed peat model to explain vertical miospore change in the Westphalian B age Hernshaw—Fire Clay coal bed of the central Appalachian basin. Cecil and others (1985) have suggested that most Lower and lower Middle Pennsylvanian coal beds in the Appalachian basin resulted from domed peat swamps.

Alternatively, the increased fern/pteridosperm influence in the terminal layers of columns 073, 054 and 036 may be the botanical response of increased nutrient levels, resulting from the introduction of extra-swamp waters. The association of an abundant pteridosperm element with high-ash coal layers and inorganic partings has been noted (DiMichele and others, 1986; Gastaldo, 1987; DiMichele and Phillips, 1989). Proximate analyses of the studied increment samples (work in progress) should help determine which interpretation is more parsimonious.

MARGINAL LOCATIONS

The three sample locations most proximal to the swamp margin, locations 016, 026 and 083 (fig. VI-31), differ from the three swamp interior locations in that they contain inorganic partings (there are no partings at any of the interior sample sites). They also contain several coal increments that yielded poorly preserved palynomorph assemblages (in contrast to excellent preservation at the interior sample sites). At locations 016 and 026 the basal coal increments yielded an arborescent lycopod dominated assemblage in which *Lepidodendron* (*Lycospora pusilla*) may have been more common than *Lepidophloios* (*Lycospora pellucida + L. granulata*) (figs. VI-36 and VI-37). A sandstone parting ("log jam unit" at location 016) occurs immediately above the bottom bench coal increments at locations 016 and 026,

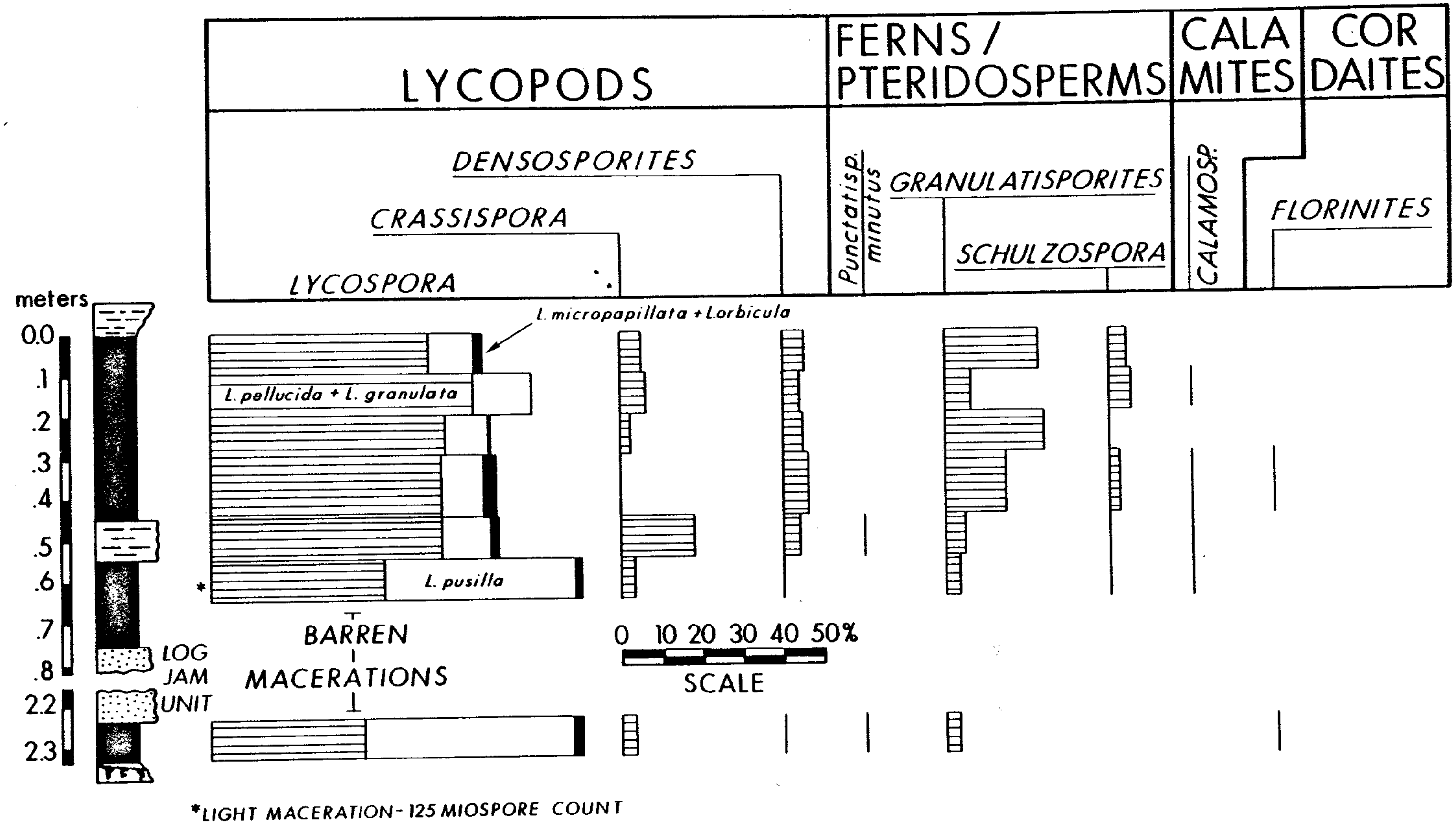

Figure VI-36.--Miospore distribution at location 026. The coal bed is split by shale (0.3-0.37 m) and sandstone (0.93-1.0 m) partings at this location.

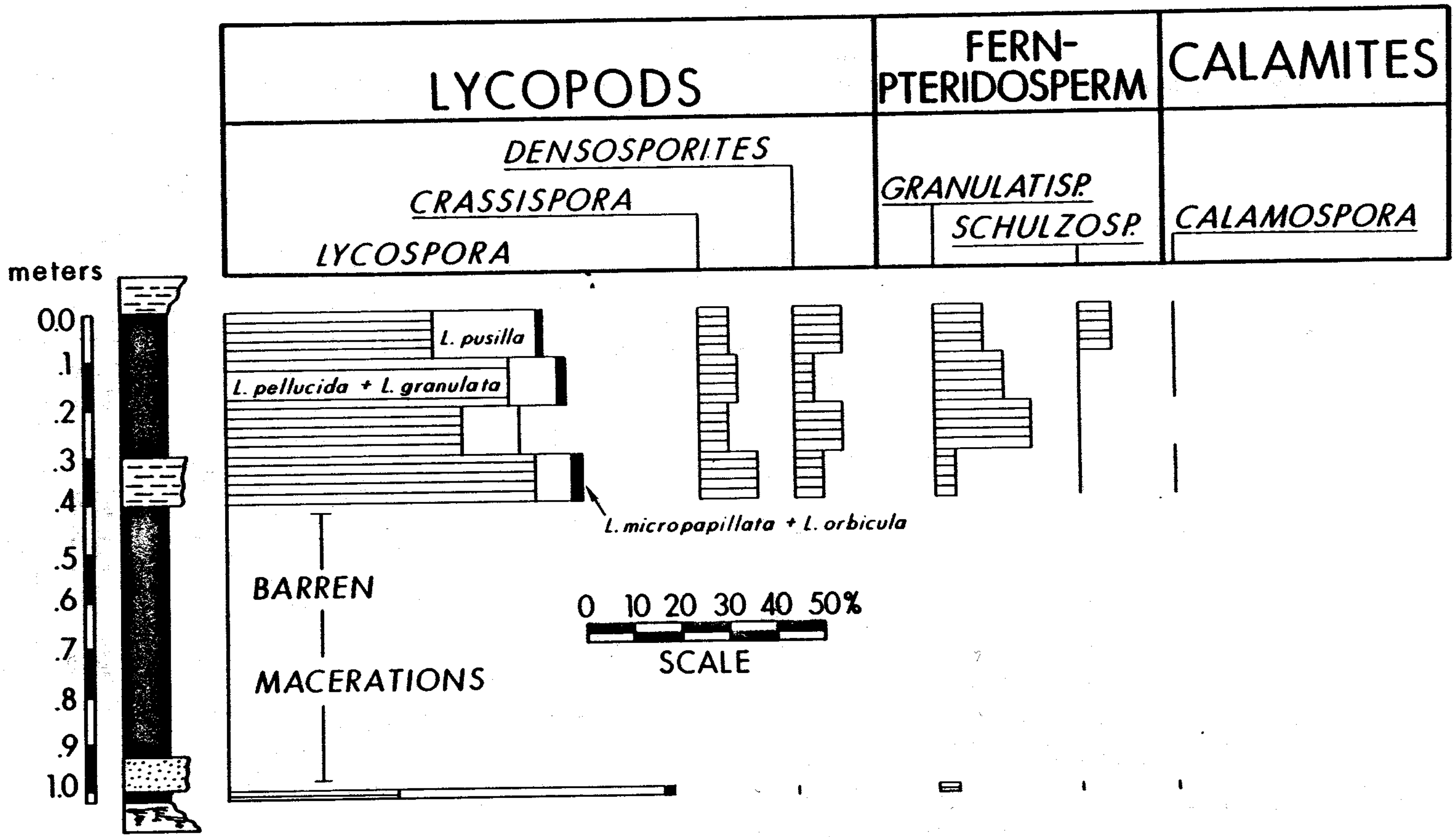

Figure VI-37.--Miospore distribution at location 016. The coal bed is split by a shale and sandstone "log jam" unit (0.76-2.31 m) at this location.

indicating a major disturbance in peat accumulation. Repeated efforts to extract well-preserved palynomorphs from this unit failed. Fragments of spore taxa (e.g. *Lycospora, Granulatisporites, Schulzospora*) were found in a few of the horizons sampled in the log jam unit. Data from etched coal at this locality can be used to assess vegetational components (see Winston, this guidebook).

Similarly, coal samples located between the sandstone parting and a shale parting located higher in columns 016 (0.45 to 0.55 m) and 026 (0.3 to 0.37 m) (figs. VI-36 and VI-37) also yielded sparse, poorly preserved assemblages that were not amenable to meaningful abundance counts (the coal sample directly subjacent to the shale parting at location 016 is an exception). The reason for the poor preservation of spore material is not entirely clear. One possible explanation may be that these increments contain high percentages of transported palynomorphs, as indicated by the highly corroded nature of the exines and high ash content of the coal. High ash content is manifested by the substantial amount of inorganic residue in the zinc chloride gravity separations. Alternatively, an extended period of peat decay and authigenic mineral emplacement (Cecil and others, 1979) may have occurred. Under such conditions, increased degradation of all plant materials, including palynomorphs, would be expected.

The miospore flora of the shale parting in columns 016 and 026 is dominated by arborescent lycopods, with a noticeable increase in *Crassispora kosankei*. *Sigillaria* has been reported to be more commonly associated with mineral, as opposed to peat, substrates and more tolerant of "drier" conditions (DiMichele and Phillips, 1985; Gastaldo, 1987). The increase in *Crassispora* in the shale partings at these locations supports this interpretation.

Miospore floras from the top bench of coal (shale parting to roof shale) at locations 016 and 026 show a continued presence of *Crassispora* and a notable increase in pteridophyte/pteridosperm affiliated spore taxa (*Granulatisporites + Schulzospora*). *Densosporites* also occurs frequently in this top bench, especially in column 016 (figs. VI-36 and VI-37). The increased pteridophyte/pteridosperm abundance in the top bench of these two columns is similar to the increase of these plant groups in the upper coal layers of the three "interior swamp" locations (073, 054 and 036). Perhaps the same edaphic conditions that affected the composition of the flora at the interior locations (doming or extra swamp water influence) also affected the flora at marginal locations (016 and 026). However, despite the similarity in palynofloras in the upper parts of the coal bed at both "distal" and "proximal swamp margin" locations, it is clear that the early to middle stages of peat accumulation at locations 016 and 026 were quite different than at interior locations (073, 054 and 036). The proximal areas of the swamp were affected by events that led to the deposition of inorganic partings and the occurrence of high ash coal layers containing poorly preserved palynomorph assemblages, whereas peat accumulation in the distal, "interior" parts of the swamp, progressed unaltered by these processes.

Location 083 is most proximal to the swamp margin. The coal bed at this location is split by a large (1.1 m) shale/siltstone parting (fig. VI-38). The top and bottom coal benches range from impure coal to carbonaceous shale. Macerations of the top bench repeatedly failed to yield sufficient, well-preserved palynomorphs. The condition of the palynomorphs in these macerations was similar to those observed between the shale and sandstone partings in columns 016 and 026. Likewise, the basal coal sample of the bottom bench also yielded a poorly preserved palynoflora.

The productive increments of the bottom bench (fig. VI-38) and the shale/siltstone parting contain a *Lycospora*-dominated palynoflora in which *L. pusilla* is an abundant component. This suggests that *Lepidophloios* was co-dominant in the arborescent lycopod element of the flora at this location. *Sigillaria*, as shown by *Crassispora*, was apparently also present. Perhaps the most significant palynological finding at 083 is the occurrence of fairly abundant *Punctatisporites minutus*, a fern affiliated miospore that was only rarely encountered at the other locations. Similarly, *Calamospora* and *Florinites* occur more frequently at this location.

The presence of clastic splits in the coal bed and the impure coal/carbonaceous shale found at location 083 suggest that conditions for peat preservation were poor, most likely because of repeated influxes of extra-swamp waters carrying sediment. These influxes may have also acted to neutralize the generally more acid swamp waters allowing for extensive

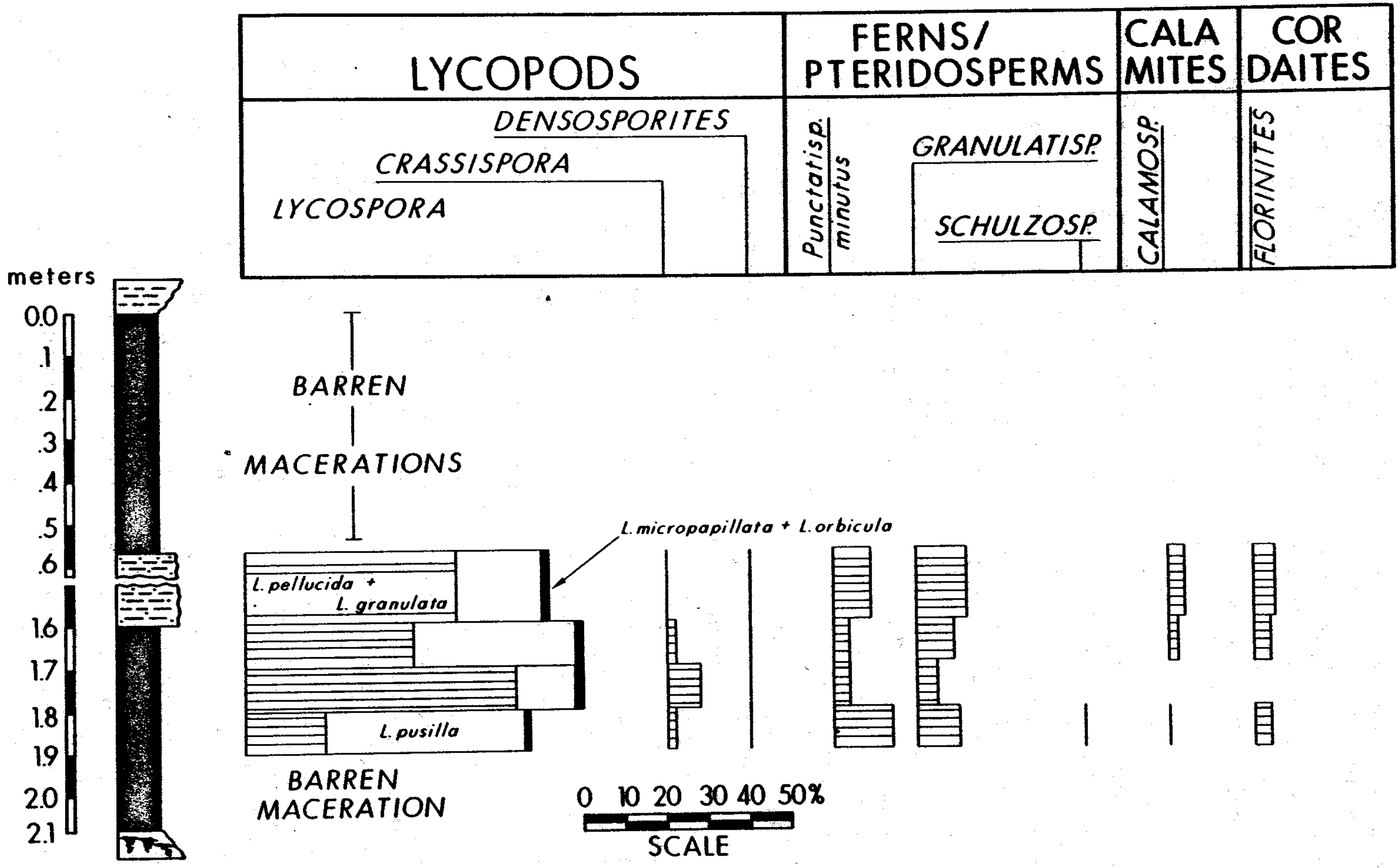

Figure VI-38.--Miospore distribution at location 083. This column represents the most "proximal swamp margin" sample location. The coal bed here is split by a shale/siltstone parting (0.57-1.67 m), and is impure throughout its vertical extent containing many thin carbonaceous shale layers.

biodegradation. The increased occurrence of plant types in column 083, notably ferns, calamites, and cordaites, that were found only in minor quantities at other locations, is understandable as edaphic conditions were undoubtedly different at this "most proximal" location, especially when compared with "interior" swamp locations.

SUMMARY

The palynological results indicate that both lateral and vertical changes occur in the arborescent lycopod-dominated palynoflora of the Mary Lee coal bed within the study area. Lateral changes in physical composition include the occurrence of inorganic partings and high ash coal layers containing poorly preserved palynomorph assemblages at "proximal swamp margin" locations, as opposed to parting-free coal containing well-preserved palynomorph assemblages at "swamp interior" locations. Lateral changes in swamp flora in a distal to proximal swamp margin direction include a general increase in the ratio of *Lepidodendron* to *Lepidophloios*, and an increase in ferns, calamites, and cordaites, especially at the most proximal swamp margin sample site. Collectively, these lateral physical and floral changes observed in the study area support the model proposed by Gastaldo (1987) for lateral spatial relationships of flora and sediments in Early Pennsylvanian swamps.

Vertical changes in palynoflora were noted at the "swamp interior" locations. At these locations basal coal layers were dominated by either an arborescent lycopod dominant assemblage with abundant *Lepidodendron*, or by an arborescent lycopod—fern/pteridosperm co-dominant assemblage. Successive layers showed a change to a *Lepidophloios*-dominant flora in middle layers and, in higher layers, a flora in which ferns and pteridosperms become increasingly abundant.

These floral changes are thought to represent a response to changing edaphic conditions within the swamp. The availability of supersaturated peat substrates (probably with consistent water cover), was possibly a controlling factor for arborescent lycopod establishment and expansion. Thus, doming of the peat surface may have been responsible for the upward decline of *Lycospora* observed at the swamp interior locations. Alternatively, the introduction of more nutrient-rich (sediment laden ?), extra-swamp waters may have been a controlling factor for pteridosperm development. Therefore, the increased percentages of *Granulatisporites* observed towards the top of the bed may be reflecting the onset of swamp drowning. Proximate analyses of the studied columns should help determine which interpretation is more correct.

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FRESHWATER TO MARINE TRACE FOSSILS OF THE MARY LEE COAL ZONE AND OVERLYING STRATA (WESTPHALIAN A), POTTSVILLE FORMATION OF NORTHERN ALABAMA

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ABSTRACT

Trace-fossil assemblages of ancient freshwater and brackish habitats are just beginning to be understood. Many freshwater and brackish trace fossils can be linked to a modern probable maker, so that the "present is the key to the past," which is not the case for most marine invertebrate burrows. The trace fossils of the Mary Lee coal zone are well preserved and exposed, providing a record of a diverse fauna otherwise not represented. Traces include those made by fishes, amphibians, transitional amphibian-reptiles, bivalves, xiphosurids, insects(?), and other organisms. Although many of these animals had broad environmental tolerances whose interpretation is difficult, ichnology yields much needed clues to the paleoenvironment, especially to salinity, degree of exposure, firmness of substrate, and sedimentation rate.

INTRODUCTION

The trace-fossil assemblages of the Mary Lee coal zone are significant because they include freshwater, brackish, and marine traces of diverse animals that are not otherwise preserved (figs. VI-39 to VI-41). The freshwater and brackish traces are preserved in exquisite detail. Collection is encouraged, because the spoil piles they come from have a limited lifetime, and few museums have specimens of these fossils.

The Mary Lee coal zone contains the best preserved and most diverse fossils yet known in the Pottsville Formation of northern Alabama (Lower Pennsylvanian: Westphalian A; Morrowan), including plants, animals, and trace fossils. (See other contributions, this guidebook). The trace fossils are of particular interest because the ichnology of the Alabama Pennsylvanian is rich, albeit poorly known (Aldrich and Jones, 1930; Jones, 1930; Gibson, 1984; Gibson and Gastaldo, 1987, 1989). A systematic study of the trace fossils of the Mary Lee coal zone will be published elsewhere. In the present paper, the trace-fossil assemblages are discussed, with an added section on recognition and collection of ichnogenera in the field area (appendix A).

FRESHWATER TRACE FOSSILS: PROSPECTS

Scientific studies of trace fossils in freshwater deposits began with the recognition of vertebrate tracks in the 1820's in England and the United States (Sarjeant, 1975). Less attention was paid to invertebrate trails and burrows, which tend to be small and inconspicuous. Freshwater trace fossils have been highlighted as the subject of several review articles (e.g., Seilacher, 1963; Chamberlain, 1975; McCall and Tevesz, 1982; Tevesz and McCall, 1982; Miller, 1984; Eagar and others, 1985; Miller and Knox, 1985).

It is well known among ichnologists that the principle of uniformity is inverted for marine invertebrate trace fossils, i.e., the "past is the key to the present," because the makers of most traces are unknown and ancient burrows are often more easily studied than their modern counterparts (Frey and Seilacher, 1980). This is not the case for freshwater to brackish trace-fossil assemblages, the study of which is more direct. Marine trace fossils are relatively familiar and the ichnogenera easily identified, but the makers of the majority of traces remain unknown. In contrast, nonmarine trace fossils are poorly known, the ichnogenera difficult to identify because of unfamiliarity even where they are well preserved. Nevertheless, the makers are relatively simple to identify, so that a well-rounded picture of Pennsylvanian

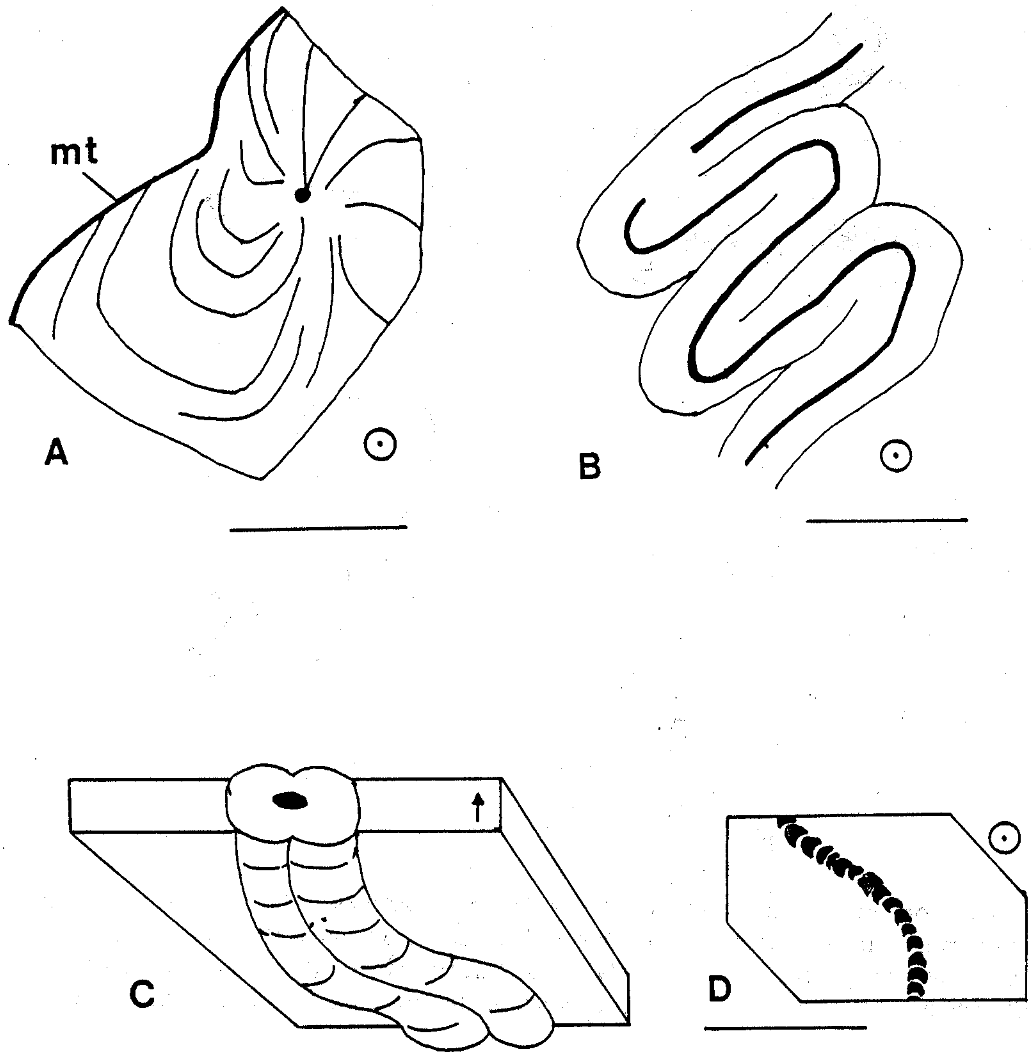

Figure VI-39.--Offshore marine trace fossils of the lower Morris shale, Pennsylvanian Black Warrior basin of Alabama. (a) *Zoophycos*, with sinuous marginal tube (mt); field sketch. Bar scale: 10 cm. (b) *Helminthopsis*, reconstruction. Bar scale: 3 cm. (c-d) *Olivellites* (c) and the inner fecal ribbon *Scalarituba*, and (d) reconstructions as block diagram c and plan view d. All are in plan view except c. Bar scale 3 cm.

freshwater communities can be constructed where trace fossils are well preserved and exposed, as in the Mary Lee coal zone.

DIFFICULTIES WITH MODERN ANALOGS

A review of the biological requirements of organisms in coastal systems sheds light on their geographic distribution. Without getting into unnecessary detail or exceptions, we can understand a coastal wetland zone as an estuarine to terrestrial system characterized by regular and irregular alternations of conditions—alternations of water level, exposure, currents, nutrients, salinity, aeration, and predation, among others. It is astonishing how quickly, and how radically, a healthy community can change in only a few months. For instance, in the modern Mobile Delta of Alabama, the marsh is enriched by nutrients coming from both rivers and tides, and yields two or three crops of plants on the same ground

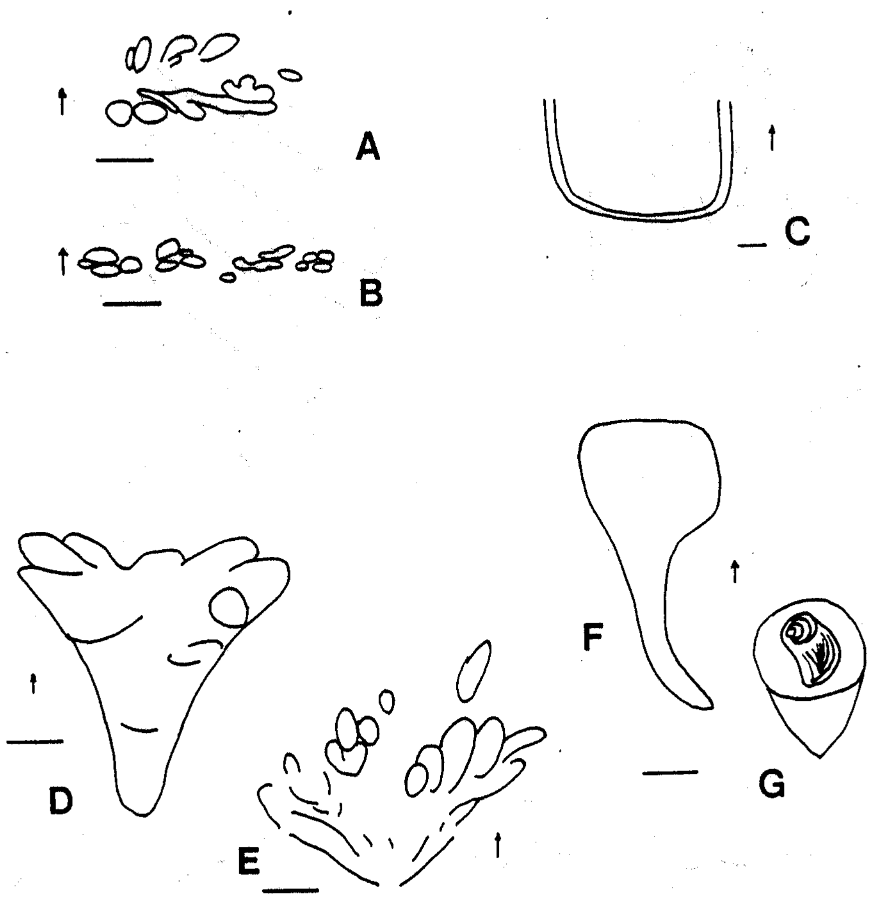

Figure VI-40.--Nearshore marine trace fossils of the "Jagger bedrock," Pennsylvanian Black Warrior basin of Alabama. (a-b) *Phycodes*, in longitudinal (a) and transverse (b) section. (c) *Arenicolites*; sole of U-burrow partly collapsed. (d-e) *Parahaentzschelinia*. (f-g) *Rosselia*, in vertical (f) and oblique (g) section. All are field sketches of vertical sections except g, an oblique section. Bar scale: 1 cm.

in a single growing season. This is enough to alter the living conditions, both physical and biological, of the marsh community. The arrival of herbivorous ducks in winter means the uprooting of vast areas of aquatic plants that hold the substrate in place in summer, as well as oxygenating it via aerenchymatous tissue in the roots. Burrowing animals must keep pace with massive quantities of sediment added to the substrate each year through various processes--quantities that are evidently in excess of their capacity to rework in much of the delta. All this furious action is normal and occurs every year in a healthy environment. The effects of catastrophic events, such as major floods, droughts, and hurricanes, are more profound and long lasting.

The result is that the plants and animals of coastal wetlands have great resilience in the face of adverse conditions and have correspondingly broad environmental ranges. For example, populations of the modern bay clam *Rangia cuneata* thrive best in water of intermediate salinity (Tarver and Dugas, 1973). The trigger for breeding is a sudden influx of salt water, as would occur during a storm, drought, or spring tide. Thus, although adult *Rangia* grows to an unusually large size in freshwater, the populations cannot maintain themselves there indefinitely and are marginal to the species' distribution. The individuals are nonetheless large and healthy, and their population could easily be misinterpreted as living in optimum conditions. Similar cases could be multiplied

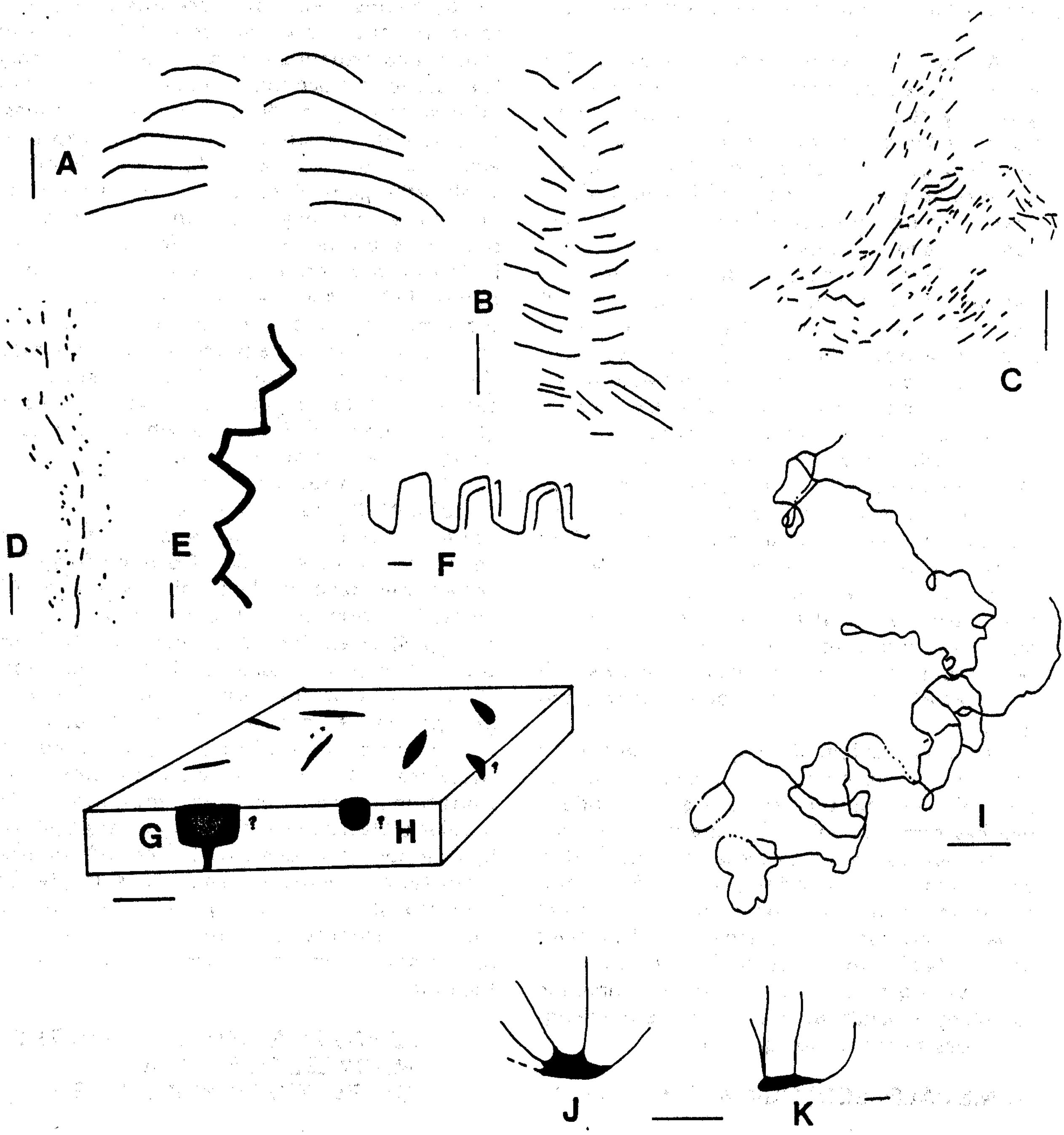

Figure VI-41.--Freshwater to brackish trace fossils of the Mary Lee coal zone, Pennsylvanian Black Warrior basin, Alabama. (a) Arthropod resting trace (n.gen.), showing imprints of five pairs of legs. (b) Arthropod trackway. (c) Comblike arthropod grazing traces (n.gen.). (d) Limulid trackway *Kouphichnium*. (e) *Treptichnus*. (f) Fish trail *Undichna*. (g-h) Resting burrows *Lingulichnus* (g) and *Lockeia* (h); reconstruction. (i) Invertebrate trail *Haplotichnus*. (j) Amphibian tracks *Cincosaurus cobbi*, showing impressions of the forefoot (j) and hind foot (k). All are in plan view except g and h. Bar scale: 1 cm.

manifold. Thus, the environmental distribution of estuarine species tends to be broader than that of strictly marine species. Single species are of little value in determining environments of deposition, although whole assemblages are useful.

An ancient example of the ambiguity that arises in paleoenvironmental interpretation is given by the xiphosurid (horseshoe crab) trackway *Kouphichnium*, which is common in the Mary Lee coal zone (fig. VI-41D). Today, adults of horseshoe crabs are marine most of the year, coming shoreward to breed in vast numbers, and crisscrossing the substrate with their trackways (Caster, 1938). The young are hatched on beaches and in estuaries and tolerate lower salinities than the adults. If Pennsylvanian conditions were strictly analogous to modern ones, a congregation of trackways would indicate low salinity, whereas a single trackway would be ambiguous as to salinity. Fisher (1979), however, interpreted the Mazon Creek (Middle Pennsylvanian) xiphosurid *Euproops* as a normal dweller in freshwater habitats, which considerably broadens the known environmental tolerance of horseshoe crabs. Thus, no clear justification exists to restrict the interpretation of *Kouphichnium* to either marine or freshwater environments. And these cases could be multiplied: bivalve burrows, fish trails, polychaete and oligochaete burrows, and so on.

Another problem of using modern analogs is that too few have yet been documented. The biogenic sedimentary structures of modern beaches, dunes, and tidal flats are relatively well understood compared to those of rivers, deltas, and swamps (Chamberlain, 1975). Field and aquarium studies of common fishes, insect larvae, oligochaetes, crustaceans, and bivalves are needed to interpret Pennsylvanian trace fossils with greater accuracy. Again, nonmarine ichnology depends far more on modern analogs than does marine ichnology.

SOME PALEOECOLOGIC ACHIEVEMENTS

Even with this inherent ambiguity, Pennsylvanian trace fossils have yielded solid and much desired information on the makers of trace fossils and on environments of deposition, without the benefit of Mazon Creek-style preservation. The Mary Lee coal zone is unusually rich in autochthonous and allochthonous plant fossils, and presumably the animal communities were correspondingly diverse. Unfortunately, body fossils of animals are few, poorly preserved, and biased toward strictly marine shells. The trace fossils thus help to round out our knowledge of the several coastal and estuarine communities. In the Mary Lee coal zone, trace fossils are our sole source of information on the following groups: fishes, amphibians, transitional amphibian-reptiles, worms, xiphosurids, insects(?), and unidentified small arthropods. Bivalves are represented by both trace and body fossils, though not in the same beds (unlike *Carbonicola* found in burrows in the Carboniferous of England; Eagar and others, 1985). Moreover, the semireliefs are of the same small size and general form as those seen today in streambeds and on estuarine tidal flats. Some common modern traces are conspicuously lacking (e.g., burrows of crabs and ghost shrimp), but on the whole this is a recognizable suite of assemblages.

In a broader context, the Mary Lee ichnofauna fleshes out the otherwise nearly nonexistent record of vertebrates in the Pennsylvanian of Alabama. No body fossils of vertebrates have yet been discovered in the Pottsville Formation (Thurmond and Jones, 1981, p. 4) except for three fishes from the Mary Lee coal zone (J. P. Lamb, oral communication, 1989). Trails or trackways made by several groups are represented: fishes (*Undichna*), rhachitome(?) amphibians (*Cincosaurus, Attenosaurus*), and seymouriamorphs, i.e., transitional forms between amphibians and reptiles (*Quadropedia*; tetrapod interpretations by Thurmond and Jones, 1981). The fact that the ichnofauna includes trackways made by transitional amphibian-reptiles is intriguing, though vertebrate specialists would prefer a record of ear bones to that of the lower half of the foot.

TRACE-FOSSIL ASSEMBLAGES IN THE MARY LEE COAL ZONE AND OVERLYING MORRIS SHALE

The Mary Lee coal zone consists of four coal seams and the clastic strata that contain them (Demko, this guidebook; Liu, this guidebook). Trace fossils are sparse to abundant in the clastic intervals between coals, and in the Morris shale, an overlying marine unit (informal name proposed by Rheams and Barnett, 1985). The coals contain no recognized trace fossils. Facies in which trace fossils are common include alluvial swamp (freshwater), tidal flat (brackish), offshore bar (marine to brackish), and inner shelf (marine).

Because the dominant ichnogenera of the Mary Lee coal zone were known previously from only a few time equivalent localities, mainly in Indiana and Oklahoma, it was necessary to establish their paleoenvironmental distribution by nonichnologic means. Demko (this guidebook) and Liu (this guidebook) derived these interpretations primarily from the evidence of physical sedimentary structures, body fossils, and stratigraphic relations. Preliminary interpretations were then checked against the ichnologic evidence derived from this study, which in most cases either confirmed previous conclusions or reduced ambiguity. Trace fossils proved to be especially helpful in determining the salinity, firmness, and degree of exposure of substrates.

CINCOSAURUS ASSEMBLAGE (ALLUVIAL SWAMP)

The interval above the Newcastle coal and below the regional transgressive unconformity represents an alluvial swamp (Liu, this guidebook; Stop 6). Trace fossils are well preserved but well exposed only in weathered spoil. Most are small, have low relief and, therefore, are difficult to detect. Rooted sediment is wholly bioturbated; unrooted sediment is only slightly bioturbated. The most distinctive forms are the wavelike fish trail *Undichna*, xiphosurid trackways *Kouphichnium*, and amphibian trackways *Cincosaurus, Attenosaurus, Quadropedia*, and others (fig. VI-41). Fish trails, some occurring on the same slabs as *Kouphichnium*, provide clear evidence that the substrate was submerged at least part of the time. Xiphosurids may have lived in nonmarine habitats during the Pennsylvanian, as discussed above.

HAPLOTICHNUS ASSEMBLAGE (TIDAL FLAT)

The strata of the Jagger to Blue Creek interval are interpreted as brackish tidal flats (Demko, this guidebook, Stop 2). Exquisite preservation of detail occurs where fine-grained, rapidly buried sediment is only slightly bioturbated, so that trace fossils do not overlap. Most of the trace fossils are small and of shallow relief, a pattern noted elsewhere in brackish settings (Hakes, 1985). Diversity is high (fig. VI-41). Xiphosurids, insects(?), other arthropods, and vertebrates are represented by trackways. Other traces include grazing traces of arthropods(?), resting traces of xiphosurids, bivalves, and lingulids, and dwelling burrows of unidentified organisms. The assemblage, an unfamiliar one to most ichnologists, is dominated by the small arthropod trail *Haplotichnus*, and by unnamed ichnogenera of comblike grazing traces and xiphosurid resting traces.

PHYCODES-PARAHAENTZSCHELINIA ASSEMBLAGE (OFFSHORE BAR)

An interesting and unique assemblage, not visited as part of this field trip, is preserved in the study area. A sandstone outcrop, whose stratigraphic relations are not thoroughly understood, occurs along U.S. Highway 78 (secs. 17-18, T. 14 S., R. 6 W., Cordova 7.5-Minute Quadrangle). This sandstone body is interpreted by Demko (personal communication) as an offshore bar subjacent to the Ream coal seam. The trace-fossil assemblage is unusual, dominated by the feeding burrows *Phycodes* and *Parahaentzschelinia* (figs. VI-40a, VI-40b, VI-40d, VI-40e). In mining terms, *Phycodes* is a "punch mine," a bundle of tunnels radiating from a single gallery. *Parahaentzschelinia* is shaped like a vertical funnel full of tubes. Both behavioral patterns are effective for deposit-feeding, *Phycodes* at depth and *Parahaentzschelinia* at the substrate surface. Horizons rich in *Parahaentzschelinia* probably represent rapidly buried substrates. These trace fossils are as yet uninformative regarding salinity; *Parahaentzschelinia* is known at so few sites that its total range is unclear, and *Phycodes* is widespread, occurring in bathyal to sublittoral substrates.

Other burrows are common at a horizon near the top of the sandstone outcrop, including the U-shaped burrow *Arenicolites* and onion-like *Rosselia* (figs. VI-40c, VI-40f, VI-40g). A lingulid has also been collected here. Both lingulids and *Arenicolites* are most common in nearshore environments, including the slightly brackish marine setting interpreted for the this unit.

SCALARITUBA ASSEMBLAGE (INNER SHELF)

The lower Morris shale overlies the regional transgressive unconformity described by Liu (this guidebook, Stops 2, 3, 4, 5, 6, 7). It is a sublittoral deposit laid down in increasingly deep water, from nearshore subtidal to offshore. The nearshore sandstones contain *Parahaentzschelinia*, arthropod resting traces (n. gen.), and uncommon *Asteriacites*. Offshore mudstones have an assemblage typical of fine-grained, quiet-water substrates of the Devonian and Carboniferous: *Zoophycos, Scalarituba, Olivellites, Helminthopsis* (fig. VI-39; compare with Conkin and Conkin, 1968; Osgood and Szmuc, 1972; Chaplin, 1980; Gibson and Gastaldo, 1989).

DISCUSSION AND CONCLUSION

Until recently, it seemed that every newly described ichnofauna from a coal-bearing sequence was unique. Nonmarine ichnofacies are diverse, and research is only now emerging from its early, descriptive stage. Although unique ichnofaunas are worthy of study, they are of limited use in the development of paleoenvironmental indicators, which require replicable patterns.

Of the four Mary Lee assemblages briefly described above, one is widespread and another is unique; two are similar to an assemblage that was previously known only in the Pennsylvanian of Indiana. The *Scalarituba* (inner shelf) assemblage (fig. VI-39) is widespread and well known, whereas the *Phycodes-Parahaentzschelinia* (offshore bar) assemblage (fig. VI-40) is, so far, unique in the literature. The other two, *Cincosaurus* (alluvial swamp) and *Haplotichnus* (brackish tidal flat) assemblages, share many ichnotaxa in common, and have a remarkably high proportion of uncommon or undescribed species (fig. VI-41). That such a diverse and unusual trace-fossil assemblage has a near-match elsewhere in similar lithofacies is highly significant.

The Hindostan whetstone beds of Indiana (Archer and Maples, 1984; Maples and Archer, 1987) have an unusual, well-preserved trace-fossil assemblage that is equivalent to the two nonmarine assemblages of the Mary Lee coal zone of Alabama (table VI-6). Both occur in thinly laminated siltstones that are only slightly bioturbated, mainly by small trace fossils parallel to bedding. Both have many kinds of locomotion traces, but only a few each of dwelling, feeding(?), and grazing traces (for explanations of these terms, see table 7). Nevertheless, the assemblages are not dominated by the locomotion traces, but by a few abundant taxa of other ethologic groups. Though generic names differ in the two lists, some refer to very similar traces (e.g., *Kouphichnium* and *Pterichnus*). Some of the most common, yet most unusual, forms occur in both lists (*Treptichnus, Haplotichnus*). The major difference is the lack of resting traces and vertebrate trackways in the Hindostan beds. The author predicts that further collecting in Indiana will reveal specimens of these groups.

Not surprisingly, the stratigraphic and paleoenvironmental settings of the Hindostan and nonmarine part of the Mary Lee are similar (Archer and Maples, 1984; Demko, this guidebook; Liu, this guidebook). They are each composed largely of laminated siltstones in coal-bounded sequences. The coals are low in sulfur and, therefore, not influenced by marine processes. Transported plant material is common; roots are sparse to abundant, in some beds obliterating primary lamination. Archer and Maples (1984) interpreted the original setting of the Hindostan whetstone beds as "channel-proximal floodplain environments, which would include swamps, floodplain lakes, levees, and upper parts of point bars." Kvale and others (1989) have reinterpreted these deposits as tidally-derived. Gastaldo and others (in press) prefer the interpretation of freshwater alluvial swamps and brackish tidal flats for the nonmarine parts of the Mary Lee coal zone. The two interpretations are thus compatible, differing essentially in the degree of inferred salinity.

Further work will undoubtedly add many other localities for freshwater, brackish, and nearshore marine assemblages of trace fossils. Their use as paleoenvironmental indicators can be refined and extended, with particular regard to salinity. Just as important is the substantial extension of the record of terrestrial life made possible by attention to these small but diverse trace fossils.

Table VI-6.--Comparison of trace-fossil assemblages of the alluvial swamp and brackish tidal flat facies of the Mary Lee coal zone (Westphalian A, Alabama) and the Hindostan whetstone beds (lower Westphalian, Indiana). Sources for Hindostan beds: Archer and Maples (1984) and Mapes and Archer (1987)

Mary Lee coal zone	Hindostan whetstone beds
Resting traces Arthropod resting traces *Lockeia*	
Dwelling traces *Rosselia* aff. *Thalassinoides*	 *Palaeophycus* *Plangtichnus*
Locomotion traces Trails Unidentified Arthropod trackways *Kouphichnium* Unidentified Fish trails *Undichna* Vertebrate trackways *Cincosaurus* *Quadropedia* *Attenosaurus*	 Trails *Cochlichnus* Boat-wake trail Arthropod trackways *Pterichnus* *Umfolozia* *Maculichna* *Undichna*
Feeding or farming traces *Treptichnus*	 *Treptichnus* *Spirodesmos* *Paleodictyon*
Grazing traces *Haplotichnus* Comblike grazing traces	 *Haplotichnus*

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Table VI-7.--Ethological classification of trace fossils (modified from Seilacher, 1953, Frey and Seilacher, 1980, and Ekdale and others, 1984). Examples are drawn from trace fossils of the Mary Lee coal zone and overlying Morris shale

Category	Recognition
Resting traces (Cubichnia)	Shallow, horizontal depressions, shaped approximately like the lower part of the animal but also reflecting the digging motions of appendages; fill from above; upper part ill-defined. Examples: arthropod resting traces (n.gen.), *Asteriacites, Lockeia, Lingulichnus.*
Dwelling traces (Domichnia)	Relatively simple burrows or burrow systems showing signs of permanent habitation, e.g., linings, passive fill, reinforced apertures, vertical upper components. Examples: *Arenicolites, Rosselia, Thalassinoides.*
Feeding traces (Fodinichnia)	Burrows simple to complex, showing regular patterns of temporary deposit-feeding, e.g., stoping, longwall mining, etc.; spreiten structures (laminae or bundles produced by periodic shifting of the burrow) common; branching common; avoidance of previously ingested sediment common; fill typically active (meniscate, concentric, etc.), but may be passive. Examples: *Zoophycos, Phycodes, Parahaentzschelinia, Scalarituba, Olivellites, Helminthopsis,* possibly *Treptichnus.*
Grazing traces (Pascichnia)	Surficial traces made by animals feeding atop the substrate and thus horizontal and two-dimensional; trails common; traces simple to complex, many showing regular strip-mining patterns, but most unbranched. Examples: comblike grazing traces (n. gen.), *Haplotichnus.*
Locomotion traces (Repichnia)	Trackways consisting of separate, individual tracks; continuous trails; generally unbranched and with rather simple ornament; broadly interpreted here to include walking, crawling, and swimming traces. Examples: *Kouphichnium, Cincosaurus, Undichna.*
Escape traces (Fugichnia)	Traces showing signs of animals moving upward or downward through the sediment in response to deposition or erosion, e.g., vertically repeated resting traces, nested funnel-shaped structures, U-in-U spreiten burrows. Examples: none.
Farming traces (Agrichnia)	Combined dwelling and feeding system utilized as a trap or farm for smaller organisms; structure typically complexly patterned, open during the life of the animal and therefore passively filled, but lacking a spreite; most basically horizontal with vertical components. Example: possibly *Treptichnus.*
Nesting traces (Nidichnia)	Traces showing signs of use for breeding young, e.g., shallow depressions with well-defined walls, burrows with one or many enlarged distal chambers (in some cases with small burrows extending outward); may include remains of eggs or young; probably indistinguishable in many cases from dwelling burrows, especially those used for hibernation. Examples: none.

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APPENDIX A.--COLLECTION AND IDENTIFICATION OF MARY LEE TRACE FOSSILS

COLLECTION OF TRACE FOSSILS

Many of the Mary Lee trace fossils are preserved in fine detail on the bedding planes of siltstones to fine-grained sandstones. These **semireliefs** (Seilacher, 1953) include most trails and trackways. Others are preserved three-dimensionally as **full-reliefs**, including most of the burrows. A slab may contain each.

Semireliefs can be collected easily by examining slightly weathered spoil piles, in which the shales are expanded into booklike sheaves of laminae. Weathering accentuates slight heterogeneities in the rock, including delicately preserved semireliefs. Shadowing in oblique light accentuates the visibility of semireliefs.

Full-reliefs are also enhanced by weathering, which commonly accentuates subtle differences in geochemistry or texture. Internal structure is diagnostic in many of the ichnogenera that are commonly preserved in full-relief, and field relations are also essential. Ichnologists are often forced to carry heavy specimens to be slabbed later in the laboratory.

Most fragmentary specimens of trace fossils, like most fragmentary shells, are not worth collecting, because they lack diagnostic features. This is particularly true of the smooth, unbranched, nondescript burrows seen throughout the Phanerozoic. Details that are worth observing include orientation, branching, sculpture, internal structure, linings, and scratchmarks.

IDENTIFICATION OF TRACE FOSSILS

Trace fossils can be useful even if not identified to ichnospecies. Several degrees of accuracy can be employed, yielding progressively more sophisticated results.

As a minimum, the **presence/absence** of trace fossils, especially burrows, and their **orientation** (predominantly horizontal, vertical, or neither) should be recorded. Presence/absence yields an index of the general capacity of the environment for supporting benthic life. Orientation is typically mostly vertical in nearshore marine environments (**Skolithos** ichnofacies), mixed in shelf environments (**Cruziana** ichnofacies), and horizontal in some special settings (e.g., **Nereites** ichnofacies) (Frey and Seilacher, 1980).

Trace fossils can also be classified, with some rigor, into categories according to their interpreted behavior (**ethological classification** of Seilacher, 1953; table 7). Although the worm's motivation for turning is not always explicable, the form of the trace fossil usually does follow its function. Categories are not mutually exclusive, as a single burrow may incorporate elements from two or three categories. Nonetheless, behavioral patterns have genuine ecologic significance, and are used as the basis of Seilacher's well-known ichnofacies model (Frey and Seilacher, 1980; Ekdale and others, 1984). From information of this sort, without formal systematics or identification of ichnogenera, it is possible to evaluate paleoenvironments.

Taxonomic inquiry is necessary for understanding the biological affinities of the trace fossils, for adequate description, and for reliable information retrieval. No comprehensive handbook exists, but guides to common species are available (Chamberlain, 1978; Ekdale and others, 1984). These guides are preferable for a first assessment to the *Treatise on Invertebrate Paleontology* (Häntzschel, 1975), which was not designed as an identification manual.

RECOGNITION OF "POTTSVILLE" ICHNOGENERA

The most common trace fossils are described here. Ranges refer only to occurrences in the Mary Lee coal zone and overlying Morris shale. For additional information, see the references cited below.

RESTING TRACES

Arthropod resting traces (new ichnogenus) (fig. VI-39a). Bilaterally symmetrical resting traces consisting of four to five pairs of shallow scratchmarks. Length up to about 25 mm; width 15 to about 45 mm. Probably the work of xiphosurids, based on the number of leg imprints. Brackish tidal flats.

Lockeia (fig. VI-39h). Almond-shaped resting traces, bilaterally symmetrical, ends angular and not identical; some with median keel on bedding soles. Length 5 to 8 mm. Bivalve burrows, distinguished from lingulid burrows (also present, though rare) on the basis of symmetry. Brackish tidal flats. (See Maples and West, 1989.)

Asteriacites. Starfish-shaped resting traces, made by starfish or brittlestars. Marine.

DWELLING TRACES

Rosselia (figs. VI-40f, VI-40g). Shaft topped by a funnel-shaped or onion-shaped structure with concentric fill. Width of funnel 10 to 20 mm. Maker unknown. Offshore bar and brackish tidal flat.

Arenicolites (fig. VI-40 c). Unbranched, vertical, U-shaped burrows with no spreite. Limbs spaced about 6 to 15 cm apart; width of vertical limb, about 5 mm. Makers diverse, mostly marine to brackish: polychaetes, enteropneusts, amphipods, etc. Offshore bar.

Thalassinoides-like burrow systems. Poorly exposed, branched burrow systems with subhorizontal and vertical components. Width of gallery 2 to 3 mm. Makers unknown, most likely arthropods. Alluvial swamp and brackish tidal flat.

LOCOMOTION TRACES

Arthropod trackways (fig. VI-41b). Trackways consisting of striae arranged in a chevronlike pattern, with striae only roughly paired. Width of trackway 10 to 18 mm. Makers perhaps diverse, possibly including insects and other multilegged arthropods. Caster (1938) interpreted similar trackways as those of xiphosurids. Easily confused with impressions of lycophyte cones. Brackish tidal flats.

Kouphichnium (fig. VI-41d). Trackways consisting of two kinds of tracks: (1) small, two-toed tracks arranged diagonally in sets of four; and (2) large, four- or five-toed tracks, one per set of four small tracks. Mary Lee specimens are small and usually do not show this much detail. Made by xiphosurids. Brackish tidal flats. (See: Caster, 1938; Goldring and Seilacher, 1971.)

Undichna (fig. VI-41f). Trail made up of one or more pairs of staggered waves. Wavelength about 2 to 25 cm; amplitude about 2 to 13 cm. Made by the fins of fish as they swim along the bottom. Alluvial swamp. (See: Anderson, 1976.)

Cincosaurus (figs. VI-41j, VI-41k). Quadruped trackway; individual tracks digitigrade (made on tiptoe). Hind foot with five digits, palm very small, digits curved outward; digits I to IV facing forward, digit V at right angles to axis of trackway. Forefoot slightly smaller than hind foot, with five(?) digits, digits rather outspread, palm small. This is most common vertebrate trackway in the Mary Lee, but several others exist. Aldrich and Jones (1930) named several species of *Cincosaurus*, of which *C. cobbi* is the most widespread. Dimensions of one specimen of *C. cobbi*: length of hind foot 3.6 cm; stride 8.1 cm; straddle 5.6 cm. Alluvial swamp and brackish tidal flats.

FEEDING BURROWS

Parahaentzschelinia (figs. VI-40d, VI-40e). A "funnel full of tubes." Shaft topped by cuplike structure consisting of radiating tubes. Width of funnel about 2.5 to 5.0 cm, Probably the work of polychaete worms. Offshore bar. (See: Chamberlain, 1971.)

Phycodes (figs. VI-40a, VI-40b). A biological "punch mine." Burrow system composed of curved gallery dividing into radiating, interpenetrating, sparsely branched tubes. Gallery 20 cm long in one specimen, 2 mm wide; tube width up to 5 mm. Probably made by polychaete worms. Offshore bar.

Helminthopsis (fig. VI-39b). Subhorizontal, simple, indefinitely long burrows that meander irregularly, but without self-penetration; smooth inner "fecal ribbon" surrounded by outer ridges of less distinct, disturbed sediment. Width about 1 cm. Probably made by worms, possibly polychaete. Sublittoral marine, in quiet water.

Zoophycos (fig. VI-39a). A "longwall mine." Sheetlike spreiten burrow, mostly horizontal to oblique, with meniscate internal structure. Width of tubes 1.5 to 7(?) mm; width of lamina 15 cm in one fragment. Maker unknown; worm? Sublittoral marine, in quiet water. (See: Osgood and Szmuc, 1972.)

Scalarituba (fig. VI-39d). "Fecal-ribbon" burrow made of meniscate pellets. The outer shell of disturbed sediment, bilobed below and meniscate, looks quite different and can be called *Olivellites* (fig. VI-39c). Width of inner ribbon 3 to 5 mm; width of outer shell 12 to 20 mm. The makers are unknown; modern analogs include irregular echinoids. Sublittoral marine, in quiet water. (See: Fenton and Fenton, 1937; Conkin and Conkin, 1968; Yochelson and Schindel, 1978.)

Treptichnus (fig. VI-39e). "Feather-stitch burrow." Subhorizontal zigzag burrow, with the zigzag branches curving upward into shafts at the corners. Length of zigzag branches 11 to 17 mm in one specimen. Maker unknown. Alluvial swamp and brackish tidal flat. (See: Maples and Archer, 1987.)

GRAZING TRACES

Haplotichnus (new ichnospecies) (fig. VI-41i). Simple trail, straight to curved, commonly in a self-penetrating "scribbled" pattern; path turned smoothly or backturned sharply. Possibly made by insects or their larvae. Brackish tidal flats. (See: Maples and Archer, 1987.)

Comblike grazing traces (new ichnogenus) (fig. VI-41c). Fields of short striae arranged in a subparallel pattern, without interpenetration. Striae are flanked in the most delicately preserved specimens by a comblike arrangement of even shorter striae. Length of larger striae up to about 6 mm. Makers clearly arthropods having comblike feeding appendages, perhaps crustaceans, xiphosurids, or insects. Brackish tidal flats.

COMMON MACROINVERTEBRATES ASSOCIATED WITH THE MARY LEE COAL ZONE (PENNSYLVANIAN, UPPER "POTTSVILLE" FORMATION), NORTHERN ALABAMA

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ABSTRACT

A survey has been conducted on the macroinvertebrates recovered from a ravinement bed in the Mary Lee coal zone, northwestern Alabama. The macroinvertebrates represent both autochthonous and allochthonous elements. The autochthonous assemblage is found within the mudstone facies, interpreted as an ancient muddy shoreline, whereas the allochthonous macrofauna is preserved in a sandstone facies, interpreted to represent a sandy shoreline. Sixteen taxa were identified in a collection of 186 specimens. These taxa or specimens consisted of bivalves, gastropods, brachiopods, a trilobite, and echinoderm stem ossicles.

INTRODUCTION

Macroinvertebrate "marine zones" are common in many of the stratigraphic units associated with the coal deposits of Alabama. Although similar occurrences of abundant invertebrates associated with coal deposits have been extensively investigated in the central and northern Appalachian basins, detailed studies are noticeably absent in the Warrior, Plateau, Cahaba, and Coosa coal fields of Alabama. This is unfortunate because much of the Upper Carboniferous stratigraphy is dominated by invertebrate-bearing shale, siltstone, and sandstone, and invertebrates could be useful for correlations. An inclusive summary of published and unpublished studies from Alabama is given in table VI-8.

The purpose of this report is to briefly illustrate some of the common invertebrates associated with the Mary Lee coal zone; in particular, those invertebrates associated with the ravinement surface and infill reported by Liu and Gastaldo (1989) and Liu (this volume). A more detailed taxonomic and paleoecologic investigation of the entire fauna is currently being pursued.

Samples of the fauna associated with the ravinement surface were collected from five localities along a northwest-southeast strike of exposures (fig. VI-42). The samples consisted of individual specimens collected directly from highwalls, talus piles, and oriented samples later picked apart in the laboratory.

RAVINEMENT ZONATION

Liu and Gastaldo (1989) have described the development of an erosional, transgressive, ravinement surface, which was subsequently covered with sediment, produced by processes associated with nearshore and shoreline development. Two types of facies represented by ravinement beds are distinguished: (1) muddy shorelines are characterized by shale with *in situ* bivalves; and (2) brachiopod assemblages and a sandy shoreline which consists of sandstone with abundant *Zoophycos* traces and assemblages of allochthonous trilobites, echinoderm ossicles, and brachiopods.

In this study, the distribution of fauna in the ravinement infill was found to vary considerably within and between localities. A vertical zonation occurs within the ravinement infill (fig. VI-43). The highwall at locality 14 exposes a ravinement bed that can be subdivided into three zones and illustrates what appears to be a complete sequence. The lowest zone consists of dark-brown to black organic-rich, shale and siltstone with reworked echinoderm ossicles, brachiopod valves, trilobite exuviae, and some bivalves and gastropods. The shells are usually randomly oriented, many are disarticulated, and productids have lost their spines.

Gradationally overlying that zone is a less fossiliferous, usually more massive shale or silty-

Table VI-8.--Chronologic listing of studies, published and unpublished, involving invertebrates associated with the Pottsville Formation of Alabama

Date	Author	Coal field	Description
1926	Butts, Charles	Warrior	Figures fauna identified by G. H. Girty in 1908. Many of the specimens figured were not collected in Alabama, rather are from Illinois, Iowa, Kansas, and Missouri.
1964	Ehrlich, R. L.	Warrior	Field guide to localities in Blount and Jefferson Counties with special mention of macrofossil and trace fossil occurrence.
1965	Metzger, W. J.,	Warrior	Listed fossils from each of his seven stratigraphic subdivisions.
1967	Ferm, J. C., and others	Warrior	Field guide with locations and limited discussions of paleontology.
1972	Ferm, J. C., and others	Plateau	Field guide with locations of marine faunal zones used as environmental indicators.
1975	McKee, J. W.	Warrior	Short study on sediment-fossil relationships.
1976	Taylor, J. D.	Warrior	Biostratigraphic correlation based on ammonites, foraminifera, and ostracods.
1977	Holmes, A. C.	Warrior	Unpublished internal report of the Geology Department at the University of Alabama on macroinvertebrates of the Mary Lee group.
1980	Rich, M.	Plateau-Cumberland	Description of Upper Mississippian to Lower Pennsylvanian Cumberland foraminifera of northeastern Alabama, south-central Tennessee, and northwestern Georgia.
1982	Rheams, L. J., and Benson, D. J.	Warrior	Field guide showing distribution of invertebrates within a portion of the Pottsville.
1984a	Gibson, M. A.	Plateau	Trace fossils as indicators of water depth changes in the Upper Cliff interval.
1984b	Gibson, M. A.	Plateau	Description of in situ versus transported assemblages in the Upper Cliff interval.
1987	Gibson, M. A., and Gastaldo, R. A.	Plateau	Geographic distribution and paleoecology of Upper Cliff coal interval.
1987	Pody, Robert D.	Warrior	Unpublished Master's thesis on the depositional environments and paleoecology of a section along State Highway 69.
1988	Garbisch, J. O.	Warrior	Unpublished Master's thesis concentrating on interval between and including the Mary Lee and Pratt coal groups in Walker County.
1988	Dewey, C., and Garbisch, J. O.	Warrior	Summary of biofacies-lithofacies relationships of the upper Pottsville Formation in Walker County.
1988	Raymond, D. E., and others	Warrior	Identification of invertebrates from bore hole material near Jasper with biostratigraphic assessment.
1989	Gibson, M. A., and Gastaldo, R. A.	Plateau	Taxonomy and stratigraphic distribution of invertebrates and trace fossils associated with the Upper Cliff coal interval.
1989	Gastaldo, R. A., and others	Southern Appalachians	Synthesis of all aspects of Alabama coal measure fauna, flora, and environments of deposition.

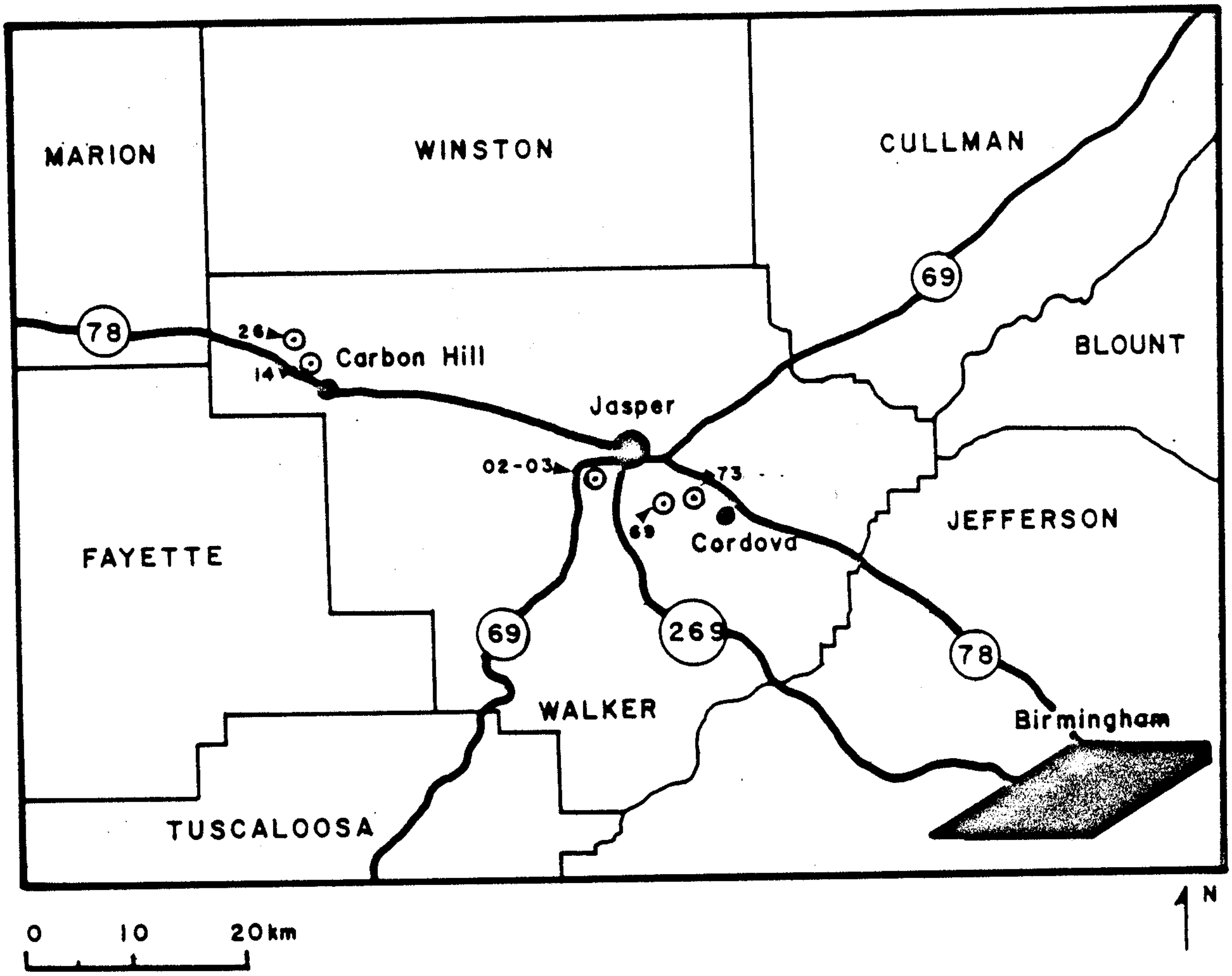

Figure VI-42.--Location map of coal mine exposures from which invertebrates were collected. Circles with dot represent five localities samples. Sample site numbers correspond to field stations.

mudstone with invertebrates in apparent living position, modified by the effects of compaction. This zone becomes less fossiliferous upward and until it grades into the overlying zone; hence, it will be referred to as the "transition zone." This zone represents the living bottom of the infill.

The first two zones do not occur persistently along a single highwall. At various places one or both zones may be missing (fig. VI-43, localities 02-03 and 69). This presumably reflects some characteristic of the substrate (current reworked versus quiet water) during transgression or characteristics of the substrate itself (physically or chemically conducive or nonconducive to fauna). Locality 73 has many barren areas along the ravinement exposure which could represent an original patchiness of distribution in the indigenous fauna. As of yet, it is uncertain as to whether our line of section represents an onshore-offshore transect, oblique transect, or alongshore transect. Pinch-outs do exist in the ravinement infill at some localities.

The uppermost zone is almost always devoid of body fossils but consists of shale or siltstone capped with siderite-infilled burrows. This zone appears to be present along the entire highwall at each of the sampled localities. It is usually overlain by shale or siltstone with abundant discrete siderite nodules. The overlying rocks contain a chonetid brachiopod- or mollusc-dominated fauna that is interpreted to be autochthonous (for a more complete description of this marine zone see Pody, 1987; Garbisch, 1988).

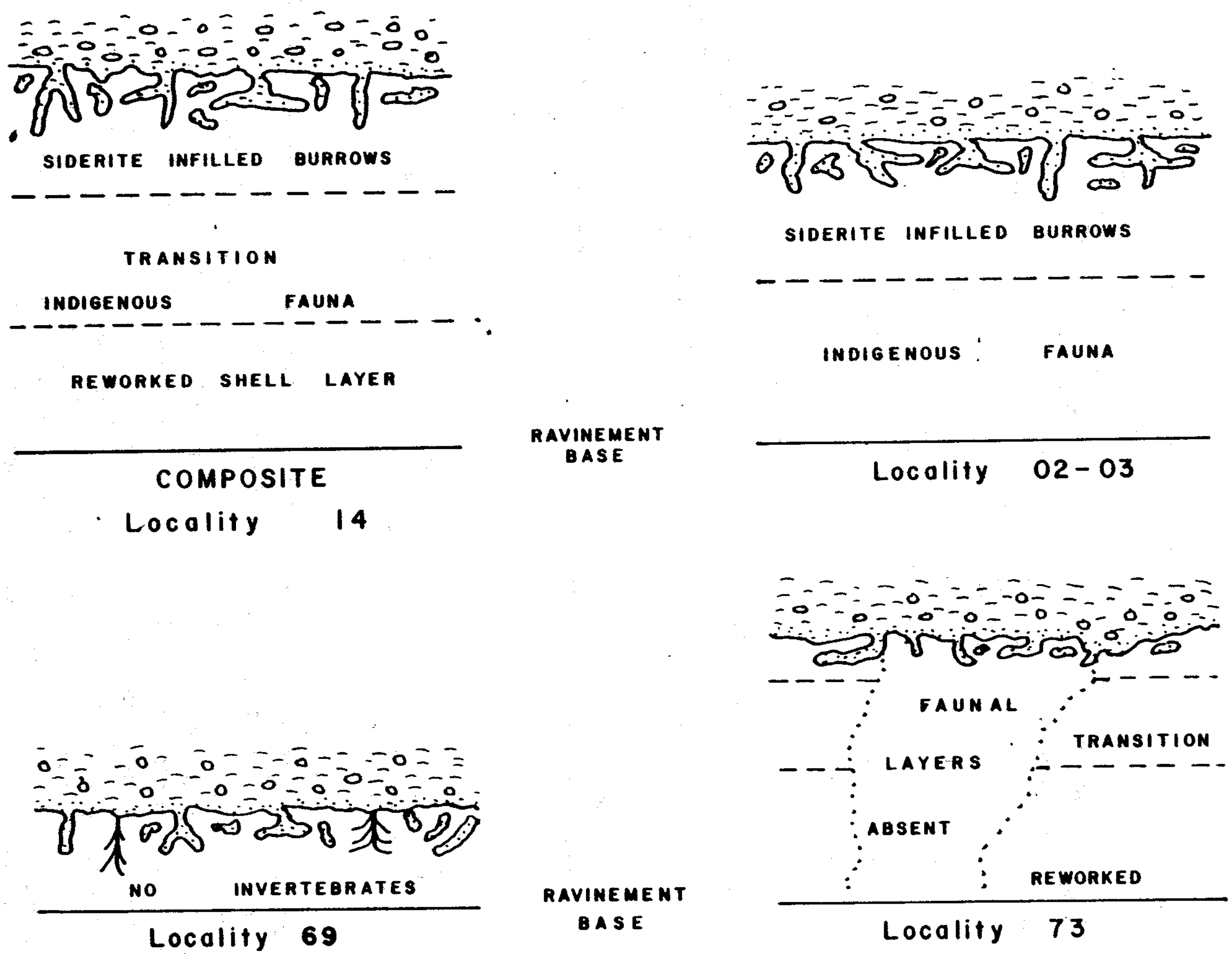

Figure VI-43.--Variations in ravinement bed. Locality 14 illustrates the composite of zones within the ravinement. Localities 02-03, 69, and 73 demonstrate the range of lateral variability within the ravinement infill. Note that the siderite infilled burrowed zone caps all exposures.

COMMON INVERTEBRATES

A total of 186 specimens were collected for this study. Sixteen taxa were identified consisting of bivalves (9 species), gastropods (3 species), brachiopods (7 species), one trilobite, and numerous disarticulated echinoderm stem ossicles (table VI-9; fig. VI-44, VI-45). Fragments of cephalopods and rugose corals have also been collected but not examined for this manuscript. The mode of preservation of the fauna is variable, but brachiopods and some bivalves are usually found with shell material intact or as molds. All of the species are characterized by thin shells with the spines of brachiopods broken at the base (except *Eolissochonetes*). Although the bivalves are often large in size, the brachiopods tend to be smaller than those of the lower "Pottsville" Formation in the Plateau coal field and probably reflect harsh substrate conditions or accumulations of juveniles. Bivalves are usually found articulated, but valves may be butterflied open indicating exposure prior to burial (fig. VI-44). In-living-position bivalves, especially ***Wilkingia elliptica*** and ***Astartella concentrica***, are common (fig. VI-44).

Siderite nodules from the shale and siltstone above the siderite-infilled layer often contain invertebrates. *Orbiculoidea* and *Astartella* were found at numerous localities and presumably served as nuclei within the sediment for siderite formation as did the sediment within the burrows of the burrowed zone that caps the ravinement bed.

CONCLUSIONS

The ravinement infill described by Liu and Gastaldo (1989) contains a mixture of allochthonous and autochthonous invertebrates that can provide us with a glimpse of the indigenous fauna that lived on the sediment at the time of transgression, as well as providing us with a glimpse of the fauna that either was reworked in place or transported onshore from the open-marine realm. Work on the invertebrates of the upper "Pottsville" Mary Lee coal zone is still mostly in the descriptive stage; however, the results of this and other studies indicate that the "marine fauna" of the Alabama coal measures have much to tell us about the development of the environments of deposition of successive coal deposits. Detailed investigation of invertebrate taxonomy and paleoecology are revealing a more complex picture for the marine phases of the Pennsylvanian rocks of Alabama than previously recognized.

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The author wishes to thank the editors of the guidebook for reviewing and Angeline Sanders for typing and editing this manuscript. I would like to thank E. Osborne, I. Thompson, and G. Guthrie for their critical review of this manuscript. Partial support for this project was provided by the University of Tennessee at Martin Faculty Development Fund, Teachers Excellence Fund, and the UTM Geosciences and Physics Gift Fund.

Table VI-9.--Common invertebrates from the ravinement beds and immediately overlying siderite-rich shale and siltstone

Brachiopods	Bivalves	Gastropods	Arthropods
Composita subtilita	*Wilkingia elliptica*	*Bellerophon percarinatus*	?*Paladin* sp.
Desmoinesia muricatina	*Palaeoneilo oweni*	*Straparollus (Amphiscapha) reedsi*	
Cancrinella boonensis	*Astartella concentrica*	*Glabrocingulum (Gabrocingulum) graysvillensis*	
Antiquatonia portlockiana	*Phestia bellistriata*		
Orbiculoidea sp.	*P. arata* *Nuculopsis croneisi* ?*Streblochondria hertzeri* *Dunbarella knighti* *Pteronites* sp.		

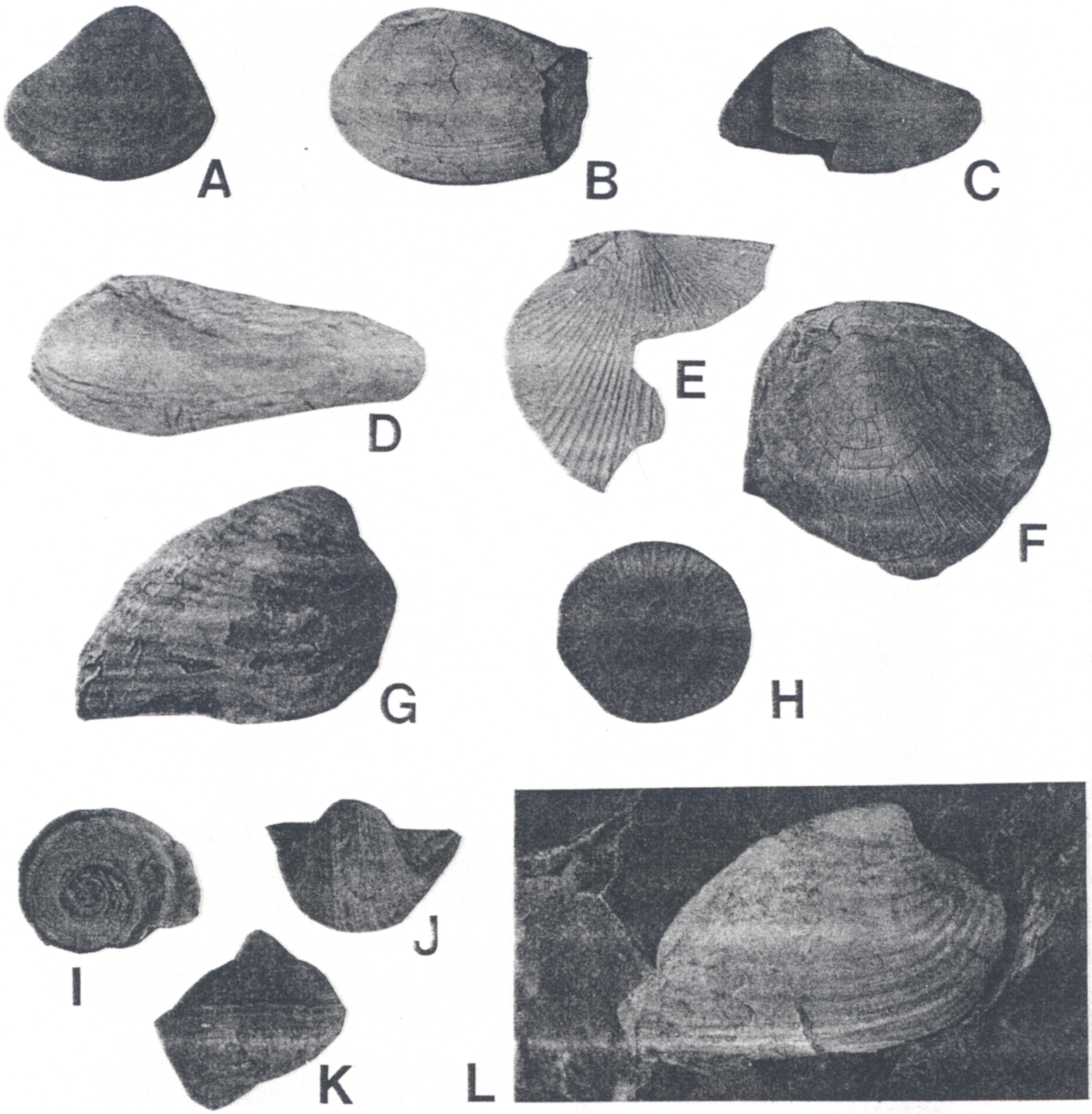

Figure VI-44.--Common invertebrates associated with the Mary Lee coal zone ravinement infill - I. (a) External mold of disarticulated *Nuculopsis croneisi*, Schenck, right valve, x3.0. (b) Fragmented articulated *Palaeoneilo oweni* (McChesney), left valve, x2.0 (c) Fragmented disarticulated *Phestia bellistriata* (Stevens), left valve, external x2.0. (d) External mold of crushed articulated *Phestia arata* (Hall), left valve, x3.0. (e) External mold of fragmented disarticulated *Dunbarella knighti*, Newell, left valve, x2.0. (f) Butterflied ?*Streblochondria hertzeri* (Meek) from a siderite nodule, left valve, x75. (g) Articulated *Astartella concentrica* (Conrad) right valve, x 2.5. (h) Stem, echinoderm ossicle, x2.5. (i) *Straparollus* (*Amphiscapha*) *reedsi* (Knight), basal view, x 2.1. (j) *Bellerophon percarinatus* (Conrad) x2.0. (k) Side view of *Glabrocingulum* (*Gabrocingulum*) *graysvillense* (Norwood and Pratten) missing apical region, x2.0. (l) Oblique view of undersurface of shale slab containing an articulated, in-living-position, *Astartella concentrica*, right valve, x4.0.

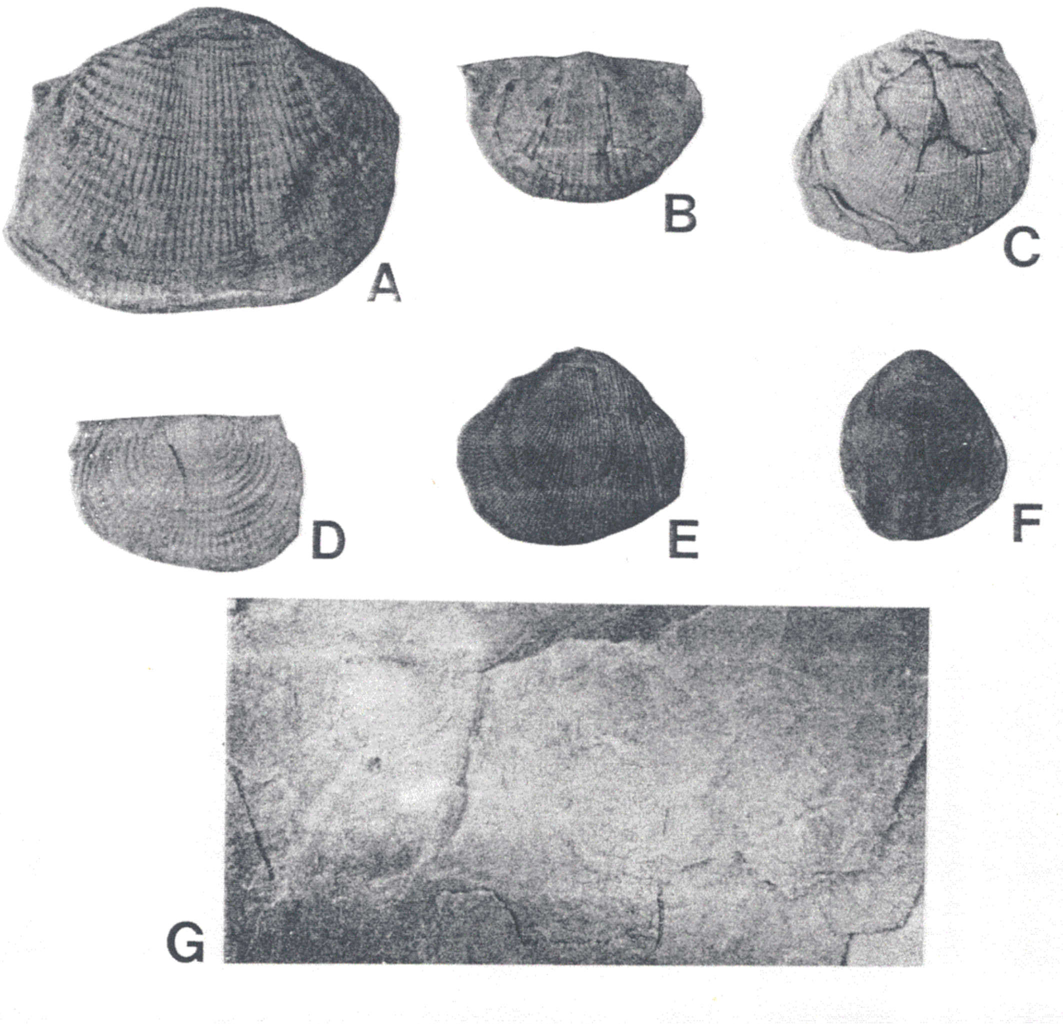

Figure VI-45.--Common invertebrates associated with the Mary Lee coal zone ravinement infill - II. (a) Pedicle view of *Antiquatonia portlockiana* (Norwood and Pratten). x2.0. (b) Pedicle valve of *Desmoinesia muricatina* (Dunbar and Conrad), x2.0. (c) Pedicle valve *Cancrinella boonensis* (Swallow), x2.0. (d) External mold of brachial valve of *Desmoinesia muricatina*, x2.5. (e) External mold of pedicle valve of *Linoproductus* sp., x1.0. (f) Articulated *Composita subtilita* (Hall), x1.0. (g) Slab containing two *Eolissochonetes morsei*, x2.

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ROAD LOG - DAY 1

Mileage Cumulative	Mileage Interval	Comments
0.0	0.0	Leave Jasper Best Western Inn. DEPART ACROSS MEDIAN. TURN LEFT (west) onto U.S. Highway 78 (fig. VI-46).
1.0	1.0	Railroad overpass.
1.2	0.2	Intersection Alabama Highway 69. CONTINUE STRAIGHT.
1.8	0.6	Outcrop on right is thin-bedded to laminated, fine-grained sandstone with moderate angle small-scale trough cross-beds, large-scale epsilon cross stratification. Weathered shale-chip conglomerates. Cross beds strike N-S, dip 16° E. Rippled surfaces. Thickness >3 m, at least two sequences separated by erosional bounding surface. Appears massive due to weathering. Possible point bar. Capped by yellowish, weathered, sideritic shale. Stratigraphic position: below Mary Lee coal zone.
2.4	0.6	Moon Road on left.
3.0	0.6	Gamble Road.
3.2	0.2	Abandoned surface mines on left in Mary Lee and Newcastle seams, south of U.S. Highway 78.
4.2	1.0	Jasper Municipal Landfill entrance on left. On right is a rhythmically bedded mudstone sequence overlain by a medium- to fine-grained sandstone sequence. The thickness is 11 m. The mudstone is characterized by graded bedding and fossil plant assemblages, and the sandstone by small-scale cross bedding, parallel, and lenticular bedding. Horizontal and vertical burrows on the bedding surfaces. Paleocurrent direction NW. Stratigraphic position: interval between the Mary Lee and Newcastle coal seams.
4.9	0.7	Outcrop of Mary Lee coal on left. Thickness is 1.35 m (thickest coal in the study area is 1.7 m). Palynological sample site (Liu station 054; see Eble, this guidebook).
5.2	0.3	Outcrop on right is interlaminated, very fine-grained sandstone and siltstone (>5 m). Microcross laminated beds (0.5 to 1 cm) with silty mud drapes. Some sandstone lenses (20 cm thick) near top of outcrop. Moderately bioturbated (vertical burrows, *Scalarituba*) in siltier intervals. Comminuted plant material. Sandy intervals devoid of plant fossils or traces. Stratigraphic position: Mary Lee coal zone, below Mary Lee coal.
6.0	0.8	Walker County Landfill entrance on right.
6.3	0.3	Blackwell Road on left.

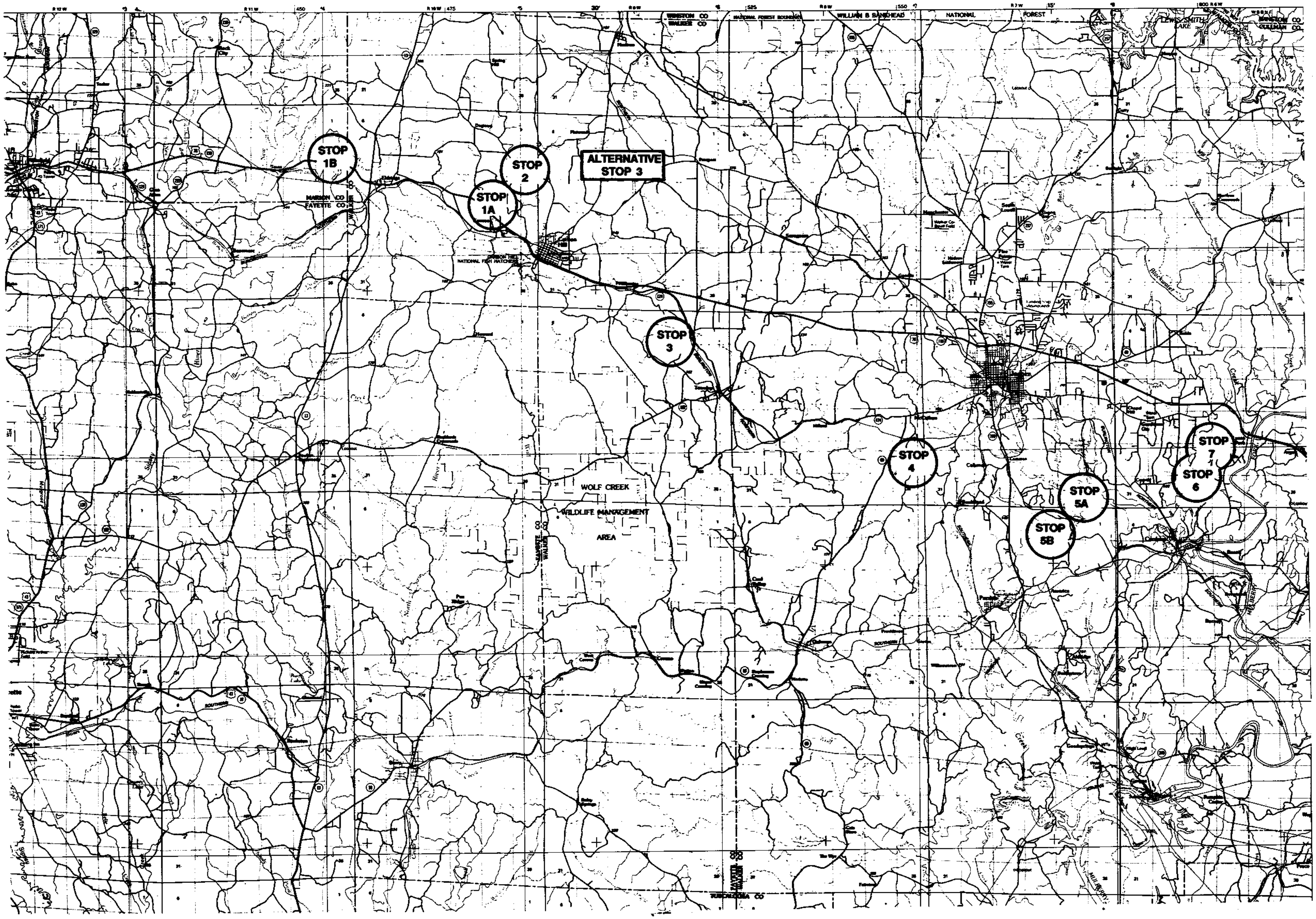

Figure VI-46.--Location map for field trip stops on days one and two.

6.9	0.6	Saragossa Road on right.
7.1	0.2	Hot Nut Hut on right.
7.3	0.2	Reclaimed surface mine on left and right in Newcastle, Mary Lee, Blue Creek, and Jagger seams.
7.6	0.3	Abandoned sandstone quarry on right. Yellowish-gray (5Y7/2), fine- to medium-grained, quartzose sandstone, thickness <3.5 m. Thin- to thick-bedded, tabular cross stratification (vector mean of paleocurrent directions—191°), some small-scale trough cross bedding, horizontal lamination. Slightly bioturbated (vertical burrows). Rare shale-chip conglomerates. Stratigraphic position: between Jagger and Blue Creek coal seams.
7.8	0.2	Scott Cemetery Road.
9.4	1.6	Abundant Life Temple on left.
9.6	0.2	Bridge over Lost Creek.
10.8	1.2	Alabama Highway 124. CONTINUE STRAIGHT.
11.2	0.4	Reclaimed surface mine in Newcastle, Mary Lee, and Blue Creek seams on right. Lost Creek Coal Company. The interval between the Mary Lee and Newcastle coal seams is characterized by rhythmically bedded mudstone and medium-grained sandstone with various cross stratification. The interval is 7 m thick. Palynological sample taken (Liu station 022; see Eble, this guidebook).
11.7	0.5	Freewill Baptist Church sign on right.
12.0	0.3	Outcrop on right is in interval above ravinement surface. Mudstone and silty mudstone with a few thin-bedded fine-grained sandstones. Mudstone is horizontally bedded, sandstone is ripple bedded. Slump structures, including soft-deformed sand balls and pillows.
13.0	1.0	Carbon Hill city limit.
14.6	1.6	Traffic signal.
14.65	0.05	Cobb Coal Company building on right.
15.0	0.35	Outcrop on right includes Jagger coal and clastic sequence above. Jagger coal is 1.38 m thick with a 18 cm carbonaceous claystone parting. Erect, *in situ*, lycopods and calamites rooted in top of coal. Coal is overlain by 0.65 m of mudstone containing cast trunk material and lycophyte leaves and stems. Sequence above mudstone consists of rhythmically bedded, interlaminated, shaly siltstone and very fine-grained sandstone. Bedding is cyclic—groups of sandy laminations (3 to 5 cm thick) 2 to 3 cm apart. Abundant current lineations (mean 310°), tool marks, microcross stratification. Trace fossils include surface trails (*Haplotichnus, Kouphichnium*) and shallow burrows

(*Treptichnus*). Interpreted as peat swamp overlain by alluvial swamp and tidal flat sediments.

15.4	0.4	Entrance to Gateway Malls, Inc. South mine on right (Mary Lee, Blue Creek, and Jagger seams currently being mined).
15.8	0.4	Kansas city limit.
16.1	0.3	Entrance to Gateway Malls, Inc., South mine on right (Mary Lee, Blue Creek and Jagger seams currently being mined).
17.1	1.0	Turn Right, proceed 0.1 mi and park.

STOP 1A - BRIDGE OVER TRINITY CREEK (1 HOUR)

T. M. DEMKO

This stop is the same as that of the lowest unit of Raymond and others (1988) measured section no. 4 (Trinity Creek section). The stop consists of outcrops along the margins of Trinity Creek and an abandoned quarry to the north of the creek (Demko Station 095) (fig. VI-47). The outcrops represent the "Jagger bedrock" sandstone. The creek exposures display the Jagger sandstone in cross sectional view, whereas in the quarry exposure the sandstone can be seen in plan view. These exposures provide a three-dimensional perspective of the "Jagger bedrock."

The "Jagger bedrock" in these exposures is a fine- to medium-grained quartzose sandstone. There is no evidence of finer clastics in the system. Mud drapes are absent, and there are no intercalated muddy or silty beds in the sequence. The sandstone is characterized by primary sedimentary structures including: (1) large-scale trough stratification; (2) trough cross stratification; (3) tabular cross stratification; and (4) ripple lamination and ripple surfaces. Paleocurrent directions from cross bed dips are to the south-southwest. These are interpreted to represent tidal flood-current derived structures. Ripples are present in runnels situated in the lee of large scale troughs. These ripples and runnels are interpreted to have been ebb current-derived structures. Strikes of ripple crests are north-northeast to south-southwest (fig. VI-3; Demko, this guidebook). Soft-sediment deformational features of the primary sedimentary structures are common. The most often encountered features are overturned cross bedding and slumps. These structures indicate movement in the same direction as cross bed dip directions.

To date, a single body fossil has been identified from this unit. It is believed to be a portion of an eurypterid. Rare surface traces are also preserved on the lee side of large-scale troughs.

The abandoned quarry (continue along road for 2.1 mi, turn right, continue 0.3 miles, quarry on right) provides an exceptional opportunity to view the paleotopography on an outcrop scale. The relationships between the paleotopography and primary sedimentary structures are easily discerned in this exposure (see Demko, this guidebook). Return to Highway 78.

17.7	0.6	Outcrop on left and right is sandstone interval above the Mary Lee coal. Medium- and fine-grained sandstone with large- to small-scale planar cross bedding (current direction 330° to 320°) and trough cross bedding. Set thickness varies from 0.5 to 10 cm.
18.3	0.6	Outcrop of sandstone split of the Mary Lee coal. Fine-grained sandstone with small-scale cross bedding. Thickness > 2 m. Prostrate sand-cast logs are oriented northeastward, which are perpendicular to the current direction. The lower bench of the Mary Lee is 0.18 m thick.

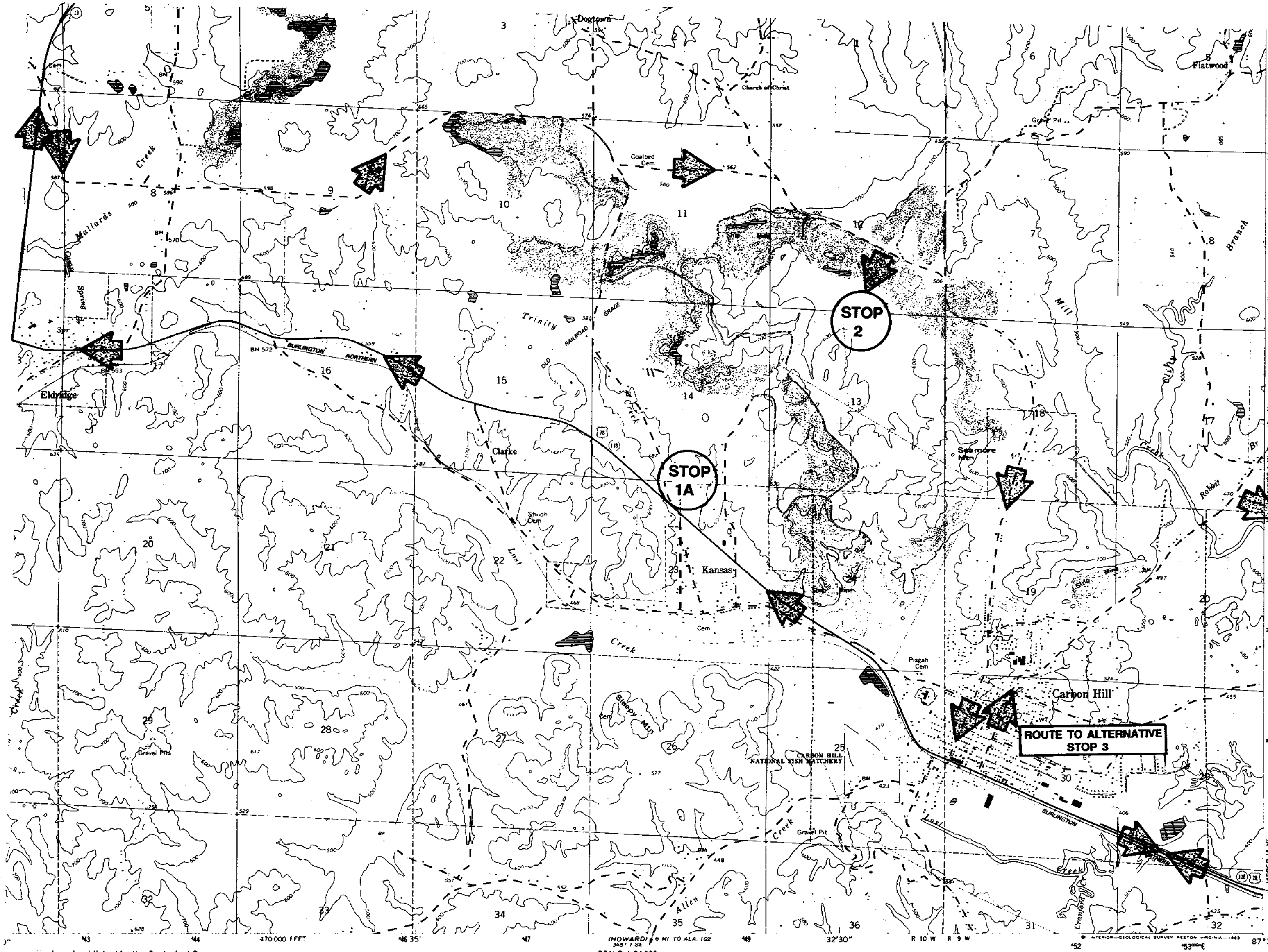

Figure VI-47.--Map of the Carbon Hill area. Location map: Stop 1A. secs. 14 and 23, T. 13 S., R. 10 W., and Stop 2. secs. 11 12, and 13, T. 13 S., R. 10 W., Carbon Hill 7.5-Minute Quadrangle, Walker County, Alabama.

19.2	0.9	Reclaimed surface mine in Mary Lee and Blue Creek seams on right.
19.9	0.7	Eldridge city limit.
20.4	0.5	Rib Crib Bar-B-Q.
21.0	0.6	Junction Alabama Highway 13. CONTINUE STRAIGHT.
22.0	1.0	Marion County line.
22.3	0.3	**STOP 1B. BRIDGE OVER MALLARD CREEK (1 HOUR).**

T.M. DEMKO

This stop includes outcrops along the margins of Mallard Creek and its unnamed tributaries (fig. VI-48). The outcrops represent the "Jagger bedrock" sandstone (Demko Station 093). The creek exposures display the Jagger sandstone in cross sectional view.

The unit is a fine- to medium-grained quartzose sandstone. The outcrops expose the upper part of the unit, but the top of the sandstone is not observable (as in Stop 1A). Primary sedimentological structures that can be viewed include: (1) large-scale trough stratification, and (2) trough cross stratification. Paleocurrent direction as discerned from cross bed orientation is to the southeast (fig. VI-3; Demko, this guidebook). Soft sediment deformational features are abundant and localized to specific glide planes within the unit. These overturned cross beds and slump features indicate movement to the southeast. Similar features can be seen in outcrops within the immediate vicinity (see below).

Sandstone overhangs along the creek were used by local indians as shelters. It is common to find artifacts, including arrow heads, in the stream sediments.

22.6	0.3	TURN AROUND at Kelly farm on right, head back east on U.S. Highway 78.
22.9	0.3	Bridge over Mallard Creek.
23.2	0.3	Walker County line.
24.2	1.0	Junction Alabama Highway 13. TURN LEFT (north).
24.5	0.3	Outcrop on left and right is "Jagger Bedrock." Covered in part. Section is believed to be the upper part of the sandstone unit of STOP 1B. Very fine- to fine-grained quartzose sandstone. Small-scale trough cross beds. Paleocurrent directions south -southeast.
25.5	1.0	TURN RIGHT (east) onto paved road, bear right (south). Sign indicating 5 ton restricted bridge ahead.
26.0	0.5	Fork in road, BEAR LEFT. Sign at intersection for Bluff Springs Poultry Project, Inc.
26.3	0.3	Outcrop along stream below bridge over Mallard Creek. "Jagger Bedrock." Same lithology as STOP 1B. The upper part of the sandstone exposed here is characterized by low-angle trough cross beds, the lower part by higher angle troughs. The cross bed sets have sloping bounding surfaces and could represent tidal bundles.

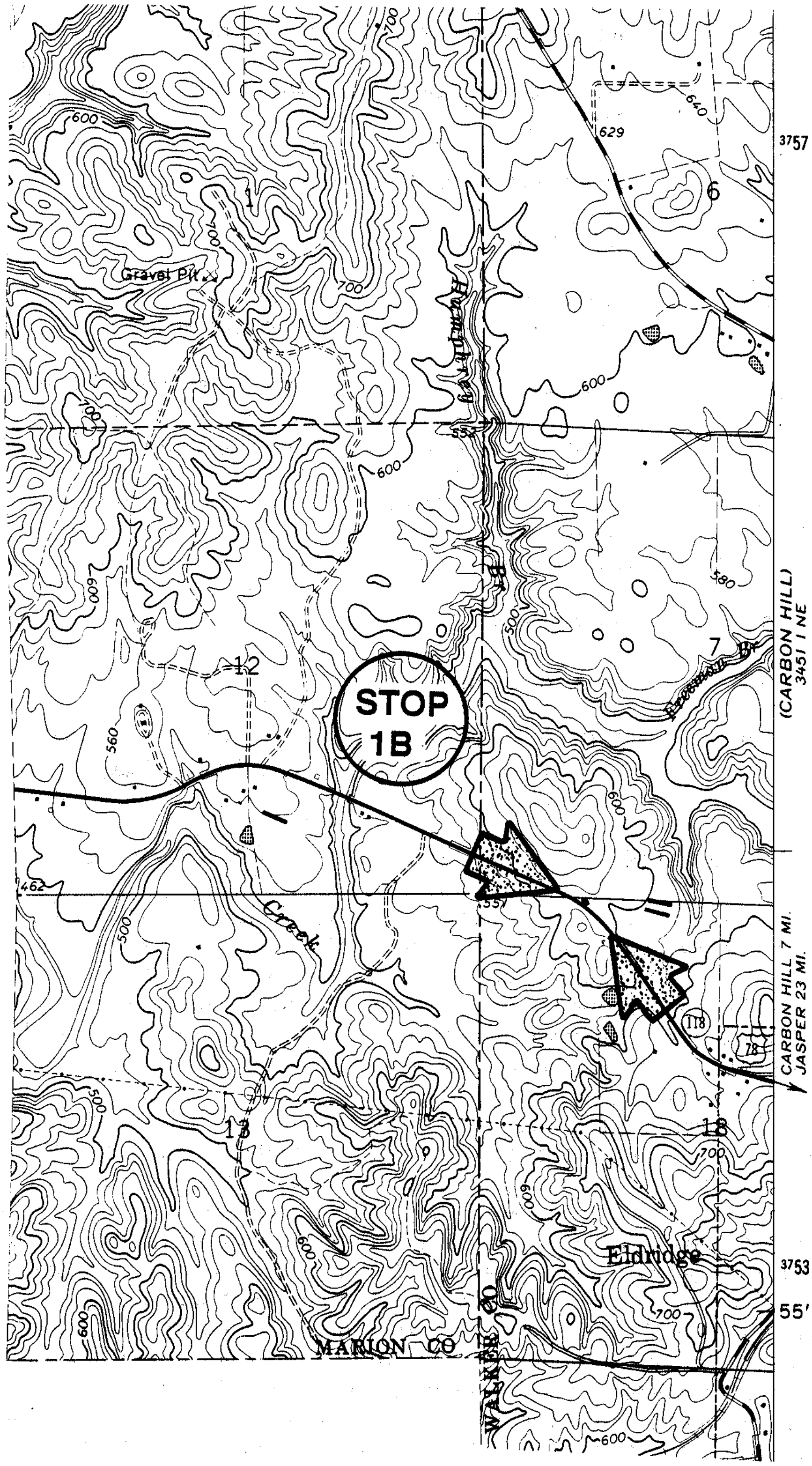

Figure VI-48.--Map of Mallard Creek area. Location map: Stop 1B, sec. 12, T. 13 S., R. 11 W., Glen Allen 7.5-Minute Quadrangle, Marion County, Alabama.

26.7	0.4	Stop sign at intersection. Proceed straight.
26.9	0.2	Reclaimed surface mine in Blue Creek seam on right. Pickens Coal Company.
27.2	0.3	Oil and gas wellhead on right.
27.8	0.6	Fork in road, BEAR LEFT.
28.7	0.9	Abandoned surface mines on right were in the Blue Creek seam, but also expose the Mary Lee coal horizon above.
28.8	0.2	Entrance to IMAC Energy, Inc., Blue Creek #2 mine on left. The interval between marine zone and the Mary Lee coal is characterized by horizontally bedded mudstone with silty laminations. Thickness is 1.8 m. Two benches of the Mary Lee: lower bench is 0.28 m, upper bench is 0.2 m (probably equivalent to the Newcastle coal). Plant leaves and vitrinized prostrate logs on bedding planes. Palynological sample site (Liu station 082; see Eble, this guidebook).
29.6	0.7	Intersection. BEAR LEFT.
30.5	0.9	Stop sign at intersection. TURN RIGHT.
31.4	0.9	**STOP 2. ENTRANCE TO GATEWAY MALLS, INC., NORTH MINE. ACTIVE SURFACE MINE IN MARY LEE, BLUE CREEK, AND JAGGER SEAMS (2.5 HOURS).**

T. M. DEMKO, Y. LIU, R. A. GASTALDO and A. K. RINDSBERG

One of the largest mining operations in Walker County, the Gateway Malls Hope Galloway North mine provides extensive lateral and vertical exposure of the Mary Lee coal zone (figs. VI-49 and VI-50). The Mary Lee, Blue Creek, Jagger, and a localized coal are exploited in the mine. The Mary Lee and Jagger coals were deep mined during the early twentieth century. The present surface mine highwall extends over 1.5 km along a northwest-southeast strike. This exposure provides an excellent opportunity to evaluate lateral and vertical facies relationships in the study area. Palynological samples were taken at this locality (see: Eble, this guidebook).

The Jagger coal is of variable thickness in this area, ranging from 0.2 m to >2.0 m. The thickness variability is dependent on the paleotopography of the underlying "Jagger bedrock" (see Demko, this guidebook). The thickest Jagger coal, comprised of two benches separated by a carbonaceous mudstone parting, occurs in paleotopographic lows. A thin, localized unnamed coal may be present below the recognized lower bench of the Jagger also in the paleotopographic lows. It may represent a "lower" split of the Jagger coal, and is called the "Ream" by the miners. It is not correlative with the Ream seam, which occurs below the "Jagger bedrock." The thinnest Jagger coal, consisting of a single bench, occurs over the highs. The Jagger coal is low in sulfur and moderate in ash content (exclusive of the parting). Two erect autochthonous forests are preserved above the Jagger coal. The first is rooted in the coal proper, the second is preserved approximately 0.5 meters above the contact of the coal and overlying sediments. Within the first 0.3 m, a coalified compression-impression assemblage of terminal peat forest litter is preserved. The second forest represents colonization of an alluvial swamp.

The interval above the Jagger and below the Blue Creek coal is characterized by interlaminated, very fine-grained sandstone, siltstone and shale. The lamination and bedding shows a pronounced cyclicity. This marks a change in the sedimentological character of the section. This change is from forested clastic swamp to tidally influenced mudflat environments. Trace fossils are abundant and

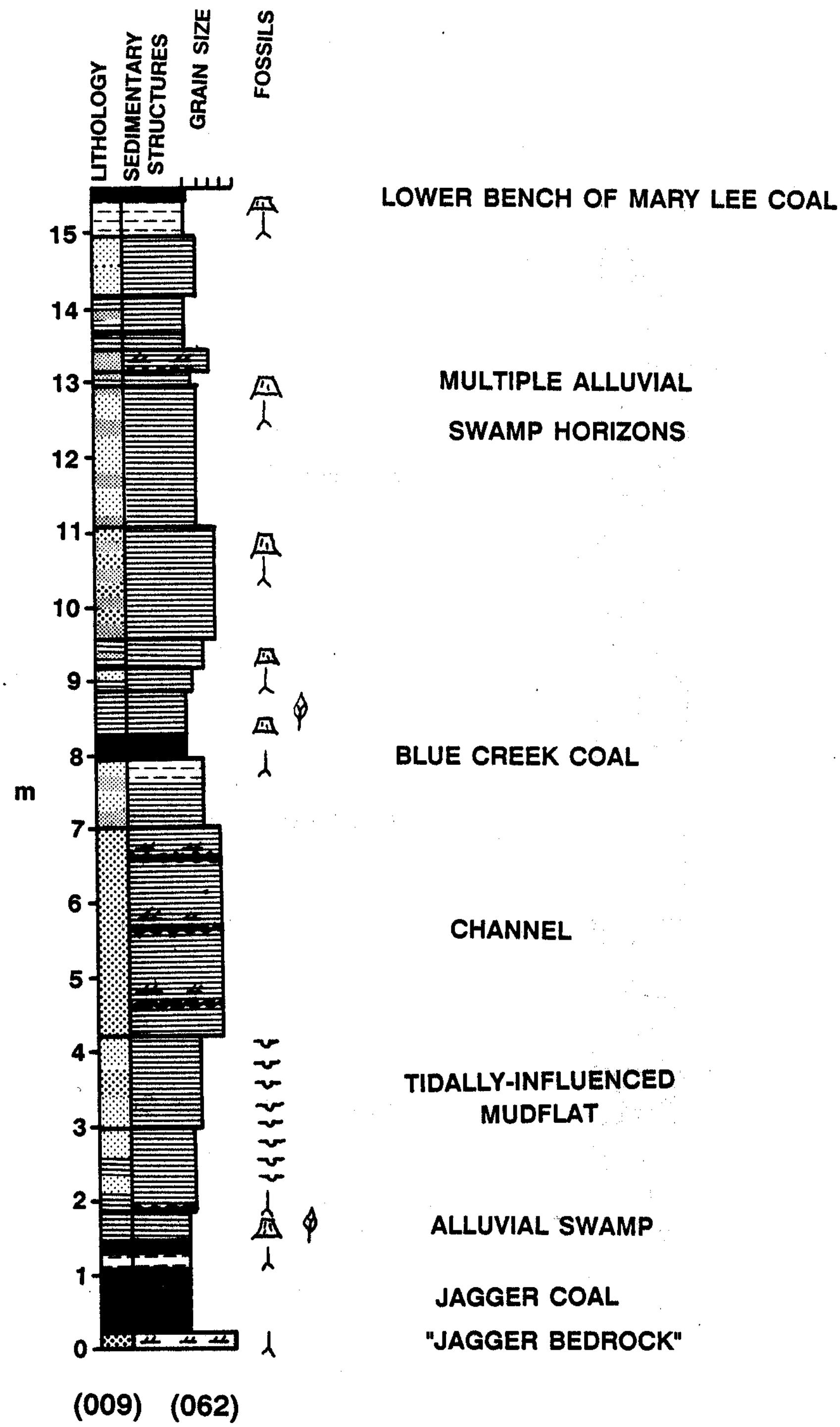

Figure VI-49.--Lithologic column with interpreted depositional environments of the Jagger to Mary Lee interval at Stop 2, Gateway Malls Hope Galloway mine (secs. 11, 12, and 13, T. 13 S., R. 10 W., Carbon Hill 7.5-Minute Quadrangle, Walker County, Alabama).

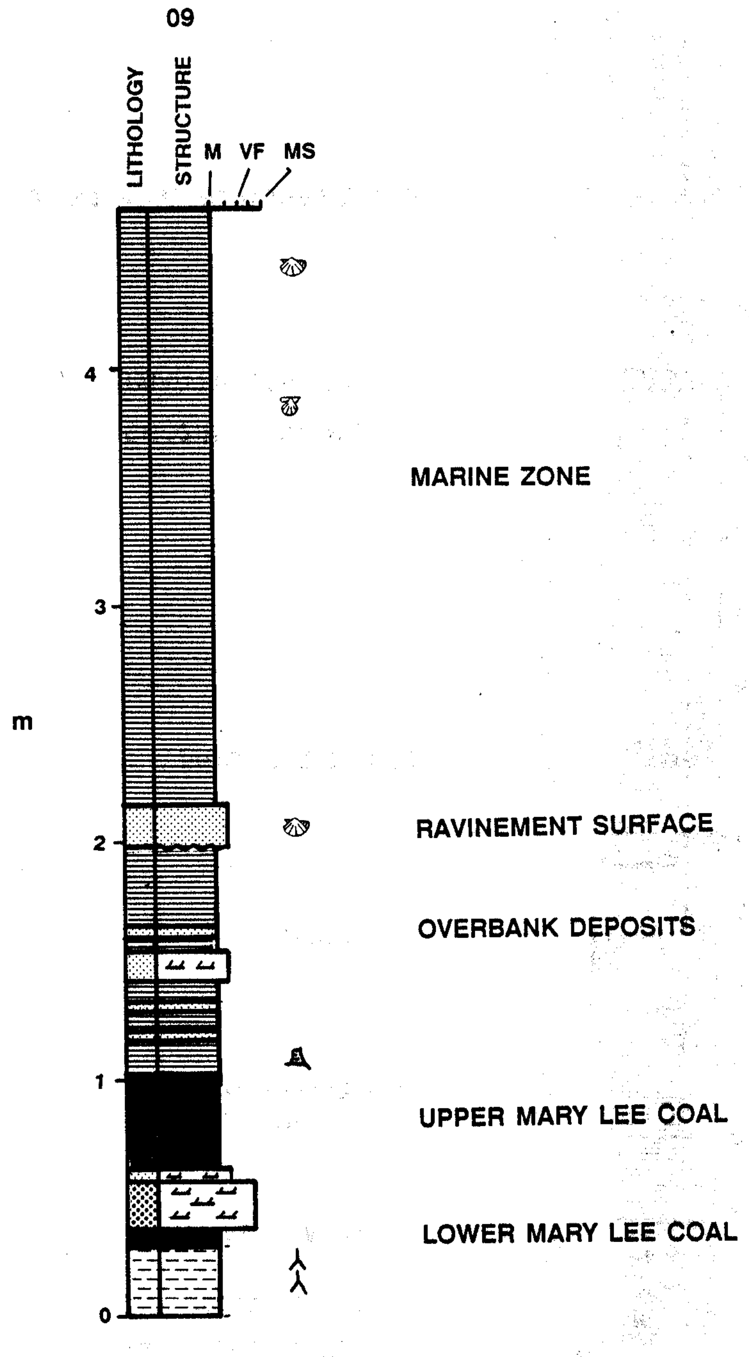

Figure VI-50.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 2, Gateway Malls Hope Galloway Mine (secs. 11, 12, and 13, T. 13 S., R. 10 W., Carbon Hill 7.5-Minute Quadrangle, Walker County, Alabama).

well preserved. Ichnofossils include resting, dwelling, locomotion, and feeding structures (see Rindsberg, this guidebook). Common genera include *Lockeia, Plangtichnus, Haplotichnus, Treptichnus, Kouphichnium*, new genera of feeding and resting traces, and vertebrate trackways. Macroinvertebrate body fossils were not preserved in this environment. The interval is topped, locally, by a thin (1 to 2 m), broad (>100 m) channel fill. The channel fill is a very fine-grained sandstone with imbricated rip-up clasts of shale and sideritic shale.

The top of the sandstone is rooted by lycophytes, and acted as the paleosol for the development of the Blue Creek coal. The Blue Creek coal averages 0.35 m across the area, is low in sulfur and moderate in ash. The terminal peat swamp forest is preserved *in situ* above the Blue Creek coal. This site offers the best exposure of the terminal Blue Creek peat swamp forestation. Erect lycophytes dominate the preserved standing forest, whereas compressed pteridosperms in the first 0.4 m of overlying mudstone dominate the contribution from the understory vegetation (see Gastaldo, this guidebook).

The Blue Creek to Mary Lee interval is characterized by a relatively homogeneous mudstone, with localized thin (0.5 to 1.0 m), very fine-grained sandstone channel forms. Between the two coals are at least five preserved alluvial swamps. These are identified in this mine by the presence of: (1) mud-cast prostrate and erect lycophyte trunks; (2) lycophyte-dominated leaf litter horizons (at the uppermost level of preserved erect trunks); (3) compression and cast *Stigmaria* with helically arranged appendages permeating the mud (in some instances primary sedimentary structures are not obliterated by this bioturbation); and (4) rhizoconcretions. It is common to find both erect lycophytes and sphenophytes (*Calamites*) below the Mary Lee coal, terminating in the base of the coal.

The Mary Lee coal is a moderate to high ash, low sulfur coal. In this area it is characterized by two benches separated by a channel-form sandstone. The lower bench of the Mary Lee varies from 0.2 to 0.3 m, the upper bench from 0.5 to 0.7 m. The coal split is a medium- to fine-grained sandstone distinguished by small-scale trough cross lamination segregated into several internally stacked sequences. The overall sequence is fining upward, but an accumulation of pebbles, cobbles and boulders is associated with a log jam that is preserved in the top of the sandstone. These clasts are associated with logs transported from the extrabasinal area by high magnitude floods. Pebbles are found within hollowed logs, and cast the inside of the tree. Cobbles and boulders are dispersed between logs. These clasts provide reliable evidence for the sediment provenance of the "Pottsville" Formation. Vertical (*Skolithos, Monocraterion*) and horizontal (*Asterichnus*) burrows are found within the lower and upper part of the channel sandstone, respectively. The channel is localized, and outside of the channel belt the lower and upper benches of the Mary Lee merge.

An erect forest occurs above the Mary Lee coal in this site. The forest is preserved in mudstone and fine-grained sandstone. These rocks are interpreted to represent deposition in alluvial swamps and contemporaneous fluvial environments. A localized channel-fill and levee/overbank deposits can be seen. The channel form is truncated, and this unconformity marks the base level of erosion (ravinement surface) by a transgressive event (see Liu, this guidebook).

Above the ravinement surface are marine deposits (Morris shale; sensu Raymond and others, 1988) characterized by shale with layers of siderite concretions in beds. The shales preserve a depauperate marine fauna (see Gibson, this guidebook). The thickness varies up to 20 meters. The Gardendale sandstone (sensu Raymond and others, 1988) overlies this unit and is present at the tops of the hills in the area. This can be observed near the tops of the highest highwalls.

31.5	0.1	Gateway Malls, Inc., North mine office.
31.6	0.1	BEAR RIGHT (northwest). Fuel tanks.
31.65	0.05	ANFO storage bins, explosive storage magazines. CONTINUE WEST.
31.95	0.3	Abandoned pit exposing Jagger coal to Mary Lee coal interval. Tidal flat sequence above Jagger. Standing lycophytes above Blue Creek coal. Mary Lee coal with sandstone channel split. BEAR LEFT uphill.

32.2	0.25	Active highwall on left exposing interval from Jagger coal to above Mary Lee coal.
32.9	0.7	Electric power substation on left.
33.1	0.2	Ravinement surface outcrop. TURN AROUND, head back uphill.
34.8	1.7	Gateway Malls, Inc., North mine entrance. TURN RIGHT on paved road to Carbon Hill.
37.0	2.2	Cemetery on right.
37.3	0.3	4-way stop sign at intersection. CONTINUE STRAIGHT.
37.8	0.5	Stop sign at intersection. Patterson Monument Company. "Slow down, we can wait."
37.85	0.05	Stop sign at intersection.
38.05	0.2	Intersection U.S. Highway 78. TURN LEFT (EAST). Downtown Carbon Hill.
38.1	0.05	Traffic signal.
38.2	0.1	Begin road log for Alternative Stop 3. LEFT TURN onto North Elm Street.
38.9	0.7	Carbon Hill Elementary School.
39.4	0.5	Active surface mine. Burleson and Mullins Coal Co., Inc. Mining Mary Lee and Blue Creek seams and Jagger when available. Jagger changes thickness rapidly (0.56 to 0.0 m). Alluvial swamps between Blue Creek and Mary Lee; three paleosols evident.
39.5	0.1	Carbon Hill Freewill Baptist Church.
40.0	0.5	Mill Creek Reclamation Project in abandoned surface mines in Jagger coal.
40.25	0.25	Bridge over Mill Creek.
40.5	0.25	Intersection. TURN RIGHT.
42.2	1.7	Road on left to reclaimed portion of Gateway Malls, Inc., Prospect Mine.
43.0	0.8	Intersection. TURN LEFT onto unpaved road.

43.3	0.3	**ALTERNATIVE STOP 3. ENTRANCE TO GATEWAY MALLS, INC., PROSPECT MINE. (1 HOUR).**

DEMKO, T. M., LIU, Y., and GASTALDO, R. A.

This stop is at an active surface mine in the Jagger, Blue Creek and Mary Lee coal seams (figs. VI-51, VI-52, and VI-53). The mine highwall is oriented approximately north-south, and extends for over 2 km in distance. The main feature at this stop that differs from STOP 2, is the appearance of the Newcastle coal as a split of the Mary Lee coal (fig. VI-54).

The Jagger coal occurs as two benches, with the lowest bench directly on top of the "Jagger bedrock." There is no evidence for the localized "lower" split developed in the topographic lows. Standing lycophytes occur within the carbonaceous mudstone parting that separates the Jagger into two benches. Spectacular rolls in the mine floor beneath the Jagger coal are the result of the paleotopography of the underlying sandstone. The stratigraphic sequence beginning above the Jagger coal to the Mary Lee coal is similar to that as described for STOP 1.

When exposed, the gleyed paleosols beneath the Blue Creek and Mary Lee coals display exceptionally preserved components of these swamps. These include *Stigmaria* axes with helically arranged "rootlets" (appendages), coalified and mud cast prostrate lycophyte trunks (which may exceed 1.0 m in diameter), and canopy litter. The canopy litter is comprised of dichotomously forked branches on which remain long, thin leaves. Often, reproductive cones are found attached to the terminus of each branch. Rhizoconcretions are commonly developed either parallel to the stigmarian axial systems or surrounding "rootlets." The vegetation in these clastic swamps is lycophyte dominated.

The Mary Lee coal averages 0.7 m in thickness in this mine (correlative with the merged lower and upper bench of STOP 2). A split of the Mary Lee coal is seen at this stop (fig. VI-54), resulting in the development and wide geographical distribution of the Newcastle coal to the east (see: Liu, this guidebook). The split is mudstone and siltstone with graded bedding. The thickness of the split ranges from 0.0 to 5.0 m. Erect lycophytes are preserved above the Mary Lee coal, and at least two stigmarian zones are preserved within the split, proper.

The ravinement surface is found above the Newcastle or unsplit Mary Lee coals. The ravinement surface is often difficult to identify in exposure due to the nature of surface mining. When the exposure is fresh, observable characteristics are subtle. The lithology of the ravinement bed is siltstone to fine-grained sandstone. This overlies siltstone or fine-grained sandstone. Because of the similarity between the ravinement bed and underlying rock, it is often difficult to distinguish the unconformity. The main criterion that can be used under these circumstances is the identification of the macroinvertebrate assemblage (see Gibson, this guidebook) in the ravinement bed, and the coalified compression plant fossil assemblage (representing an alluvial swamp) below.

TURN AROUND, return to Carbon Hill.

44.4	1.1	Bridge over Lost Creek.
46.6	2.2	Reclaimed surface mine on left. Lost Creek Coal Company.
47.0	0.4	Junction Alabama Highway 124. TURN RIGHT.
47.05	0.05	BEAR LEFT.

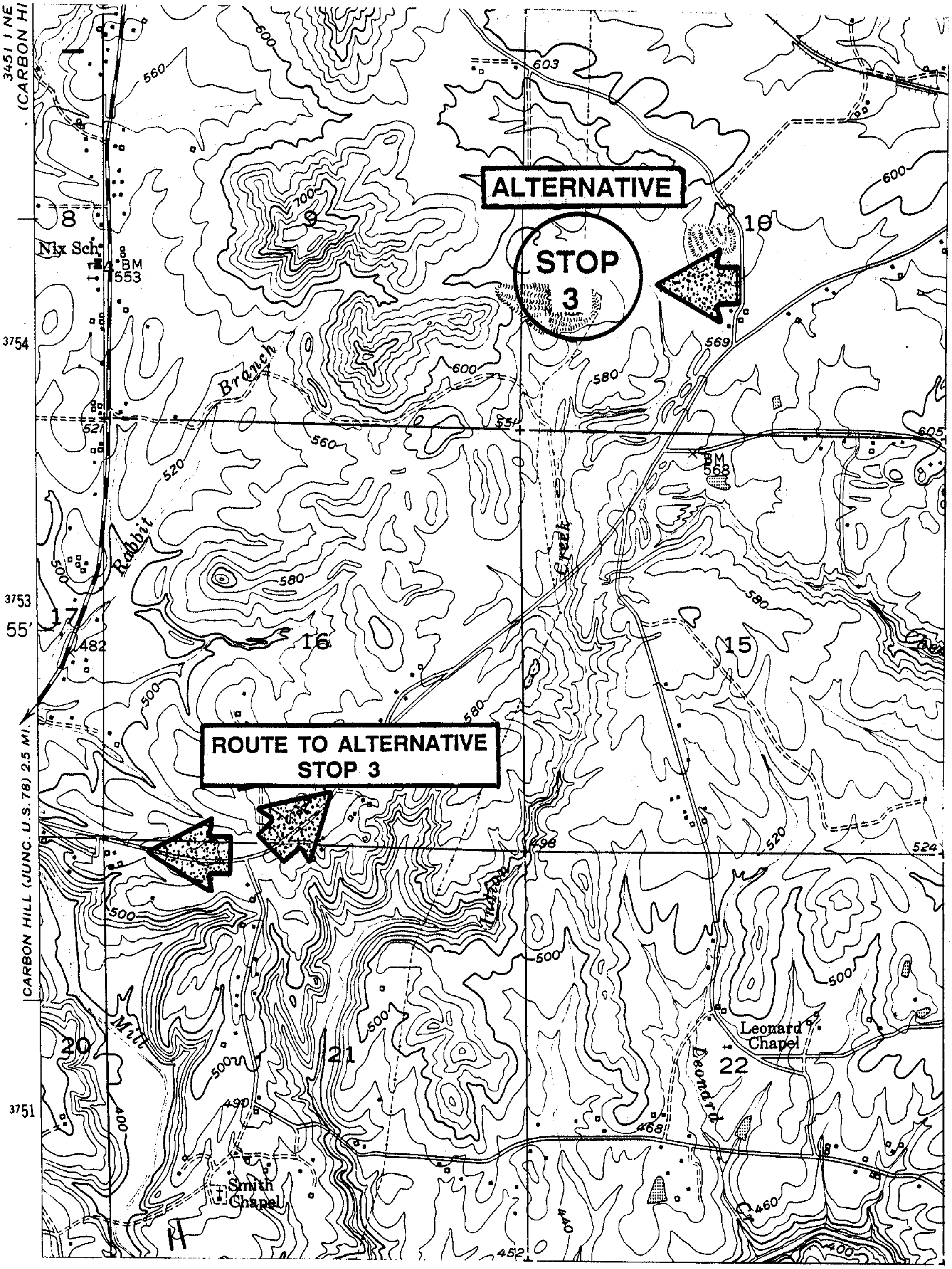

Figure VI-51.--Map of Prospect area with route to alternative Stop 3, sec. 16, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle, Walker County, Alabama.

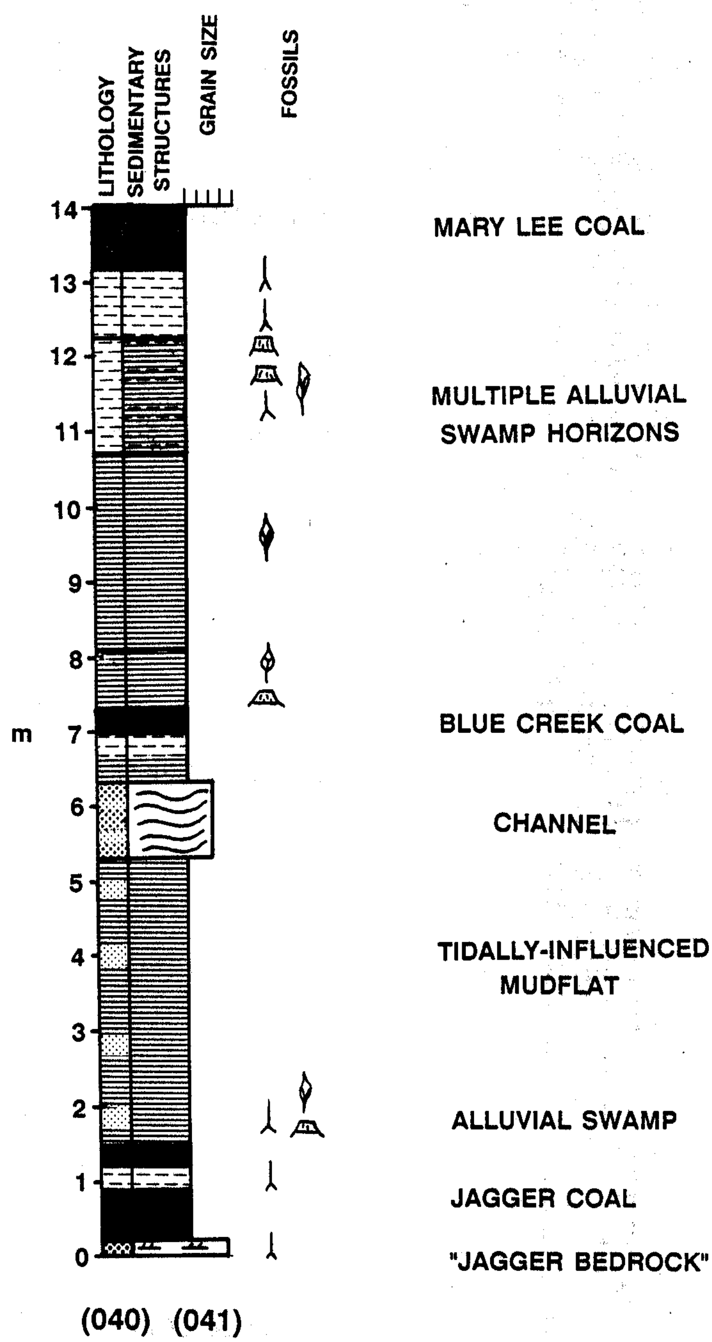

Figure VI-52.--Lithologic column with interpreted depositional environments of the Jagger to Mary Lee interval at alternative Stop 3, Gateway Malls Prospect mine (sec. 16, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle, Walker County, Alabama).

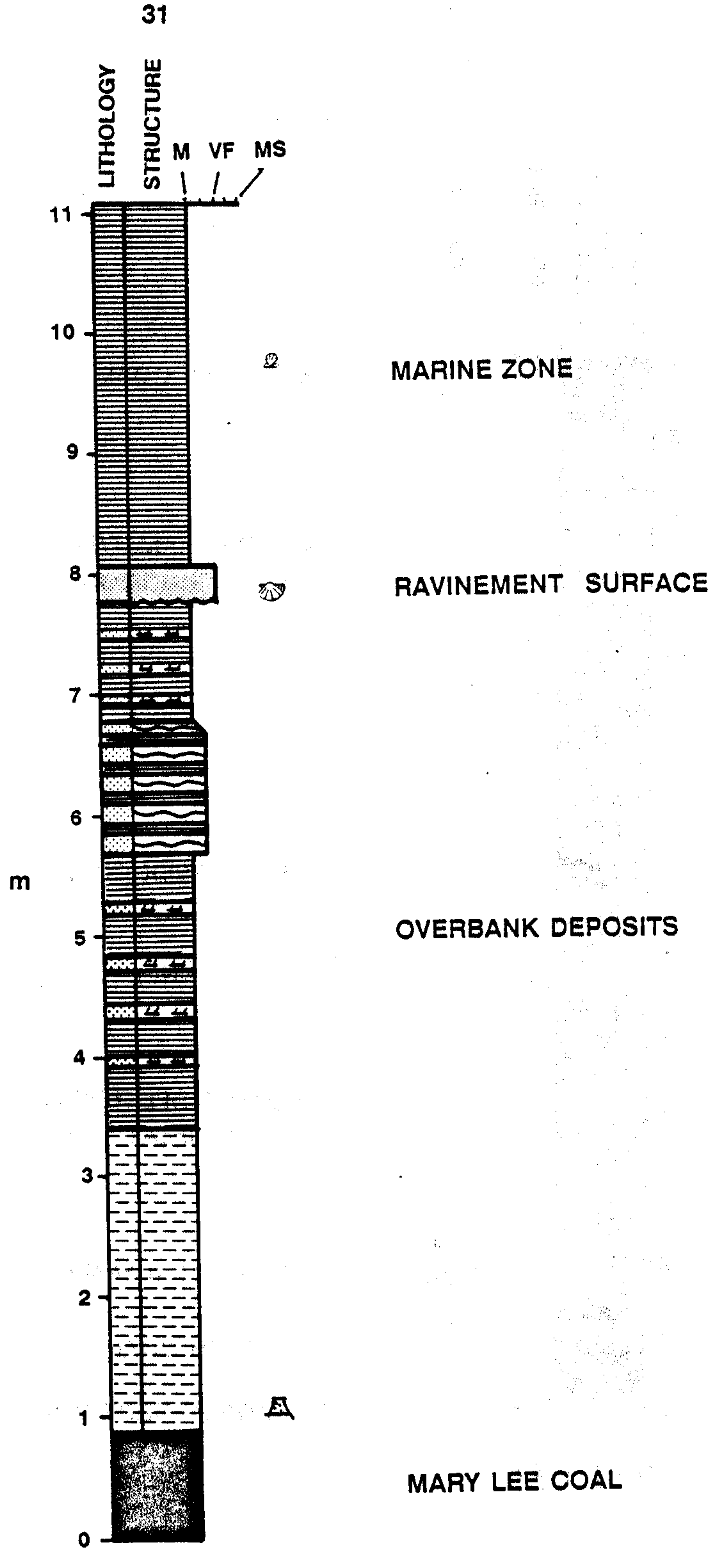

Figure VI-53.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at alternative Stop 3, Gateway Malls Prospect mine (sec. 16, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle, Walker County, Alabama).

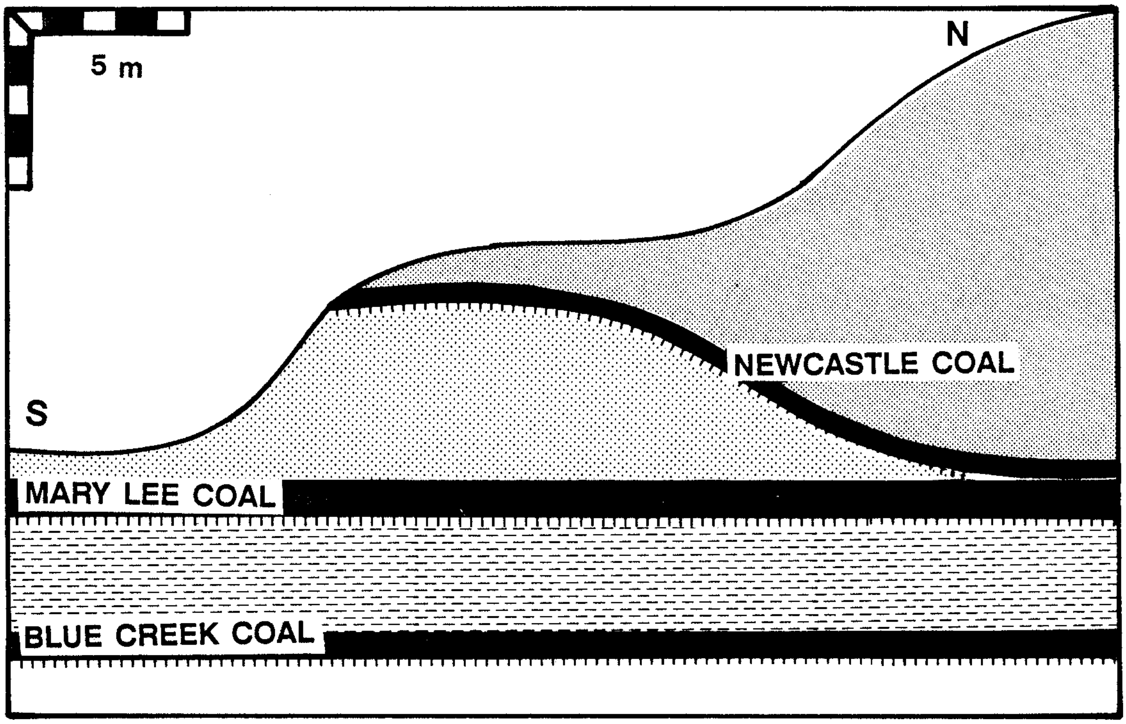

Figure VI-54.--Illustration of highwall depicting the split of the Newcastle coal from the Mary Lee coal in the Gateway Malls Prospect Mine (sec. 16, T. 13 S., R. 9 W., Nauvoo 7.5-Minute Quadrangle, Walker County, Alabama).

47.7 0.65 **STOP 3. TURN RIGHT OVER RAILROAD TRACKS. DRUMMOND CO., INC. CEDRUM MINE FIELD OFFICE (2 HOURS).**

T. M. DEMKO, Y. LIU, and R. A. GASTALDO

This stop is at an active surface mine composed of two pits on either side of Alabama Highway 124 (fig. VI-55). The availability of exposure is dependent on stage of reclamation. The 2570 highwall, located east of Highway 124, is oriented northwest-southeast. It parallels the highway and extends for over 2 km. The stacked alluvial swamp horizons are best developed and exposed in the Blue Creek to Mary Lee interval at this location (fig. VI-56). The 8750 highwall, located west of Highway 124, is curvilinear and changes from east-west to north-south. The highwall extends for over 3 km. The Mary Lee to Newcastle interval is best exposed at this mine (fig. VI-57).

The Jagger coal is in contact with the underlying "Jagger bedrock" sandstone, and the thick Jagger coal here is a separate peat body from that in the Carbon Hill area (see Demko, this guidebook). Rocks above the Jagger coal differ slightly from those to the west, being characteristically finer grained. The trend of fining to the east is interpreted to represent a transition from mixed sand/mudflat (Dogtown, Carbon Hill, Prospect area) to a true mudflat environment.

The Blue Creek coal to Mary Lee coal interval preserves at least five separate alluvial forested swamps (see Demko, this guidebook; Gastaldo, this guidebook). These can be identified most easily by the presence of erect vegetation.

The interval between the Mary Lee and Newcastle coals is a coarsening upward sequence. The basal lithology is a mudstone preserving an erect forest. Above the trees is a fine-grained sandstone. The basal mudstone appears to have been deposited in large-scale wedge-shaped structures. These wedge-shaped structures vary in their paleo-orientation, but generally dip towards the west (see Liu,

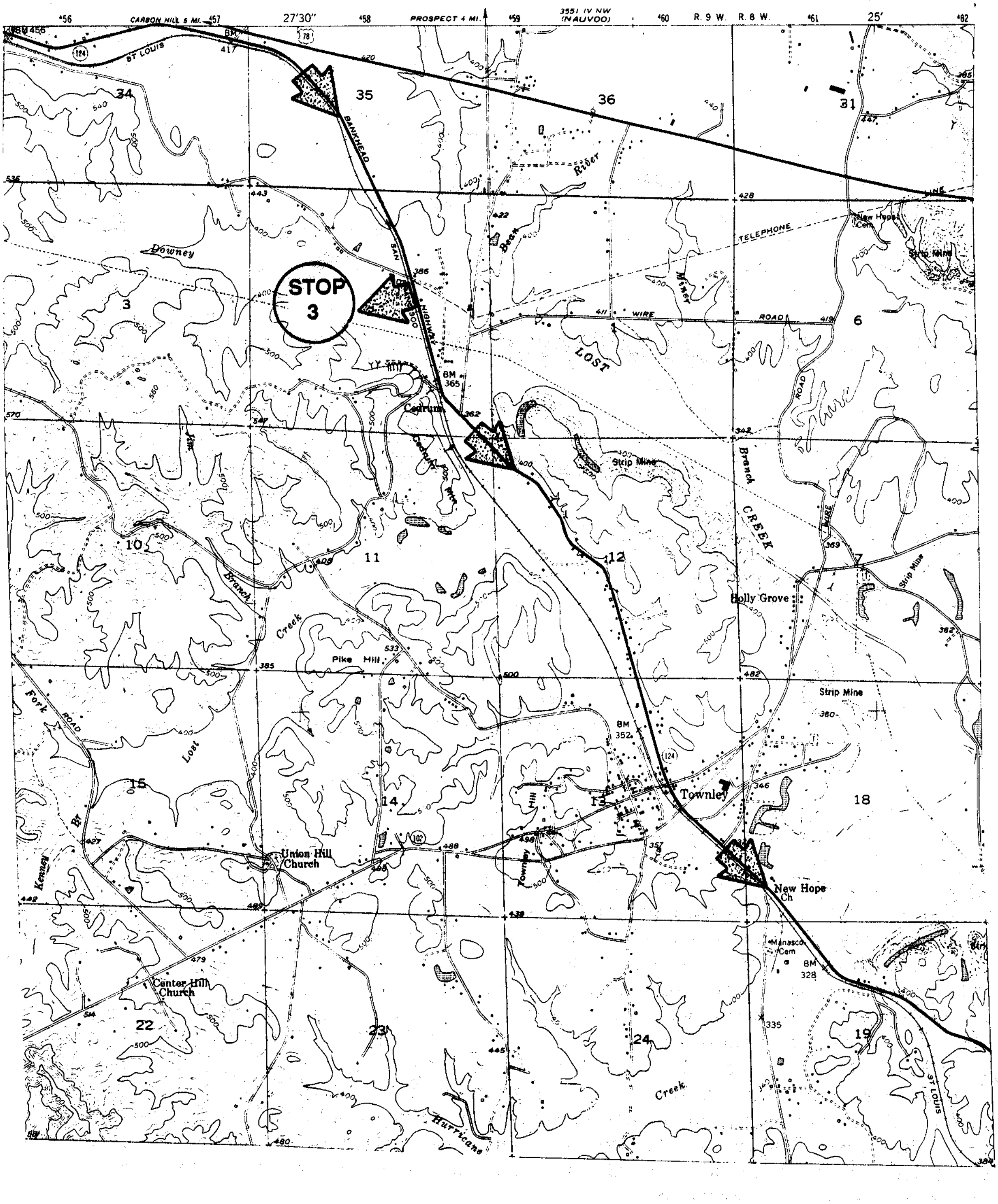

Figure VI-55.--Map of Cedrum area. Stop 3, secs. 3, 4, 12, and 18, T. 14 S., R. 9 W., Townley 7.5-Minute Quadrangle, Walker County, Alabama.

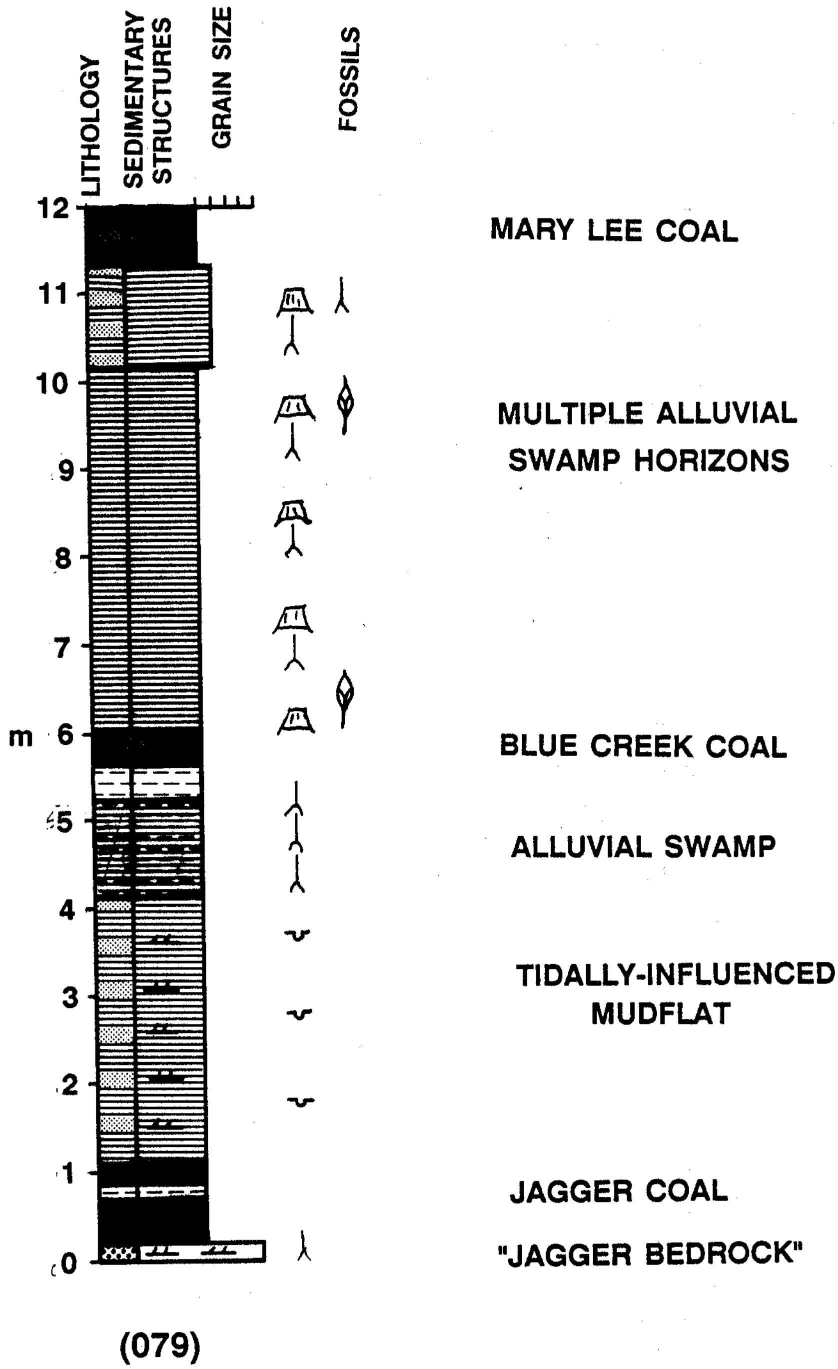

Figure VI-56.--Lithologic column with interpreted depositional environments of the Jagger to Mary Lee interval at Stop 3, Drummond Company, Inc., Cedrum mine (secs. 3, 4, 12, and 18, T. 14 S., R. 9 W., Townley 7.5-Minute Quadrangle, Walker County, Alabama).

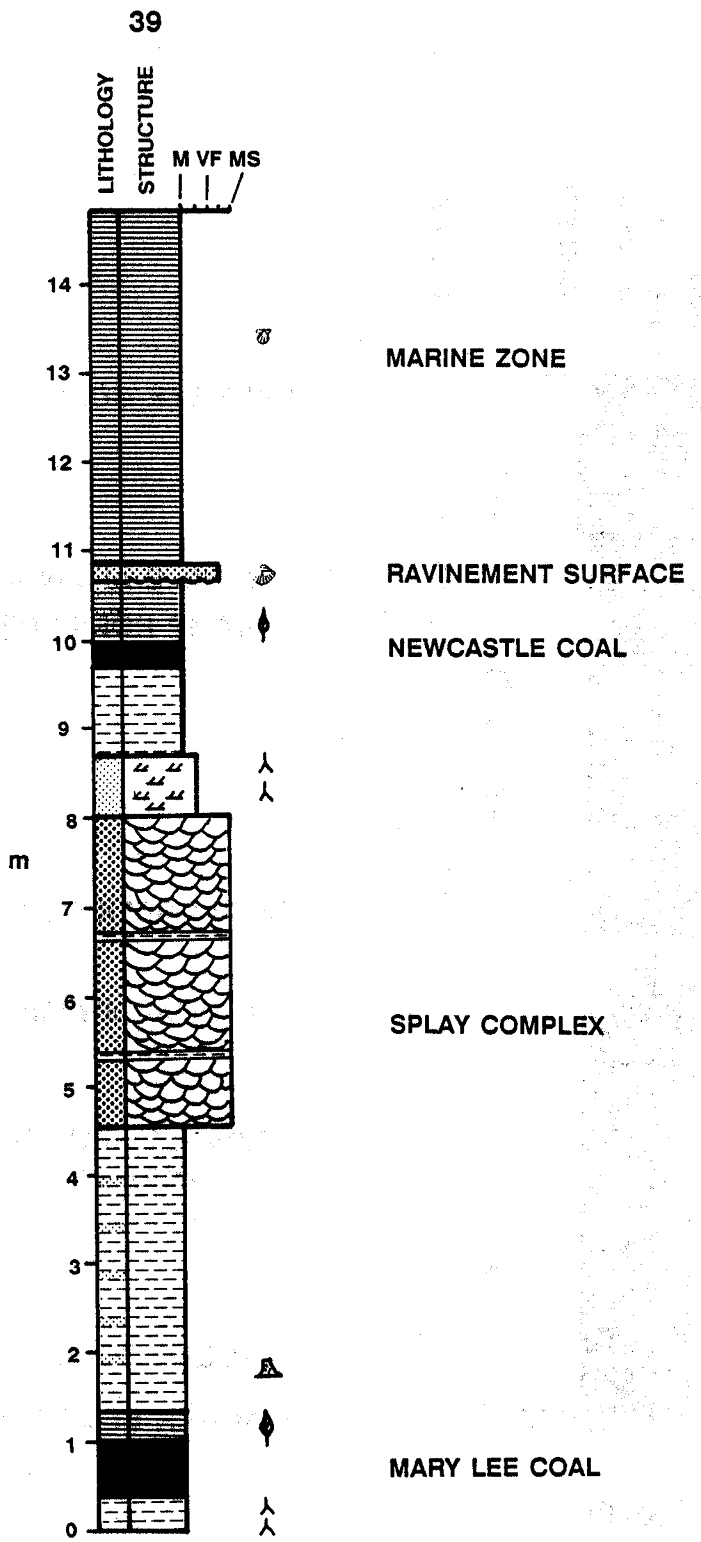

Figure VI-57.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 3, Drummond Company, Inc., Cedrum mine (sec. 3, 4, 12, and 18, T. 14 S., R. 9 W., Townley 7.5-Minute Quadrangle, Walker County, Alabama).

this guidebook). The sandstone facies beneath the Newcastle coal preserves horizontal *Stigmaria* with radiating "rootlets" penetrating depths up to 0.5 m.

This is the best locality to observe the final Mary Lee peat swamp vegetation. The trees are molded by the surrounding mudstone, and cast by the overlying sandstone facies. The maximum preserved height of lycophytes above the coal is 5 m. The coalified compression-impression assemblage found directly above the coal is a mixed lycophyte-pteridosperm flora (see: Gastaldo, this guidebook).

The ravinement surface is similar in character to that seen at STOP 2, but the ravinement bed is a sandstone bioturbated by *Zoophycos*. An abundant marine fauna is preserved not only in the ravinement bed, but also in the overlying Morris shale (sensu Raymond and others, 1988). The thickness of the Morris shale is variable depending upon the distribution of the overlying sandstone. Trace fossils are common in the thin, flaggy sandstone bodies within the Morris shale. Depending upon the stratigraphic position within the unit, ichnofossils may include vertebrate trackways, meniscate burrows, and starfish resting traces (*Asteriacites*).

The uppermost lithology exposed in the mine highwalls is the Gardendale sandstone (sensu Raymond and others, 1988). This unit is characterized by large-scale soft-sediment deformational features. These include rotational slumps, ball and pillow structure, and overturned bedding. The muddy-silty sandstone has abundant mica and comminuted plant material distributed on bedding surfaces. This sandstone probably represents the initial coarse clastic deposits of the subsequent regression. This regressive phase eventually resulted in the terrestrial deposition of the Pratt coal zone.

RETURN TO ALABAMA HIGHWAY 124 EAST.

48.7	1.0	Entrance on left to Drummond Co., Inc. Cedrum mine, 2570 pit.
50.3	1.6	Junction Alabama Highway 102. CONTINUE STRAIGHT.
51.9	1.6	Outcrop on left is within the Mary Lee coal zone -Pratt coal zone intergroup; Gardendale sandstone of Raymond and others (1988).
52.5	0.6	Reclaimed surface mine on left. Drummond Co., Inc., Cedrum mine, 2570 pit. Mined Newcastle, Mary Lee, Blue Creek, and Jagger seams.
53.6	1.1	Old entrance to Drummond 2570 pit on left.
53.8	0.2	Bridge over Lost Creek.
54.6	0.8	Coal load-out facility on right.
54.7	0.1	Intersection with Hillard Loop. CONTINUE STRAIGHT.
55.1	0.4	Abandoned surface mines on left in Newcastle and Mary Lee seams.
55.4	0.3	Abandoned surface mine on left in Newcastle and Mary Lee seams. Abandoned coal-loading facility on right.
55.8	0.4	Intersection with Hillard Loop. CONTINUE STRAIGHT.
56.0	0.2	Reclaimed surface mine in Newcastle and Mary Lee seams.
57.1	1.1	Junction Alabama Highway 69. End Alabama Highway 124. CONTINUE STRAIGHT on Alabama Highway 69 north.

57.5	0.4	Outcrop on left and right includes fine- to medium-grained micaceous sandstone, small-scale tabular and trough cross stratification (vector mean of paleocurrent directions 348°), channel-form. Thickness >2.5 m, erosional base. Unit below consists of sandy siltstone with common siderite nodules. This unit is moderately bioturbated (vertical, sand-filled burrows), and contains poorly preserved shelly fossils (*Orbiculoidea*?). Raymond and others (1988) Measured Section #7, McCollum Section.
58.6	1.1	Jasper city limit.
59.4	0.8	Outcrop on left at Deano's Hickory Pit Bar-B-Q. Badly weathered exposure consisting of mudstone with rhizoconcretions crosscutting bedding. The upper bench of the Ream coal outcrops at the top of this paleosol and is 0.1 m in thickness. The unit above consists of interbedded siltstone and sandstone. Thin siltstone beds (0.01 to 0.02 m) alternate with thicker mudstone beds (0.1 m). Trace fossils (*Scalarituba*) are abundant in the siltstone beds.
60.1	0.7	Junction Alabama Highway 269. TURN LEFT, continue on Alabama Highway 69 north.
60.3	0.2	Traffic signal. CONTINUE STRAIGHT.
62.3	2.0	Junction U.S. Highway 78. TURN RIGHT (EAST). George "Goober" Lindsey Highway.
63.4	1.1	Traffic signal at Jasper Inn Best Western. TURN RIGHT into parking lot. End day 1.

ROAD LOG - DAY 2

Mileage Cumulative	Mileage Interval	Comments
0.0	0.0	Leave Jasper Inn Best Western. Depart across median. Turn left (west) onto U.S. Highway 78 (fig. VI-46).
1.0	1.0	Railroad overpass.
1.2	0.2	Intersection Alabama Highway 69. TURN LEFT onto 69 south.
1.6	0.4	Outcrop on right is epsilon cross-stratified sandstone, cross beds dip to the northwest (316°); calamite stem orientation 275°; similar to sandstone at mile 1.8 of Day 1; stratigraphic position is below Mary Lee coal zone.
3.2	1.6	Traffic signal. Continue straight.
3.4	0.2	Intersection Alabama Highway 269. TURN RIGHT, continue south on Alabama Highway 69. Outcrop on right at intersection is medium gray shaley siltstone (>0.5 m thick) overlain by very fine- to fine-grained sandstone (1.75 m thick) with shaley interbeds. Siltstone and sandstone are thin bedded (5 to 15 cm), and exhibit small-scale trough cross stratification; sandstone contains stigmarian axes and rootlets and is moderately root-worked along these horizons; sandstone is, in turn, overlain by highly weathered mudstone, probably the Ream coal underclay; this contact dips 4° to the north, and drapes over the sandstone below; entire interval contains abundant comminuted plant material and common siderite concretions (possibly rhizoconcretions); interval interpreted as sparsely vegetated tidal flat overlain by alluvial swamp.
4.1	0.7	Deano's Hickory Pit Bar-B-Q. Outcrop of Ream coal.
5.0	0.9	Alabama National Guard Armory.
5.9	0.9	Outcrops on left and uphill on right comprise Raymond and others (1988) Measured Section 7, McCollum Section. See DAY 1, 52.3 miles.
6.4	0.5	Junction Alabama Highway 124. TURN LEFT, continue on Alabama Highway 69 south.
7.1	0.7	Bridge. Abandoned surface mine on right in Mary Lee seam.
7.2	0.1	**STOP 4. ENTRANCE TO BIRMINGHAM COAL AND COKE McCOLLUM MINE (2 HOURS).**

Y. LIU and M. A. GIBSON

This stop is in an active surface mine exploiting the Mary Lee and Newcastle coals (figs. VI-58 and VI-59). The highwall is oriented east-west and extends for approximately 0.5 km.

The Mary Lee coal is one bench attaining a maximum thickness of 0.9 m. The thickness of the terrestrial sequence (Mary Lee to ravinement surface) averages 12 m. Above the Mary Lee coal is a

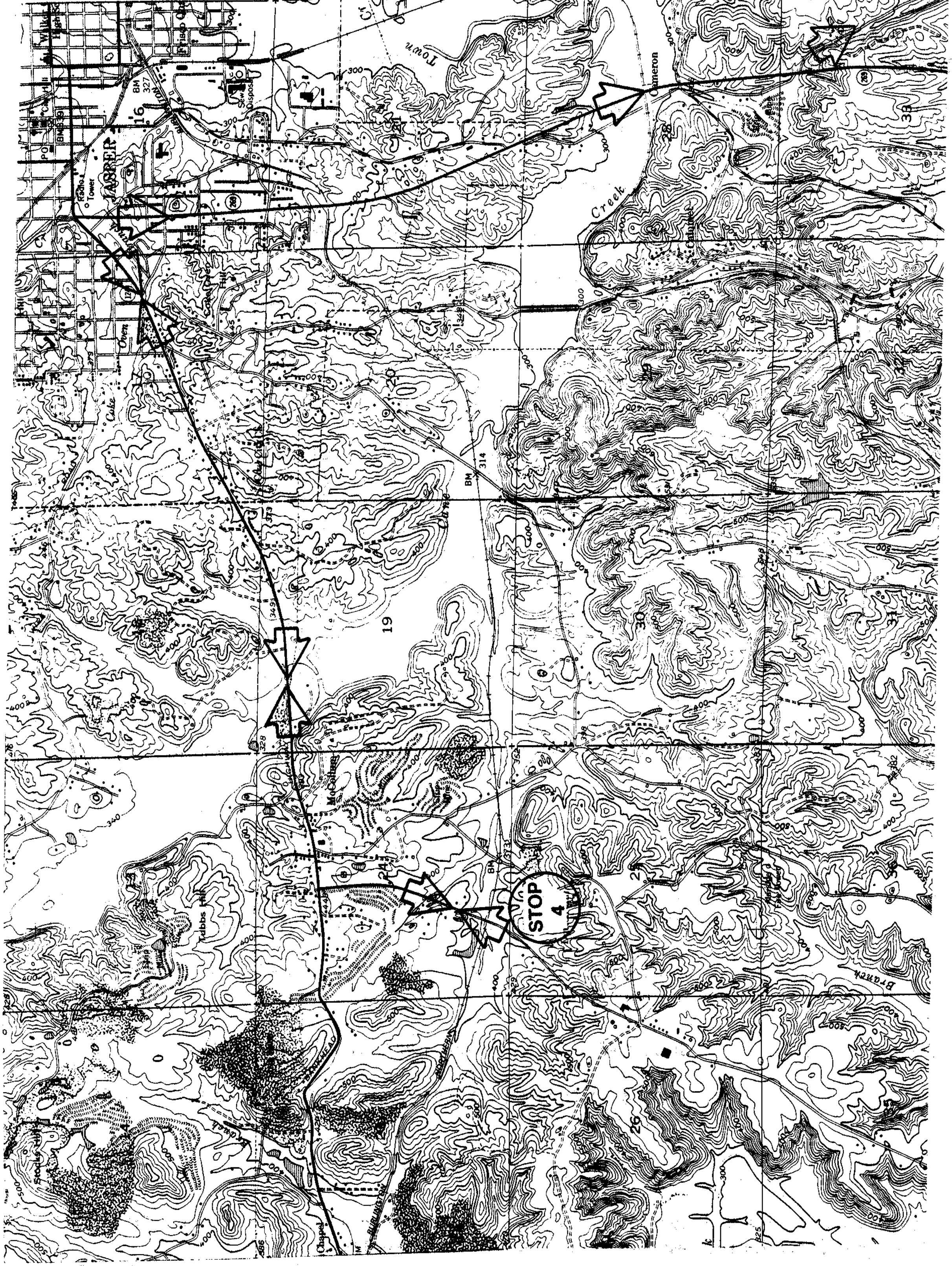

Figure VI-58.--Map of Jasper area. Stop 4, sec. 25, T. 14 S., R. 8 W., Jasper 7.5-Minute Quadrangle.

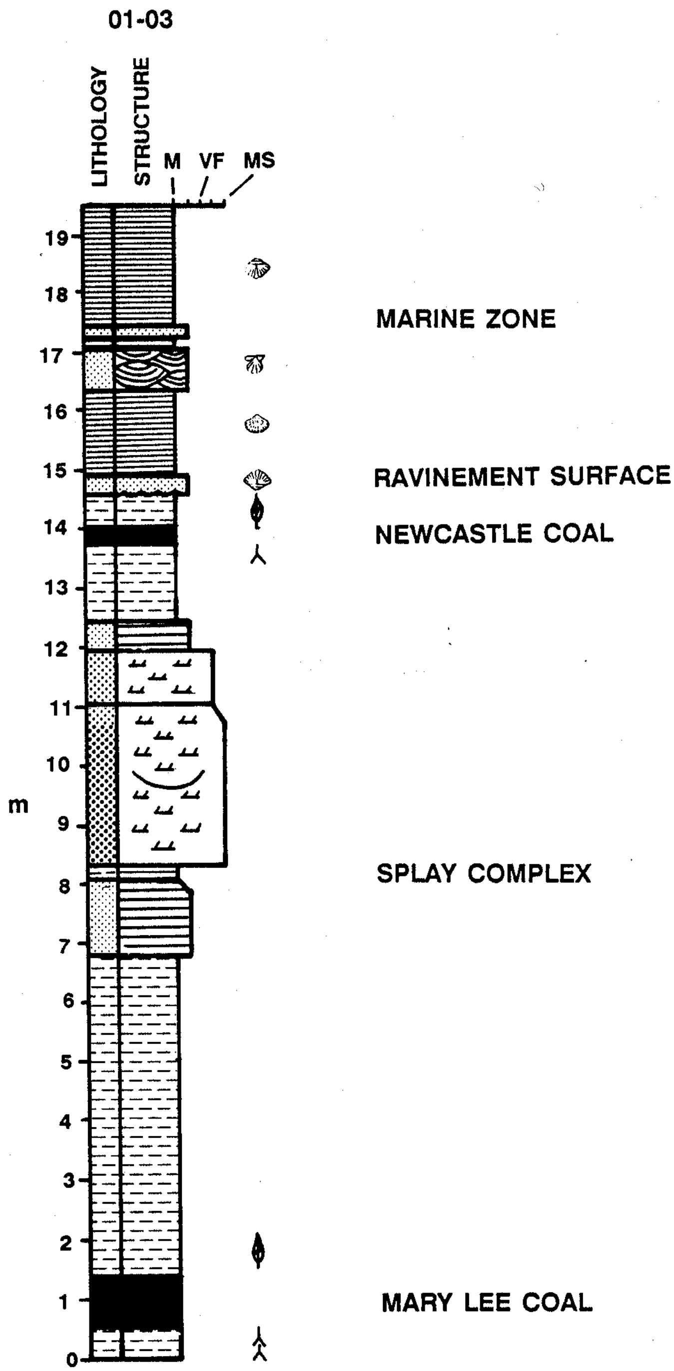

Figure VI-59.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 4, Birmingham Coal and Coke, McCollum mine (sec. 25, T. 14 S., R. 8 W., Jasper 7.5-Minute Quadrangle, Walker County, Alabama).

fossiliferous mudstone overlain by medium- to fine-grained sandstone. The compression-impression flora above the Mary Lee is dominated by lycophytes and pteridosperms. The overlying sandstone is about 3.3 m thick, is channel-form in cross section, and displays small-scale trough cross laminations. The top of the sandstone is rooted, not all roots are of the stigmarian type. The Newcastle coal immediately overlies the rooted zone and averages 0.25 m in thickness. A coalified compression flora is preserved in the overlying mudstone.

The ravinement surface unconformably truncates the mudstone (alluvial swamp deposits) above the Newcastle coal. The ravinement bed, ranging in thickness from 0.25 to 0.30 m, is siltstone containing abundant macroinvertebrates (see Gibson, this guidebook). The macroinvertebrate assemblage includes brachiopods (*Composita subtilita, Desmoinesia muricatina, Cancrinella boonensis, Antiquatonia portlockiana*, and *Orbiculoidea*), bivalves (*Wilkingia elliptica, Palaeoneilo oweni, Astartella concentrica, Phestia bellistriata, P. arata, Nuculopsis croneisi, Dunbarella knighti*, and *Pteronites*), gastropods (*Bellerophon percarinatus, Straparollus reedsi*, and *Glabrocingulum graysvillensis*), and arthropods (*Paladin*). Unidentified corals and cephalopods are also constituents of the macrofauna. The ravinement bed is capped by a 5-cm thick siderite layer. The siderite may extend downwards into the ravinement bed cementing vertical burrows. Additionally, the siderite may have precipitated around macroinvertebrate nuclei. This is particularly characteristic of the lower part of the Morris shale.

Within the first meter above the ravinement surface are two thin layers of sideritic siltstone with hummocky cross stratification and disordered, fragmented marine macroinvertebrates. Paleocurrent lineations include flute marks, tool marks, and scours. These features are oriented in a southeast direction. These sideritic siltstones are interpreted to represent storm deposits in an environment transitional between nearshore and offshore conditions.

TURN AROUND, HEAD BACK NORTH ON ALABAMA HIGHWAY 69.

8.0	0.8	Junction Alabama Highway 124. TURN RIGHT, continue on Alabama Highway 69 north.
9.6	1.6	Jasper city limit.
11.0	1.4	Junction Alabama Highway 269. TURN RIGHT, head south on 269.
11.4	0.4	Outcrop of Ream coals on left. Two benches of the Ream coal are exposed. The lower bench, 15 cm in thickness, is overlain by a papery carbonaceous shale. This is overlain by a 5 to 6 m sequence of burrowed sideritic siltstone. The upper bench of the Ream coal averages 7 cm in thickness and is overlain by a weathered, bioturbated (*Scalarituba, Palaeophycus*) sideritic siltstone. Backfilled meniscate burrows are also common features.
12.0	0.6	Bridge over railroad. The outcrop along the railroad cut on right exposes sandstones above the Ream coal. Characteristic ball and pillow structures and other soft-sediment deformation can be seen.
12.95	0.95	Brawley Road on right.
13.4	0.45	Bridge over railroad.
13.7	0.3	Outcrop on left is in interval below Mary Lee seam.
14.0	0.3	TURN LEFT onto paved secondary road.

14.9	0.9	Reclaimed surface mine. Drummond Co., Inc., Hay Valley mine.
15.1	0.2	Highwall exposure on right. Newcastle seam is exposed.
15.7	0.6	Abandoned dragline on left.
16.6	0.9	TURN LEFT onto unpaved road. BEAR LEFT onto top of reclaimed spoil. Abandoned highwall parallels spoil. Newcastle seam and overlying sequence exposed.
17.4	0.8	**STOP 5A. DRUMMOND COMPANY, INC., HAY VALLEY MINE. RECLAIMED. (1 HOUR).**

Y. LIU, M. A. GIBSON, and A. K. RINDSBERG

This reclaimed mine consists of a vertical highwall exposing a section a few meters below the Newcastle coal to the Gardendale sandstone (sensu Raymond and others, 1988) (figs. VI-60 and VI-61). The orientation of the highwall is north-south, and extends for over 1.5 km. The characteristics of the ravinement surface and overlying ravinement bed observed here are typical for most of the study area. The weathered condition accentuates the inherent color differences between the ravinement bed and the underlying mudstone.

The interval below the Newcastle coal is characterized by a sequence of medium-grained sandstone interbedded with fine-grained sandstone and mudstone. Small-scale cross bedding is a feature of the medium-grained sandstone. A thicker medium-grained sandstone occurs within the unit. Primary sedimentary structures in the thick sandstone include small-scale trough cross bedding and ripple lamination. Channel-form geometries are not evident due to limited exposure. The sequence is interpreted to represent channel deposition within a splay complex, containing interchannel deposits. This sequence can be compared to STOP 5B (2 km to the south) in which three stacked channel sequences occur.

The ravinement bed averages 0.3 meters in thickness and is composed of mudstone. The unconformity between the underlying terrestrial mudstone and the overlying marine mudstone is difficult to discern in the absence of alteration by weathering (oxidation of pyrite coupled with the solution of carbonates). In the absence of weathering features, several criteria can be used to distinguish the terrestrial mudstone from the overlying marine mudstone. The terrestrial mudstone may preserve a coalified compression plant assemblage characteristic of alluvial swamp deposits. Marine muds preserve a disordered and dispersed, fragmental plant assemblage consisting of comminuted debris and *Calamites* branches. The terrestrial mudstone is commonly interlaminated with siltstone or very fine-grained sandstone. Above the ravinement surface, the mudstone (ravinement bed) is heavily bioturbated (vertical burrows and occasional *Zoophycos*) and capped by a siderite layer. In addition, an *in situ* macroinvertebrate fauna may be preserved (see Gibson, this guidebook).

The overlying Morris shale (sensu Raymond and others, 1988) is comprised of interlaminated mudstone, siltstone, and fine-grained sandstone. A thin, laterally continuous limestone (approximately 0.3 m) occurs in the upper part of the section. The marine section is heavily bioturbated. Trace fossils are most obvious in siltstones and fine-grained sandstones. The ichnofauna (*Scalarituba* assemblage) represents an open marine community (see Rindsberg, this guidebook). Ichnogenera include *Olivellites, Zoophycos, Helminthopsis, Parahaentzschelinia*, and arthropod resting traces.

TURN AROUND, HEAD BACK TO PAVED ROAD.

18.2	0.8	TURN LEFT onto paved road.

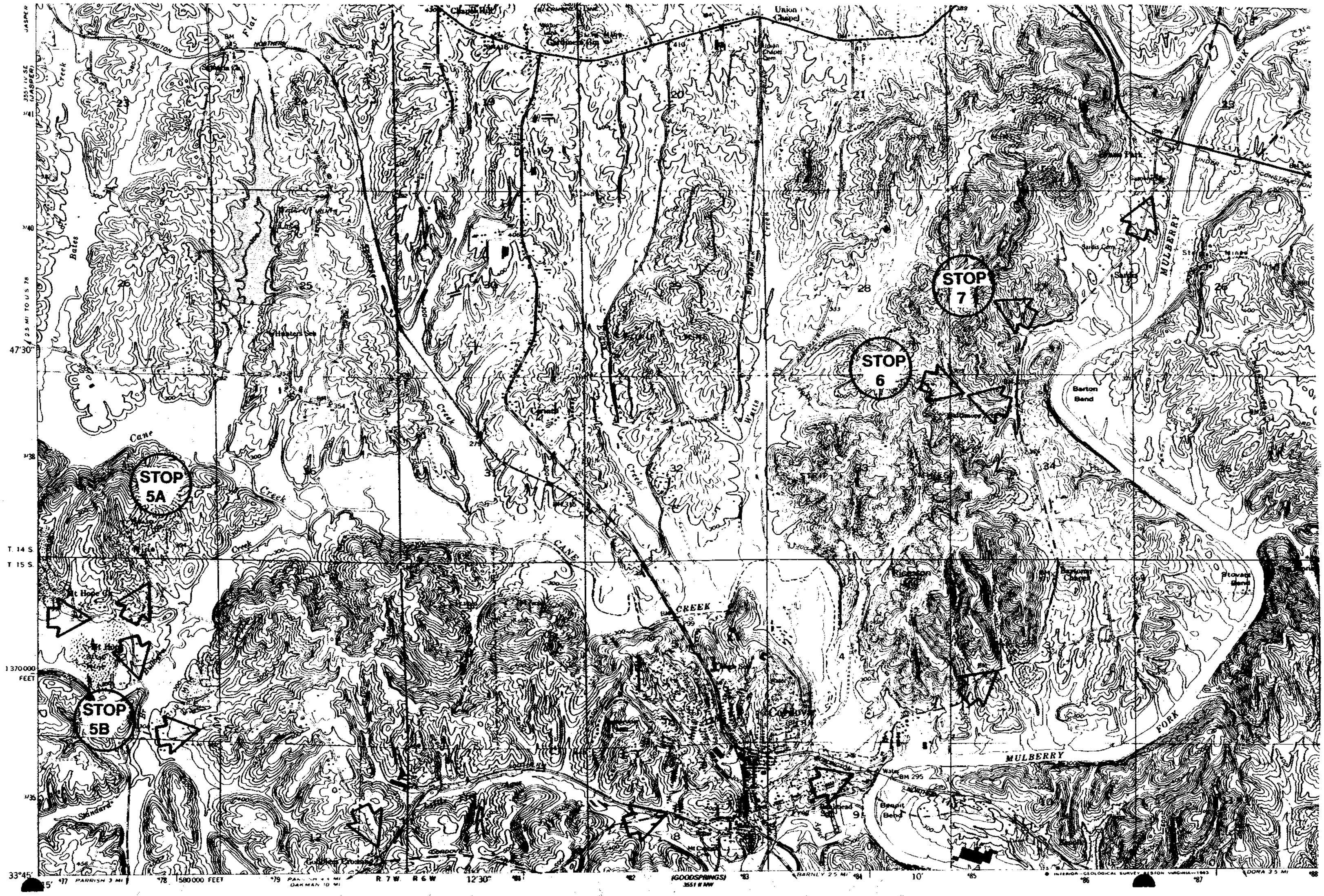

Figure VI-60.--Map of Cordova area. Stop 5A, sec. 35, T. 14 S., R. 7 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama. Stop 5B, sec. 2, T. 15 S., R. 7 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama. Stop 6, secs. 28 and 33, T. 14 S., R. 6 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama. Stop 7, sec. 27, T. 14 S., R. 6 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama.

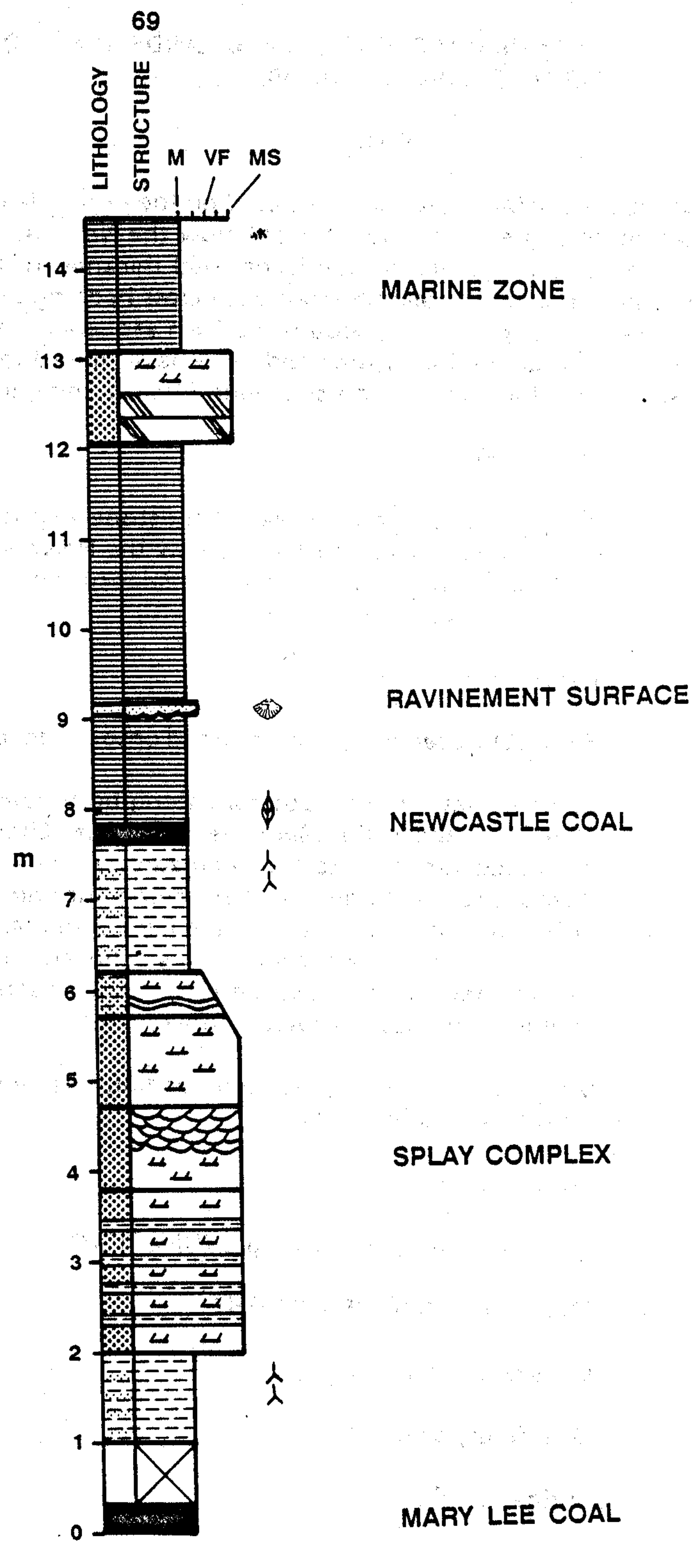

Figure VI-61.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 5A (sec. 35, T. 14 S., R 7 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama).

18.6	0.4	Bridge over Bullbarn Creek.
18.7	0.1	**STOP 5B. ROADCUT EXPOSING SANDSTONE SEQUENCE ABOVE THE MARY LEE COAL. (0.5 HOUR).**

Y. LIU

The sandstone sequence above the Mary Lee coal is exposed on the right side of the road (figs. VI-60 and VI-62). This stop can be compared with the interval below the Newcastle at Stop 5A. Three sequences of splay channel deposits are observable, with the total thickness of the deposits >3 m. The sandstone is medium to fine grained containing small-scale cross bedding and rippled bedding. The average paleocurrent direction is to the west-southwest. Each sequence fines upwards from a medium-grained sandstone to a fine-grained sandstone and has a basal mud-chip conglomerate. The section represents vertical stacking of the splay channel sediments (see Liu, this guidebook).

18.8	0.1	TURN LEFT.
18.85	0.05	Bridge over Standard Creek. Sandstone exposed in creek bed is above the Mary Lee coal and below the Newcastle coal. Small-scale troughs can be seen in plan view. Paleocurrent directions are to the west-southwest (see above).
20.7	1.85	Fork in road. BEAR RIGHT.
20.8	0.1	BEAR LEFT over bridge over railroad onto Cordova Parrish Highway.
21.8	1.0	Cordova water tower. Outcrops along both sides of road to bottom of hill are above the Mary Lee coal zone. Characterized by finely laminated very fine- to fine-grained silty sandstone with slump and flow structures. Undisrupted structures include parallel lamination, microcross lamination, and ripple lamination. A prostrate *Calamites* cast is oriented west-southwest. Paleocurrent direction as determined from cross beds is also southwest. Interesting "pseudoboudinage" structures are present.
22.4	0.6	Drummond Company, Inc., coal-loading facility on left, old Cordova Junior High School on right.
22.6	0.2	Cross railroad tracks.
23.0	0.4	Cross railroad tracks. Stop sign. TURN RIGHT onto Amory Avenue.
23.6	0.6	Stop sign. CONTINUE STRAIGHT.
23.8	0.2	Cross railroad tracks.
23.9	0.1	Oil refinery on left.
24.0	0.1	Bridge over Cane Creek.
24.2	0.2	Cross railroad tracks.
24.3	0.1	Entrance on right to Port Cordova, Alabama State Docks.

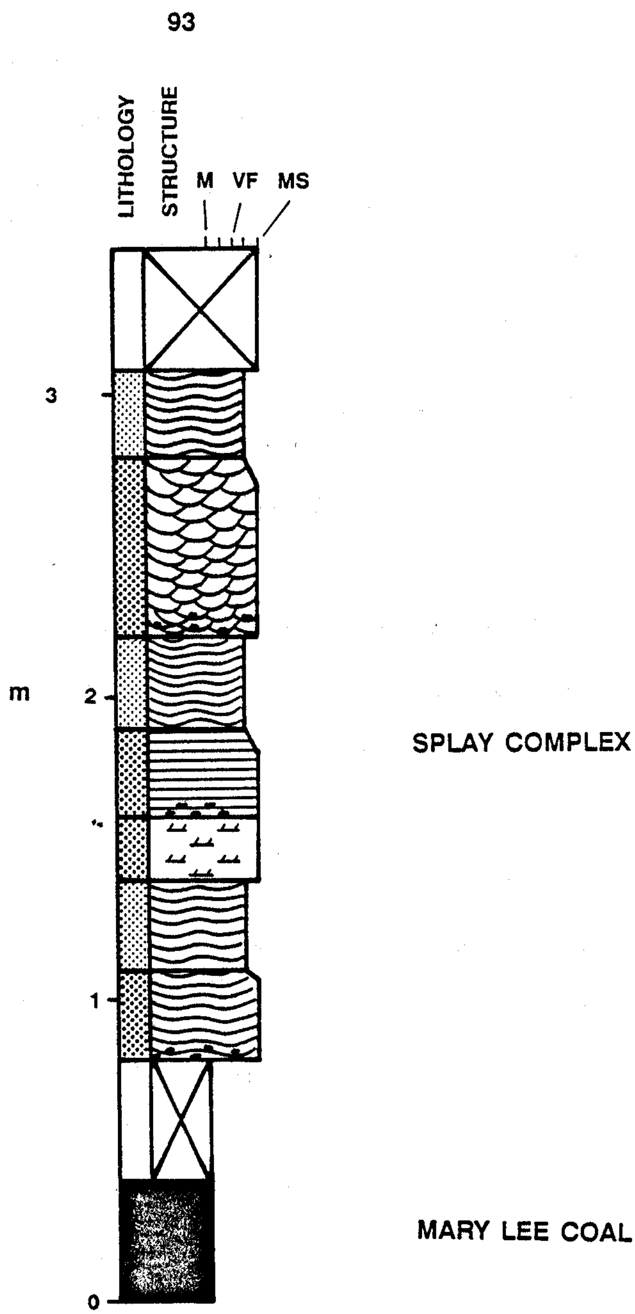

Figure VI-62.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 5B (sec. 2, T. 15 S., R. 7 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama).

24.8	0.5	Abandoned surface mine on right in Newcastle and Mary Lee seams.
26.4	1.6	Outcrop on right is below Mary Lee coal. TURN LEFT onto dirt road.
27.2	0.8	**STOP 6. ABANDONED SURFACE MINE IN NEWCASTLE AND MARY LEE COAL SEAMS AND UNDERCLAY BELOW MARY LEE.**

Y. LIU, M. A. GIBSON, A. K. RINDSBERG, and R. A. GASTALDO

Abandoned and unreclaimed surface mine on the University of Alabama property (fig. VI-60). The highwall exposes the interval from the Mary Lee underclay to the Morris shale (sensu Raymond and others, 1988) (fig. VI-63). The Mary Lee underclay is fossiliferous, preserving *in situ Stigmaria*. The Mary Lee coal is a single bench, averaging 0.65 m in thickness. Palynological samples have been taken (Liu station 073; see Eble, this guidebook). Erect lycophytes are preserved *in situ* above the Mary Lee and Newcastle coals. The mudstone that occurs between these coals not only preserves an erect cast forest, but also a coalified compression-impression plant fossil assemblage representing the peat swamp forest litter. Above the Newcastle coal, also in alluvial swamp deposits, a suite of trace fossils is preserved. This *Cincosaurus* assemblage (see Rindsberg, this guidebook) consists of locomotion traces of vertebrates (*Undichna, Cincosaurus, Attenosaurus*, and *Quadropedia*), trackways of xiphosurids (*Kouphichnium*), and feeding/farming traces (*Treptichnus*).

This site is one of the best exposures to examine the mudstone ravinement bed. Criteria used at STOP 5A apply to the recognition of the unconformity at this locality. In addition, the ravinement bed can be identified by the presence of abundant, *in situ* productid brachiopods (see Gibson, this guidebook).

TURN AROUND, head back downhill to paved road.

28.0	0.8	TURN LEFT back onto paved road.
28.3	0.3	**STOP 7. ENTRANCE TO BEARD CLAY COMPANY MINE.**

Y. LIU and R. A. GASTALDO

The operation at this locality (fig. VI-60) exploits the Mary Lee underclay, a refractory grade clay, and the Mary Lee and Newcastle coals as a byproduct (fig. VI-64). The best coalified-compression forest litters can be collected in the mudstones between standing vegetation above both coals. These litters include large pteridospermous (gymnospermous "seed ferns") trunks and leaves, pteridophyllous (true ferns) leaves, and lycophyte canopy detritus. Erect lycophytes may be molded and cast by mudstone, or molded by mudstone and cast by the overlying sandstone facies. In the case of the forests above the Newcastle coal, the encasing mudstones represent alluvial swamp deposits, whereas the casting sediments may have been derived, in part, from the overlying marine deposits. Erect trunks above the Newcastle coal, greater than 2.0 m in height, often extend above the ravinement surface.

The ravinement surface, ravinement bed, and overlying Morris shale (sensu Raymond and others, 1988) is the same as in STOP 6.

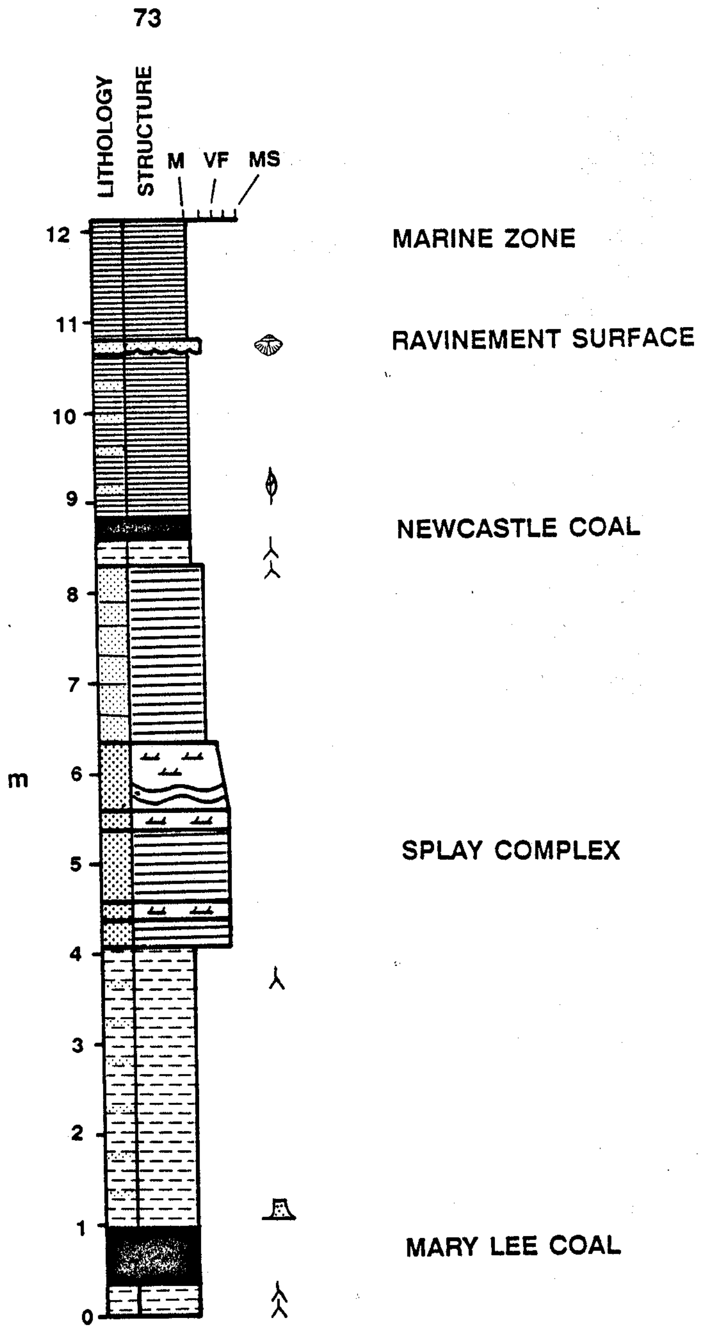

Figure VI-63.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 6 (secs. 28 and 33, T. 14 S., R. 6 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama).

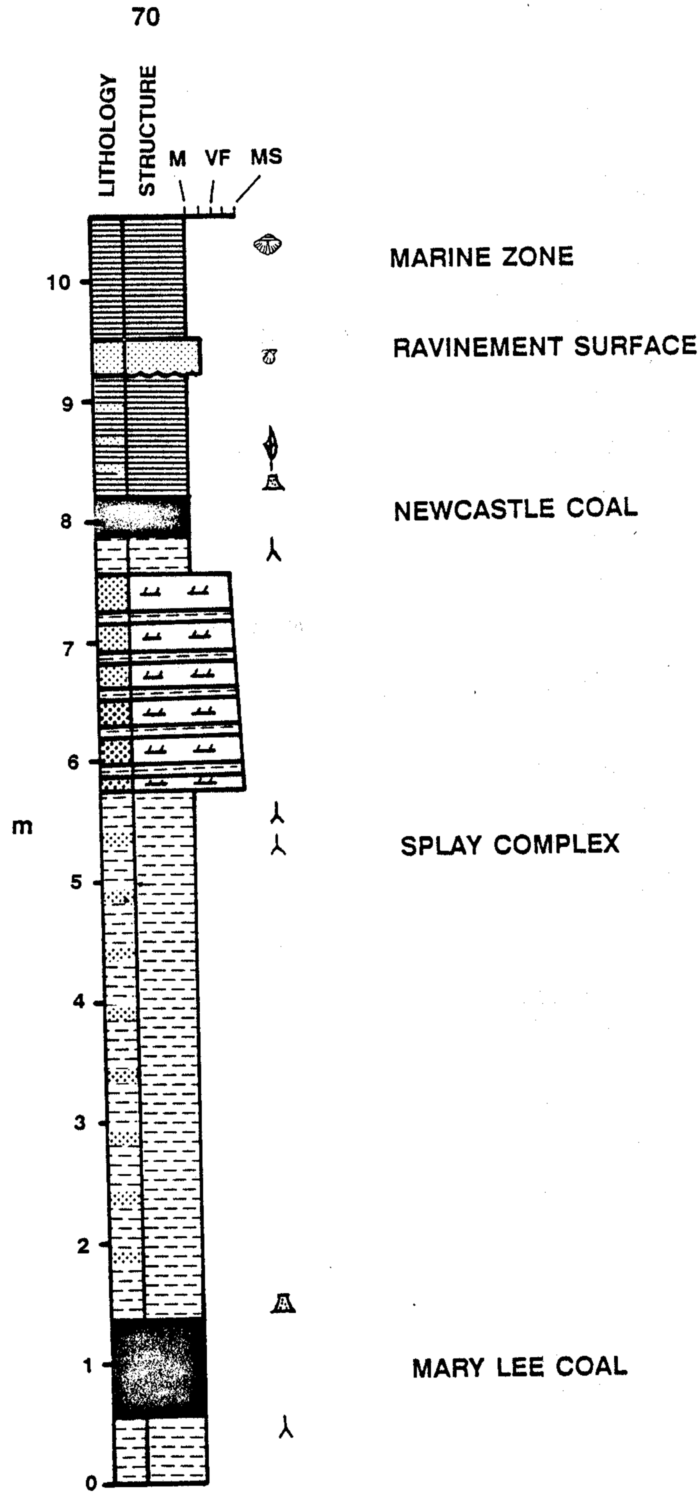

Figure VI-64.--Lithologic column with interpreted depositional environments of the Mary Lee to Morris shale interval at Stop 7 (sec. 27, T. 14 S., R. 6 W., Cordova 7.5-Minute Quadrangle, Walker County, Alabama).

TURN AROUND AND PROCEED BACK TO U.S. HIGHWAY 78.

29.7	1.4	Junction U.S. Highway 78. TURN LEFT to go back to Jasper. TURN RIGHT to go to Birmingham.

END OF FIELD TRIP.

REFERENCE CITED

Raymond, D. E., Rheams, L. J., Osborne, W. E., Gillespie, W. H., and Henry, T. W., 1988, Surface and subsurface mapping for the establishment of a stratigraphic and biostratigraphic framework for the Pennsylvanian section in the Jasper quadrangle of the Black Warrior basin of Alabama, A summary report of investigations for 1986-87: Alabama Geological Survey Open-File Report, prepared for the United States Geological Survey under Agreement No. 14-08-0001-A0437, 427 p.

Abbreviations and Symbols

centimeter	cm	milligram	mg
centimeters per second	cm/sec	milliliter	ml
correlation coefficient	r	millimeter	mm
degrees Celsius	°C	no data	n.d.
delta value	δ	not detected	ND
feet	ft	number	n
gallon	gal	parts per billion	ppb
gram	g	parts per million	ppm
inch	in	per mil	‰
kilobar	kb	pressure	P
kilogram	kg	Range	R.
kilometer	km	section	sec.
liter	l	temperature	T
loss on ignition	LOI	Township	T.
mega-annum (10^6 years ago)	Ma	trace	tr
meter	m		

Conversion Factors

Metric unit		Inch-Pound equivalent	
		Length	
millimeter (mm)	=	0.03937	inch (in)
meter (m)	=	3.28	feet (ft)
kilometer (km)	=	.62	mile (mi)
		Weight	
gram (g)	=	0.035	ounce, avoirdupois (oz avdp)
gram	=	.0022	pound, avoirdupois (lb avdp)
metric tons (t)	=	1.102	tons, short (2,000 lb)
metric tons	=	.9842	ton, long (2,240 lb)

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