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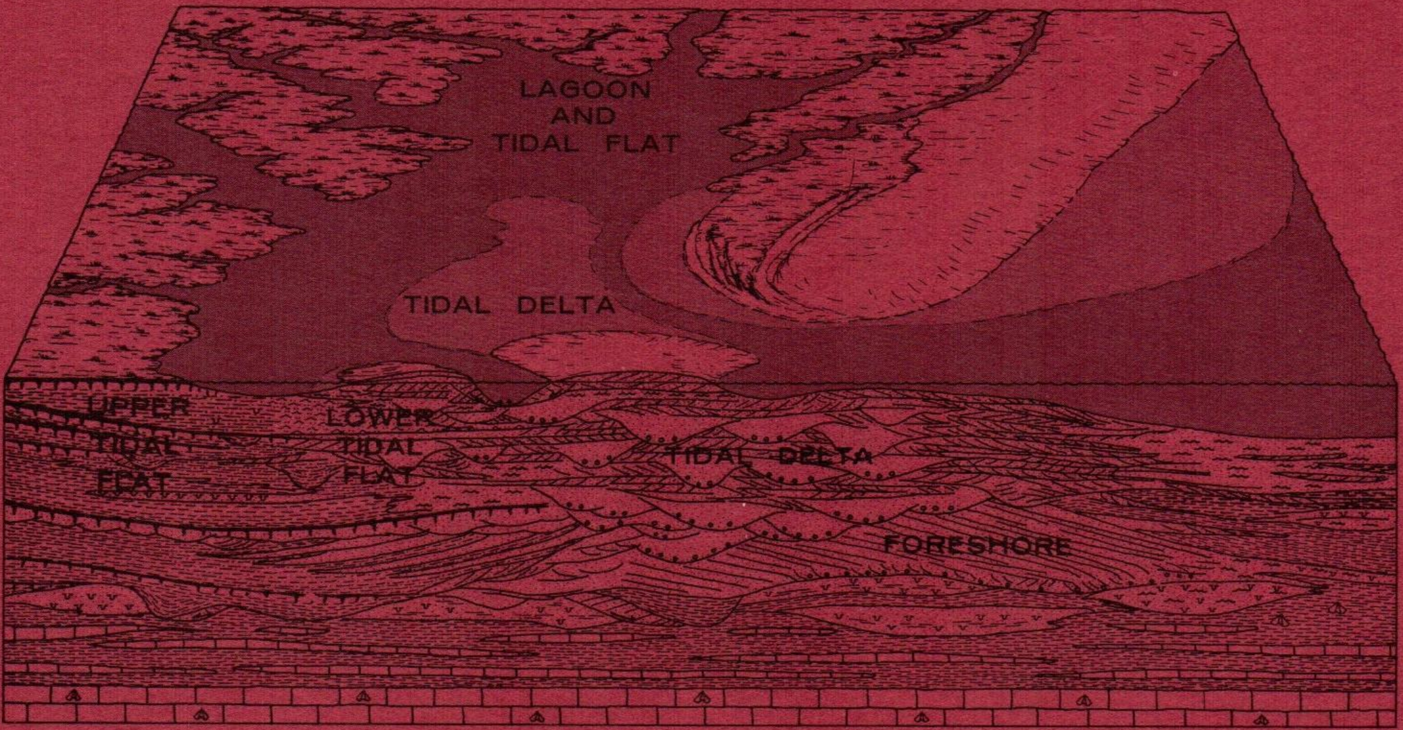

CARBONIFEROUS DEPOSITIONAL ENVIRONMENTS IN THE CUMBERLAND PLATEAU OF SOUTHERN TENNESSEE AND NORTHERN ALABAMA

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ACKNOWLEDGEMENTS

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CARBONIFEROUS DEPOSITIONAL ENVIRONMENTS IN THE CUMBERLAND PLATEAU OF SOUTHERN TENNESSEE AND NORTHERN ALABAMA

John C. Ferm, Robert C. Milici and James E. Eason

ABSTRACT

Carboniferous strata in southern Tennessee and northern Alabama record the transition from marine shales and limestones through shore-face, barrier, and back-barrier sedimentary environments to deposits dominated by lagoonal shales and tidal deltas. Shore-face sandstones are interbedded with carbonates and marine shales and are commonly burrowed and lenticular in shape. Barriers are composite orthoquartzitic sand bodies characterized by very low-angle accretion beds (foreshores), beach-step conglomerates, and steeply dipping shore-face crossbeds. Accretion beds are generally cut by massive channel fills. Back-barrier deposits are coarsening-upward sequences of shale, siltstones, sandstones, seat rock and coal, with tidal-channel, tidal-delta and washover sandstones. Tidal-delta sandstones are characterized by massive channel fills and high-angle crossbeds. Tidal flats are flasered siltstones and sandstones which in places are channeled and slumped.

Regional stratigraphy and crossbed azimuths show that the Carboniferous littoral system prograded southward and westward into Tennessee from southern West Virginia and Virginia. Crossbed azimuths are related to dip amounts and can be interpreted in terms of a littoral environment.

INTRODUCTION

The principal geologic features of the southern Cumberland Plateau have been known since Safford (1869) designated as Lower Carboniferous the strata between the Black Shale (now Chattanooga) and Coal Measures and then divided the Lower Carboniferous into the Siliceous Group (now Fort Payne Formation) and Mountain Limestone. Subsequently, most workers in Tennessee and adjacent states have classified Safford's Lower Carboniferous as Mississippian and the Coal Measures as Pennsylvanian.

The Cumberland Plateau has been studied intermittently since the turn of the century. Rock layers and coals were named, described, and traced for many miles as geologic knowledge accumulated and techniques improved with the decades. However, classification schemes developed by workers in different states for contiguous strata are not consistent, and different criteria are employed for boundaries between some geologic units (table 1).

Of particular importance to the stratigraphy of this area is the Mississippian-Pennsylvanian systemic boundary. In some places thick orthoquartzitic sandstones containing thin coal beds lie with scoured contacts upon limestones and red and green shales containing a rich marine (Mississippian) fauna. Elsewhere, red and green shales, limestones, coal, and gray and black shales constitute a more or less irregular transition zone between limestones and orthoquartzites. In some parts of the southern Appalachians the transition zone is thin and is of little consequence in conventional mapping. In parts of Tennessee and Alabama, however, the zone is thick (Raccoon Mountain, Parkwood) and may contain both coal and Mississippian fossils. In any case, the position of the Mississippian-Pennsylvanian boundary has proved troublesome, and there seems to be no way to resolve the question by using conventional techniques.

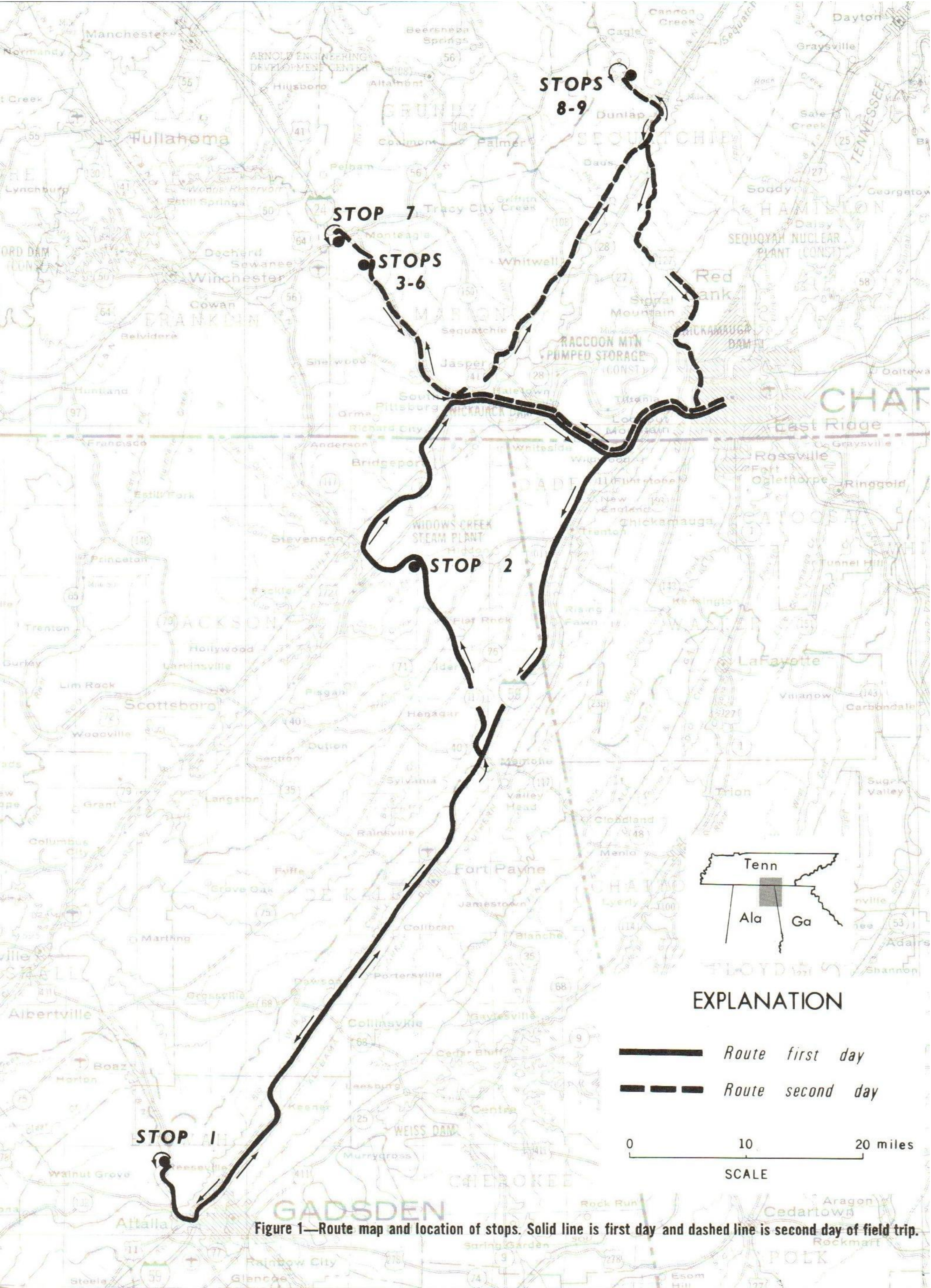


Figure 1—Route map and location of stops. Solid line is first day and dashed line is second day of field trip.

Approaching the problem in a slightly different fashion in northern Alabama, Ehrlich (1965) and Ferm, Ehrlich, and Neathery (1967) suggested that the contact did not reflect a systemic break at all. Instead, it was interpreted as a time-transgressive environmental boundary along which orthoquartzitic sandstones and gray and black coal-bearing shales represent beach-barrier and back-barrier environments, and underlying fossiliferous shales and limestones represent offshore clays and carbonate muds. However, they were not specific about designating subenvironments and used only regional evidence to support their case. Later, in northern Alabama Hobday (1969) studied orthoquartzitic sandstones in detail and was able to identify different parts of beach-barrier units within orthoquartzites and some zones of intertonguing of both beach-barrier and offshore "Mississippian" facies. In similar strata in northern Kentucky, Ferm, Horne, Swinchatt and Whaley (1971) showed the environmental and intertonguing nature of rocks previously classified as Mississippian and Pennsylvanian. Although they were able to describe carbonate units as tidally affected offshore islands, and intertongued dark shales and orthoquartzites as barrier deposits, they were unable to expand the question of the orthoquartzites as beach barriers.

The southern Plateau of Tennessee provides an excellent opportunity to study these time-transitional deposits in some detail. New highway construction has provided a series of excellent cuts, and detailed geologic maps make possible the placing of this new information in a regional context. It is the purpose of this trip to examine a few of these new exposures in the light of environmental hypotheses and, where possible, to indicate their regional importance (fig. 1).

Table 1—*Stratigraphic nomenclature of Lower Pottsville[1] strata in Tennessee and adjacent states*

NORTHEAST GEORGIA (Culbertson, 1963)		**FABIUS, ALABAMA (after Shotts and Riley, 1966, fig. 6)**	**TENNESSEE DIVISION OF GEOLOGY**		**MIDDLESBORO SOUTH QUADRANGLE, TENNESSEE-KENTUCKY (Englund, 1964)**
(Unit missing)	CRAB ORCHARD MOUNTAINS FORMATION	(Unit missing)	Rockcastle Conglomerate	CRAB ORCHARD MOUNTAINS GROUP	Lee Formation
Vandever Member			Vandever Formation		
Newton Shale Member			Newton Sandstone		
Whitwell Shale Member			Whitwell Shale		
Sewanee Member		Upper conglomerate	Sewanee Conglomerate		
					..........?..........
Signal Point Shale Member	GIZZARD FORMATION		Signal Point Shale	GIZZARD GROUP	Pennington Formation
Warren Point Member		Lower conglomerate	Warren Point Sandstone		
Raccoon Mountain Member		Parkwood Formation	Raccoon Mountain Formation		
Pennington Shale		Pennington Formation	Pennington Formation		

[1]The name Pottsville as used throughout this report is considered informal nomenclature, and is used as a rock-stratigraphic term for Gizzard (Mississippian and Pennsylvanian) and overlying Pennsylvanian strata.

AN ENVIRONMENTAL MODEL FOR THE LOWER POTTSVILLE OF THE SOUTHERN CUMBERLAND PLATEAU

Hobday's (1969) beach-barrier model indicated that Pottsville orthoquartzite units were composites of linear sand bodies, each of which represented a barrier island. The seaward sides of the islands were made of slightly inclined, evenly laminated accretion beds ("A" beds) which seem to be the result of deposition on a beach foreshore. Accretion beds grade downward and laterally (seaward) into festooned sandstones ("B" beds). These B beds were interpreted as sand waves formed by long-shore drift. A-type accretion beds also formed on the landward side of the barrier, as did some festoons (B). Cutting through the barrier were massive channel sandstones ("F" beds), representing tidal channels, and rip channels which are either parallel to or at right angles to beach ridges (ridge and runnel topography). On landward and seaward edges of the barrier, thin sandstone beds which may be rippled (C), horizontally bedded (D), or massive (E) are interbedded with lagoonal and offshore shales.

In southern Tennessee our experience has shown that foreshore accretion beds (A) comprise only a small part of orthoquartzite bodies, and festoon types (B) form a much larger proportion. There is considerable variation among B-types. Some are scoop-shaped and quite steep, but others are broad and gentle. Some of the broad crossbeds contrast with conventional concave festoons in that they appear to be lobate planar bodies with convex slip faces. Massive channel (F) units as well as rippled (C) units are as common in Tennessee as in Alabama. However, Hobday's differentiation of D and E beds seems to be of little utility; these beds were simply designated thin sandstones with interbedded shales in this guidebook.

Back-barrier deposits in southern Tennessee—coarsening-upward gray and black shale sequences, coals and seat rocks, thin tidal-channel sandstones, and slumped tidal-channel walls—seem to be similar to deposits in northeast Kentucky described by Ferm, Horne, Swinchatt and Whaley (1971). However, some of the gray and black shales in southern Tennessee are thicker, more silty, and less burrowed than those in Kentucky. Moreover, the total volume of rippled sandstone and thick flaser-bedded siltstone is much greater in southern Tennessee than in Kentucky. Finally, some Tennessee localities show masses of flaser siltstone and sandstone interfingering laterally with crossbedded sandstones, a relationship not observed in Kentucky.

Our genetic interpretation of the barrier and back-barrier units in the southern Plateau of Tennessee is shown schematically on figure 2. Dominating the sandy facies are tidal deltas composed of massive channel (F) units which mark the position of the localized vigorous current activity, and planar B beds which, driven by tidal currents, spread out over largely submerged flats of the delta surface. High-energy tidal-delta deposits grade landward into units of flaser-bedded siltstones overlain by planar cross-bedded "B" sandstones. In some places the upper contact of the sandstones is abrupt and the lower contact is gradational—a feature reminiscent of lagoonal or deltaic bay sequences (Ferm and Cavaroc, 1969; Coleman and Gagliano, 1964). In other places channels cut deeply into flaser-bedded siltstones and sandstones, the deposits that were channeled then slumped, and the channels were filled with silt and sand. Moreover, some deposits show multiple slumps in which slumped surfaces are rechanneled, filled, and again slumped. Such occurrences are prominent in recent deposits where the full force of tidal action is concentrated in lower tidal flats (Van Straaten, 1959). Landward on the upper tidal flats, slumps and channels are much diminished.

Both upper and lower tidal-flat deposits are characterized by coarsening-upward sequences of shale, siltstone and sandstone. Such coarsening-upward sequences arise from gradual filling of depressions as finer materials in the bottom are overrun by progressively increasing grain sizes transferred laterally across the basin. The upper part of fill sequences is commonly sandstone, which in some places is in shallow scoured channels but in others is in rippled or horizontally bedded sand sheets.

Coarsening-upward sequences of the upper tidal flat are commonly bounded at the top and bottom by coals and seat earths or beds of ironstone. Marshes form when depressions are completely filled and vegetation can take root; ironstones may form when filling is incomplete and detrital influx is diminished. Thickness of the coal-bounded sequences provides some clue to the depths of the lagoons, because the interval of subaqueous deposits between coals and seat rock indicates the **maximum** depth of the original depression.

Among the most conspicuous features of dark silty and clayey back-barrier deposits are thin, sheet-like bodies of sandstone that interrupt the normally

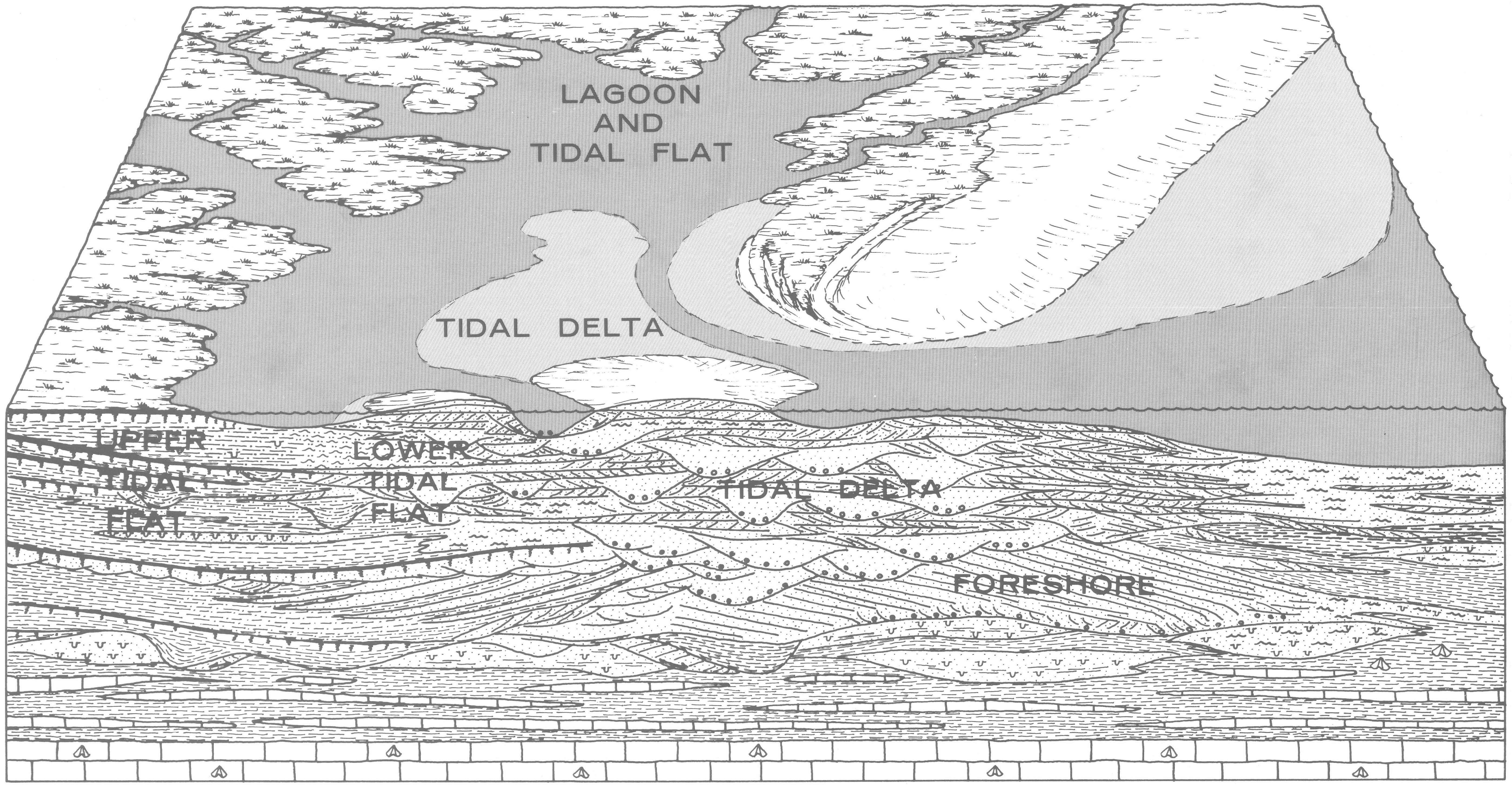
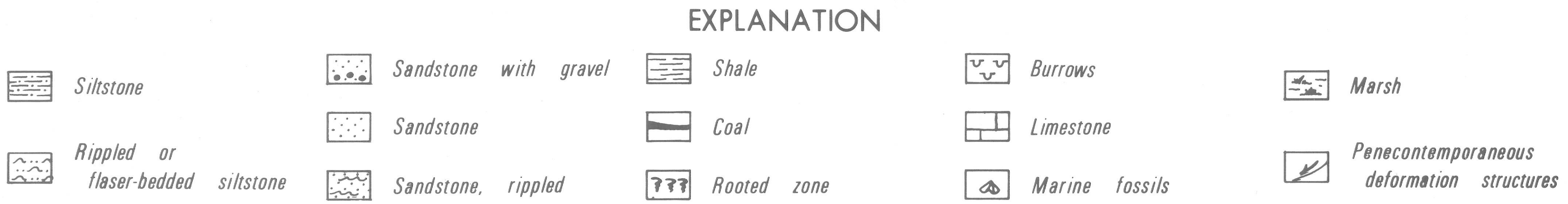


Figure 2—The littoral model. The vertical sequence reflects general progradation of the shore line. Limestones and fossiliferous shales are overlain by burrowed shore-face sandstones and then by foreshore accretion beds. Tidal-delta deposits are represented by massive channel fills and high-angle crossbeds. Behind the barrier sand body are lagoonal and tidal-flat silts and clays interbedded with coals.



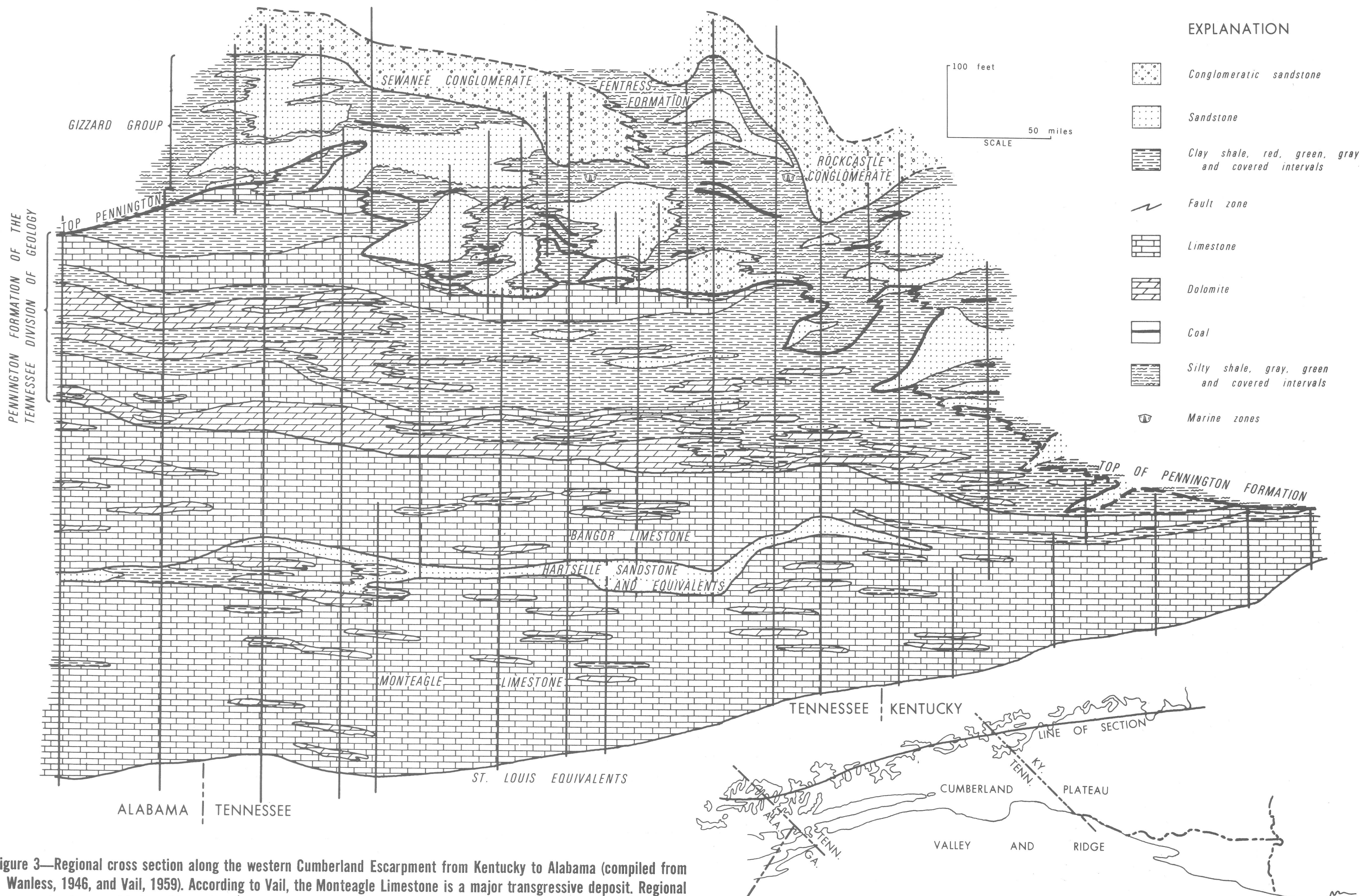


Figure 3—Regional cross section along the western Cumberland Escarpment from Kentucky to Alabama (compiled from Wanless, 1946, and Vail, 1959). According to Vail, the Monteagle Limestone is a major transgressive deposit. Regional regression began with deposition of the Hartselle and continued through the Rockcastle.

gradual pattern of coarsening-upward. In a few cases, such as in the lagoon of the foreshore-dominated barrier sandstone shown in the lower part of figure 2, these thin sandstones are so numerous that they dominate the sequence. In most cases, however, they are much less abundant and clearly indicate a break in the normal sedimentation pattern. Such breaks in a back-barrier setting are best attributed to overwash of the main barrier, or to periods of high storm tides within the lagoon which injected limited but widespread volumes of coarser sediments into areas of normally quiet-water deposition. Some of these sandstones show rippling or minor crossbedding, whereas others have been intensely burrowed.

Evenly laminated and gently dipping accretion beds (A), interpreted as beach foreshore sand deposits, comprise a relatively small proportion of the Pottsville in southern Tennessee but seem to be somewhat more abundant in northern Alabama. Foreshore beds (A) grade downward into festoons (B). As indicated by Hobday (1969), foreshores in most places are cut by massive channel sandstones. In many places the lowermost portion of foreshore sequences contains gravels of quartz or chert as well as locally derived material, and the gravels probably represent deposits of the beach step. The associated festoon bedding may represent bedforms which extend from the beach step onto the upper shore face.

Shore-face or offshore deposits are of two major types—relatively pure carbonate sequences, and terrigenous sediments containing some carbonate material. The former are treated by Bergenback, Horne, and Inden in this volume, and the remainder are reviewed here. The most obvious characteristic of all of these sediments is their distinctly brighter colors relative to the overlying sediments. This characteristic, which probably is a function of greater oxidation in the open circulation of the offshore, is reflected by lighter grays, reds or pale greens in the shales and siltstones. Some sandstones are virtually unwinnowed and contain large quantities of clay or granular nonquartz detritus, whereas others are washed as cleanly as the overlying barrier orthoquartzites from which they may have been derived. Burrowing in these shore-face sandstones is relatively intense, and sedimentary laminations of any sort are commonly lacking. All of these sand bodies are lenticular, and in many places it is not clear whether their geometry is depositional or the result of scour by tidal currents.

In some places scoured contacts mark the traditional position of the Pennsylvanian-Mississippian systemic boundary. Scouring of shore-face deposits is no better developed or more laterally continuous than of back-barrier deposits that directly overlie them. If an erosional surface on these shore-face deposits is to have more temporal significance than erosional features observed elsewhere in the barrier system, then it must be demonstrated that such a surface is both continuous and of regional extent, characteristics which have long been supposed but have not been proven.

REGIONAL ASPECTS

The concept of a prograding system of littoral environments for Carboniferous successions in southern Tennessee and northern Alabama provides the geologist with a new tool for regional interpretation. Regional interpretations can be made at many different scales, but in this guidebook only two examples are given. On a very large scale, figure 3 shows a general cross section along the western escarpment of the Plateau between central Kentucky and northern Alabama compiled from data by Vail (1959) and Wanless (1946). According to this section the lower 200 feet of Pennsylvanian in Kentucky can be regarded as beach-barrier and back-barrier equivalents of Bangor and Pennington limestones, dolomites and shales in northern Tennessee. Similarly, lower Pennsylvanian formations of the Gizzard Group in central Tennessee are interpreted as barrier and back-barrier equivalents of the Bangor and Pennington in southern Tennessee and Alabama. The massive Sewanee sandstone and conglomerate of the Plateau in Tennessee is shown grading northward into back-barrier shales and coals, but the seaward deposits have been lost by erosion.

The principal regional implication of this section is that progradation appears to have proceeded generally from north to south and differs from a northwestward direction indicated by both Englund (1968) in northern Tennessee and south Kentucky, and by Horne (in Smith and others, 1971) in central Kentucky, and from a northern progradation given by Ferm and Cavaroc (1969) in the northern Plateau of West Virginia and Pennsylvania. It also differs from a northward direction of progradation for the Carboniferous in central Alabama noted by Ehrlich (1965) and Ferm, Ehrlich and Neathery (1967). Hobday (1969), however, has pointed out that although beach deposits of central Alabama face seaward to the north, those of northern Alabama (like those in figure 3) do show southward progradation. Ferm (in press) has suggested that, in spite of apparent differences,

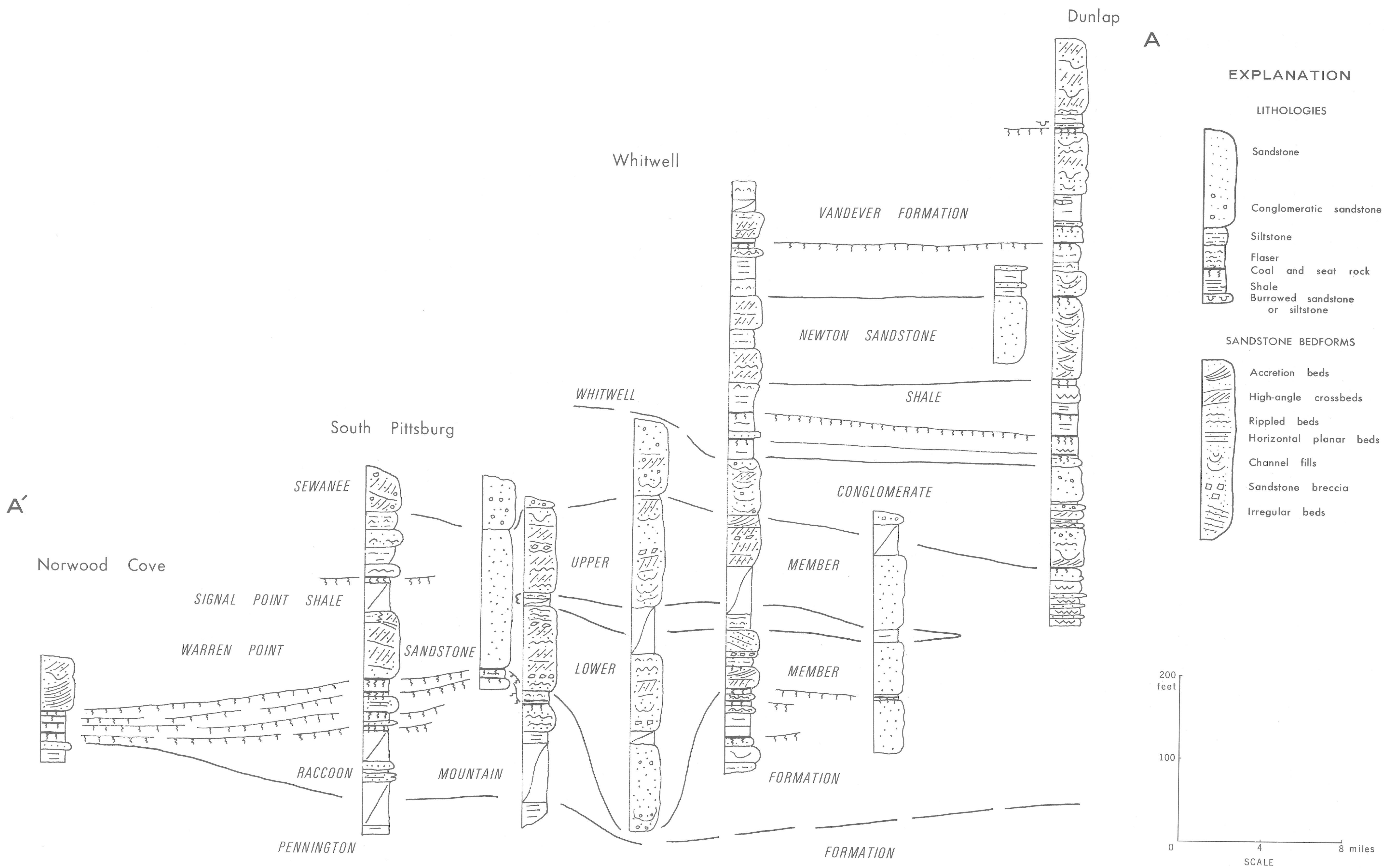


Figure 4a—AA' cross section from Dunlap, Tennessee, to Norwood Cove, Alabama. See Figure 5 for location.

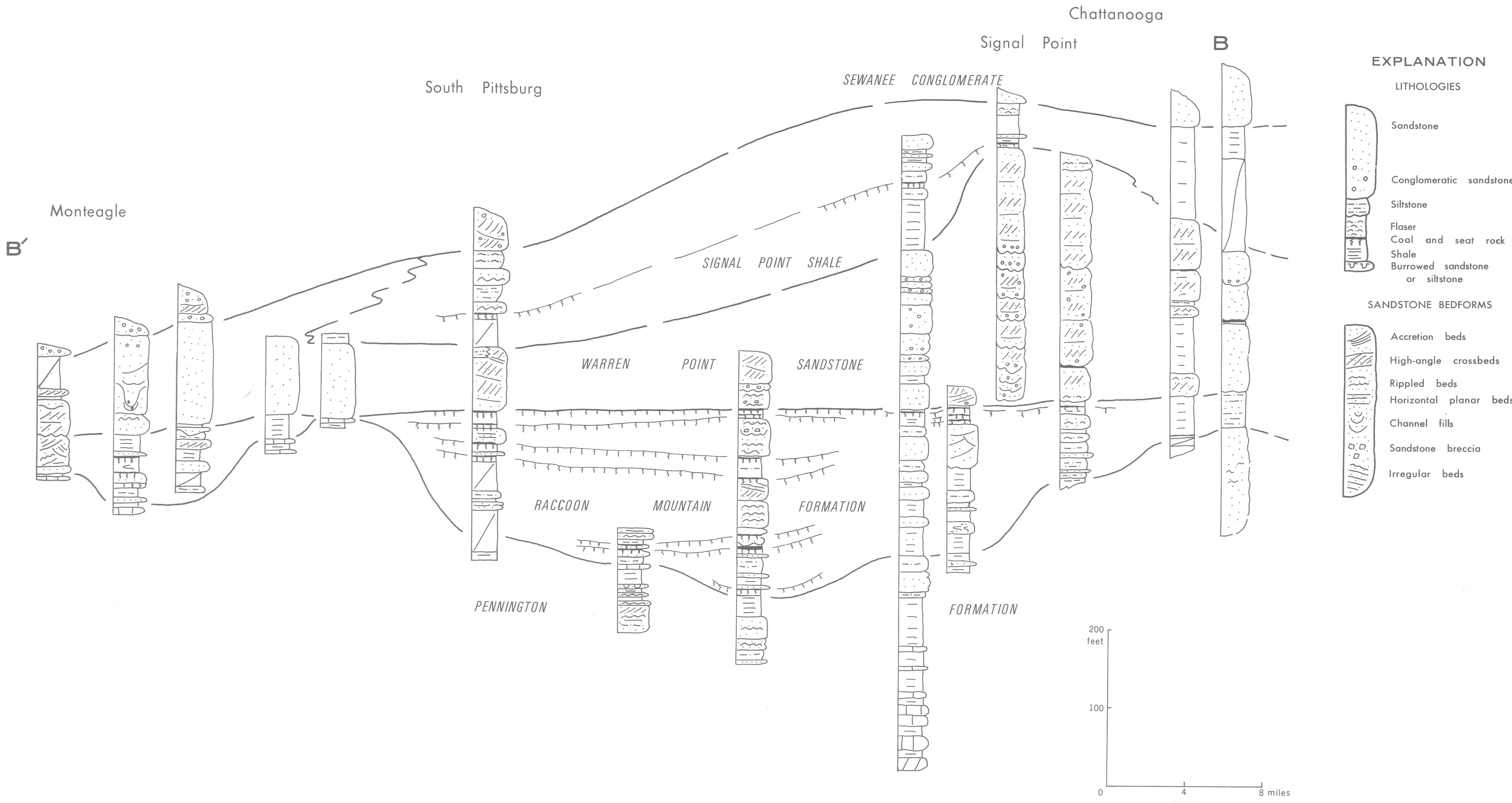


Figure 4b—BB' cross section from Monteagle to Chattanooga, Tennessee. See Figure 5 for location.

all cross sections from Tennessee northward are components of the major sedimentation pattern which, because it radiates from a point in the Carolinas, yields apparently conflicting results.

A small-scale and more detailed application of the environmental model is shown on figures 4 and 5. Figure 4 shows two general stratigraphic cross sections extending southward from Dunlap to Norwood Cove and eastward from Monteagle to Chattanooga—substantially the area of this field trip. Rocks shown range from Pennington to Vandever, but the principal zone of interest extends upward from the Pennington to the Sewanee Conglomerate. Figure 5 shows a paleogeographic map illustrating probable development of these lower Pottsville units, and generalized cross sections show the mechanics of southward progradation (fig. 6). According to the section and map the earliest formed barrier is a body of Gizzard sandstones extending northwestward from Chattanooga toward Spencer. Back-barrier phases of this unit are represented by the thick sequences of Raccoon Mountain gray and black shales and coal centered near Sale Creek (fig. 1), and offshore equivalents are represented by Pennington shales and limestones in the vicinity of Monteagle and Norwood Cove. The next barriers, possibly formed by southward spit extension from the Dunlap area, developed in the vicinity of Monteagle and Orme (figs. 5 and 6). This, in effect, sealed off a large embayment in the South Pittsburg-Chattanooga area and then a smaller one northwest of Monteagle in which additional Raccoon Mountain shale-coal units could be deposited. Tidal deltas and migrating barriers spread over these filled embayments, extending sands over the first formed Gizzard barriers, and created a sandstone cap covering Raccoon Mountain lagoons and marshes. Western barriers were drowned, and the main Gizzard barrier at Signal Mountain was built. When regional progradation was re-established a barrier was again formed near Monteagle, creating a Signal Point lagoon between Chattanooga and South Pittsburg.

Not only does this section illustrate the pattern of southward progradation across part of the southern Plateau in Tennessee, but it also illustrates the pattern of subsidence associated with it. Clearly, between the time of formation of the westernmost Warren Point barrier (see (b) on figure 6) and deposition of the Sewanee Conglomerate, the eastern area subsided 400 feet relative to the Monteagle-Norwood Cove district. Given a maximum accumulation of about 600 feet for the Gizzard, this subsidence seems large relative to the almost negligible differential subsidence in the upper Pennsylvanian of the northern Plateau indicated by Ferm and Williams (1965) and Ferm (1970), but very small relative to the amount of subsidence indicated by Ferm and Cavaroc (1969) in southern West Virginia. Thus, in a relative sense, the southern Plateau in Tennessee is tectonically intermediate between actively subsiding areas directly to the north and those stable shelflike regions of Ohio and western Pennsylvania adjoining the Cincinnati Arch and Canadian Shield.

ROAD LOG—FIRST DAY

MILEAGE Interval	MILEAGE Cumulative	DESCRIPTION
0.0	0.0	Depart Read House 8:00 a.m. Proceed on West 9th Street under I-124.
0.2	0.2	Enter South ramp.
1.1	1.3	Intersection of I-124 and I-24. Enter I-24 West ramp to Nashville, Birmingham. Lookout Mountain is to the southwest and Moccasin Bend of the Tennessee River is on the right (north) side of road.
1.6	2.9	Lookout Mountain syncline; bluffs to the left (south) of road are Monteagle Limestone (Mississippian).
0.1	3.0	Entering Lookout Valley and Lookout Valley anticline. Mountains of the Cumberland Plateau are in the background. Elder Mountain is on the right (north) and Raccoon Mountain on the left. Raccoon Mountain is the site of a TVA pump-storage power project.
1.2	4.2	Roadcuts in the Fort Payne Formation.
0.3	4.5	Chattanooga Shale exposed on right (north) side of Interstate.
0.1	4.6	Browns Ferry exit. Continue on Interstate.
0.5	5.1	Interstate crosses Lookout Valley anticline axis, then turns and follows the Valley south into Georgia.
0.6	5.7	Rockwood Formation, with thin beds of hematite.
0.2	5.9	Tiftonia exit. Continue on Interstate.
0.3	6.2	Hill on right is underlain by the Fort Payne, Chattanooga, and Rockwood Formations.

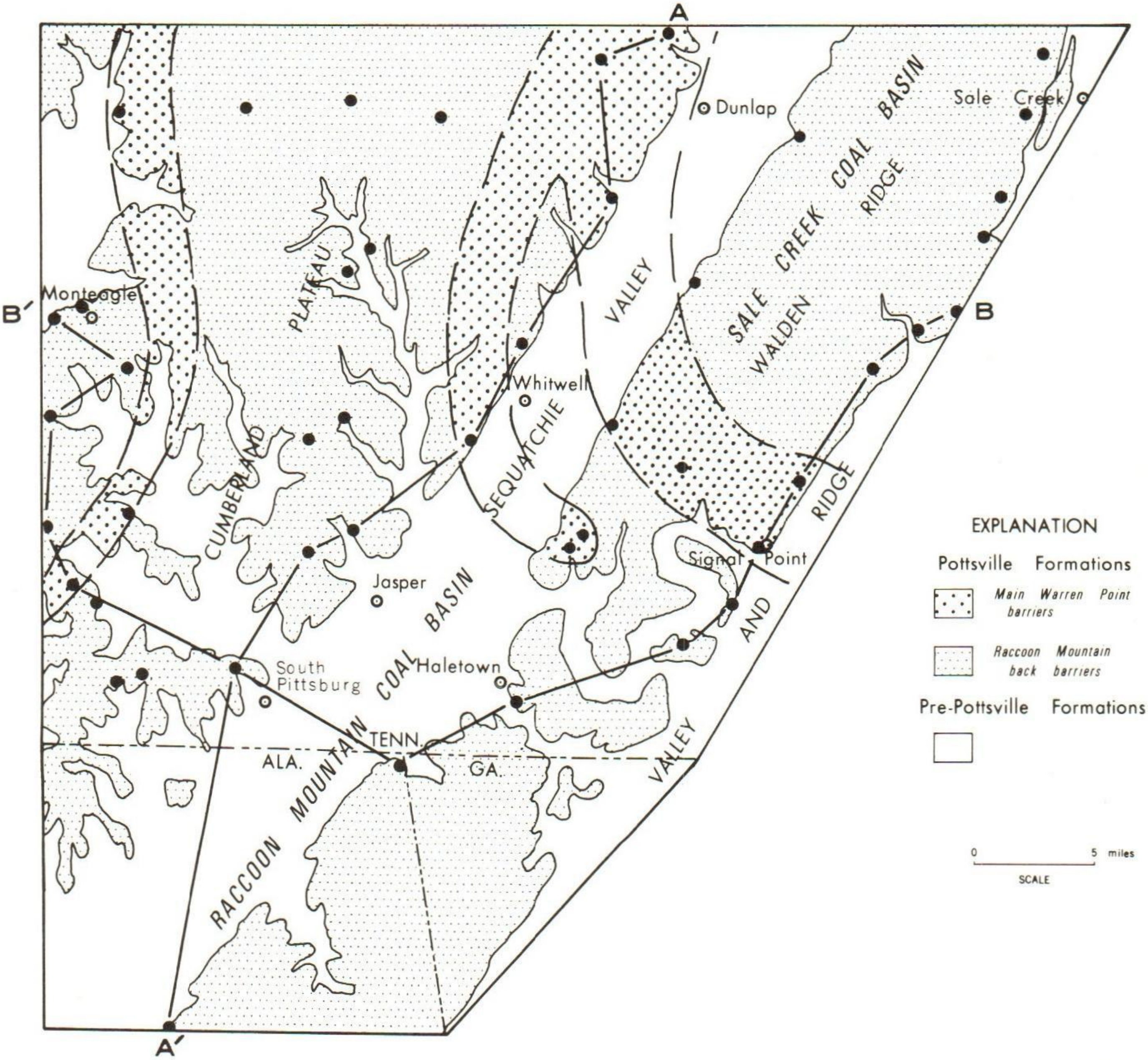
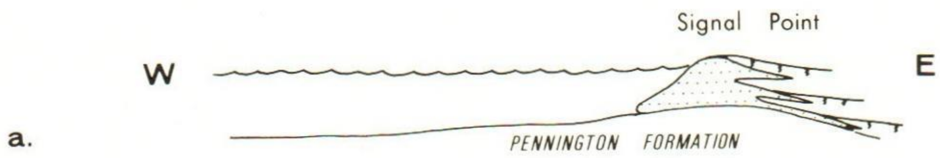
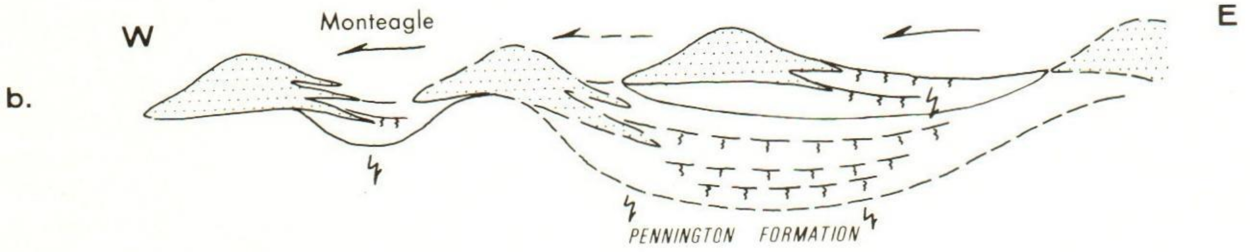


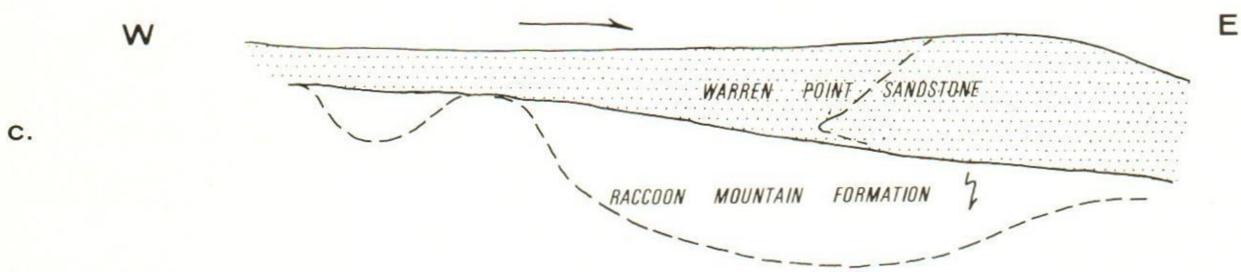
Figure 5—Generalized geologic map showing location of major Warren Point barriers and Raccoon Mountain back barriers in Tennessee. Barriers and back barriers are not differentiated in Alabama and Georgia. Solid circles are measured sections and drill holes. Compiled from Wanless (1946) and Tennessee Division of Geology files.



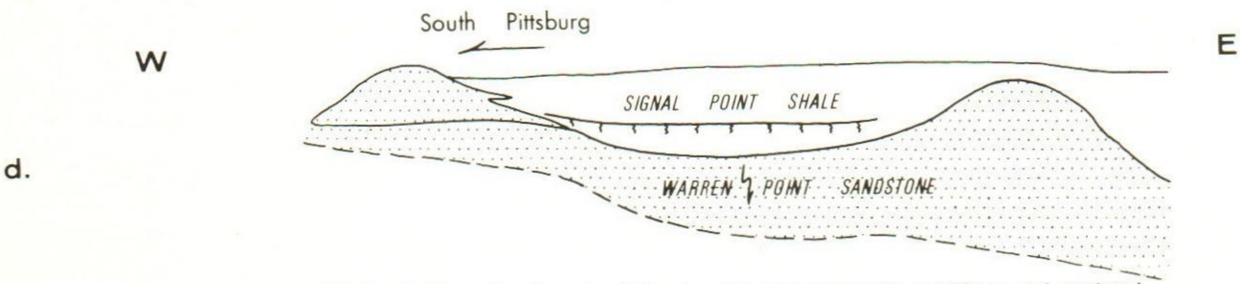
a. Development of lower barrier on Walden Ridge and formation of the Sale Creek coal basin.



b. Westward barrier migration or spit development concurrent with differential subsidence and filling of Raccoon Mountain coal basins.



c. Barriers migrate eastward over tidal deltas, depositing the Warren Point as a blanket sandstone, and forming a thick multistoried barrier across Walden Ridge to Dunlap. Signal Point back-barrier deposits accumulate in Sale Creek basin.



d. Westward barrier migration or spit development concurrent with subsidence and westward extension of Signal Point back-barrier deposits into the Raccoon Mountain basin.

Figure 6—Interpretive cross sections from Signal Point to Monteagle, showing the development of Gizzard barrier and back-barrier deposits. Horizontal arrows indicate directions of barrier and tidal-delta construction. Vertical arrows indicate subsidence.

1.5	7.7	Rockwood Formation on right (west) side of Interstate contains beds of hematite.
0.1	7.8	Quarry on mountainside on right side of Interstate is in Mississippian limestones (Fort Payne, St. Louis and Monteagle).
0.4	8.2	Rockwood Formation exposed on right (west) side of road for the next mile.
0.9	9.1	Georgia State line.
0.5	9.6	Quarry to left (east) of Interstate contains the upper part of the Inman Formation, the Leipers Limestone, and the lower part of the Shellmound Formation (Upper Ordovician).
0.1	9.7	Exit 32. Continue on Interstate.
0.1	9.8	Shellmound Formation with Fernvale Member exposed along entrance ramp on right (north) side of Interstate. The Shellmound Formation with seams of chamosite and hematite is exposed along the Interstate for 1.2 miles.
1.2	11.0	Shellmound-Rockwood contact on right (west) side of Interstate.
0.4	11.4	Junction I-59 and I-24. Bear left on I-59 toward Birmingham. Chattanooga and Fort Payne exposed on right (west) side of road.
0.8	12.2	Mississippian limestones exposed along Interstate for the next 0.8 mile.
1.8	14.0	Exit 3—Slygo Road, New England. Continue on Interstate.
2.0	16.0	Roadcuts are in the Inman, Leipers, and lower Shellmound Formations (Upper Ordovician).
0.4	16.4	Middle and Upper Ordovician limestones are exposed along the route to Trenton, Georgia.
3.4	19.8	Exit 2—Trenton, Georgia Highway 143. Continue on Interstate.
0.3	20.1	Carters Limestone (Middle Ordovician) in entrance ramp to right (west) of Interstate. Interstate follows Middle Ordovician outcrop belt to south end of Lookout Valley anticline.
5.0	25.1	Upper Ordovician limestone to right (west) of Interstate.
1.0	26.1	Interstate crosses Fort Payne hills into Mississippian limestone outcrop belt.
1.1	27.2	Exit 1—Rising Fawn. Continue on Interstate. Interstate crosses structural saddle between Lookout Valley and Big Wills Valley anticlines.
0.6	27.8	Bangor Limestone in cuts along Interstate.
3.2	31.0	Enter Big Wills Valley. Middle Ordovician on right (west) of Interstate.
0.7	31.7	Alabama State line. Middle Ordovician limestones, with bentonites, along right (west) side of road.
1.4	33.1	Exit—U.S. 11, Ider. Continue on Interstate. Interstate follows Ordovician and Silurian strata for the next few miles along faulted side of anticline.
8.1	41.2	Exit—Henager, Hammondville; Scottsboro, Valley Head, Alabama Highway 117, 40. Continue on Interstate.
4.4	45.6	Interstate turns south across ridge of residual Knox cherts and into east side of Big Wills Valley.
3.0	48.6	Interstate turns southwest and follows Middle Ordovician strike valley.
0.6	49.2	Middle Ordovician limestone exposures along Interstate are on the east limb of Big Wills anticline.
1.3	50.5	Exit—Fort Payne, U.S. 11. Continue on Interstate. Middle Ordovician limestones in cuts along Interstate.
0.7	51.2	Exposures of Middle Ordovician limestones, with bentonites, on east (left) side of Interstate.
2.7	53.9	Exit—Scottsboro, Fort Payne, Alabama Highway 35. Continue on Interstate.
13.7	67.6	Exit—Alabama Highway 68, Collinsville, Albertville. Continue on Interstate.
0.6	68.2	Exposures along Interstate are Middle Ordovician limestones.
10.0	78.2	Exposures along Interstate are Middle Ordovician limestones.
0.7	78.9	Interstate turns southeast and ascends Red Mountain.
0.6	79.5	Red Mountain Formation (Silurian) exposed in cuts along Interstate.
0.2	79.7	Chattanooga Shale (Devonian) exposed in cuts on right (south) of Interstate.
0.1	79.8	Fort Payne Formation (Mississippian) exposed in cuts on right (south) of Interstate.
0.6	80.4	Interstate turns southwest into Little Wills Valley, a strike valley in Mississippian limestones.
4.0	84.4	Exit—U.S.11, Noccalula Falls. Continue on Interstate.

4.8	89.2	Parkwood-Pennington (?) shales exposed to left along east side of Interstate. Prepare to leave Interstate.
0.2	89.4	Exit—U.S. 278, 431, Gadsden, Attalla. Leave Interstate.
0.3	89.7	Stop. Turn right (west), toward Attalla.
0.1	89.8	Stay left, and turn left at intersection to Interstate 59, U.S. 278, 431, 11.
0.1	89.9	Intersection. Turn right; to U.S. 11.
0.5	90.4	Intersection. Proceed straight under overpass.
0.3	90.7	Turn left. Follow U.S. 278, 431 through Attalla.
0.5	91.2	Bear right. Follow U.S. 278, 431 toward Huntsville. Route crosses complex structures along Rome fault.
0.7	91.9	Hills are residual cherts of the Knox Group, and limestones are probably Middle Ordovician.
1.1	93.0	Junction; U.S. 278. Continue straight on U.S. 431.
0.4	93.4	Junction; Alabama Highway 77. Continue straight on U.S. 431.
0.6	94.0	Knox residuum exposed on hill to right.
2.1	96.1	Proceed past Pottsville outcrop. Enter left lane.
0.8	96.9	Junction U.S. 431 and rural road. Turn around and proceed downhill on U.S. 431.
0.2	97.1	STOP 1—ROCKLEDGE.

STOP 1

DEPOSITIONAL ENVIRONMENTS AT ROCKLEDGE, ALABAMA

The stratigraphic position of rocks exposed at this stop is not definitely known but is low in the Pottsville and near the Parkwood Formation (Pennington equivalent) in the lower part of the cut. Because strata dip steeply into the hill, stratigraphic observations require some care. The diagram for this cut on figure 7 has been corrected for dip.

Environmental units exposed here range from offshore (perhaps shore face) to back-barrier lagoon and tidal deltas. Sandstones at the top of the cut, composed of massive channel-fill (F) and high- to low-angle crossbeds (B) probably represent a tidal delta, but the exposure is too small for complete study. Beneath the tidal-delta sandstones are two small lagoonal sequences separated by marsh deposits, now represented by a thin coal bed and seat earth. Both sequences coarsen upward as is typical of such deposits. These units thin to the south against the underlying sandstone and probably represent areas lying directly behind the barrier. The lower sequence is particularly well exposed and contains long tongues of sandstone which dip northward from the barrier and probably resulted from overwash. These sandstones have sharp upper and lower contacts, typical of thin sandstones associated with Pottsville beach-barrier sediments. The uppermost sandstone in the lower lagoonal sequence probably represents accumulations in tidal channels which migrated over the surface of the filled lagoon. Just before they dip below road level the channels truncate older marsh deposits.

The sandstones upon which the back-barrier sandstones and shales rest consist of multiple (probably three) foreshore units. Long, sweeping, evenly laminated foreshore sandstones (A beds) pass downdip into festoons (B beds) which, in this case, seem to represent sand waves that formed seaward of the beach step. At the southern end of the outcrop some of the "B" beds grade laterally into offshore rippled sandstones. The foreshore sequences are cut in many places by massive channel sandstones (F beds), which possibly represent rip channels that formed by channelizing of backrush into small areas. Other gravel deposits may represent beach steps.

The beach-barrier sandstones are separated from strata with marine fossils by a sequence of dark-gray siltstones interbedded with sandstones similar to those on the landward side of the barrier. Such features suggest that a barrier to the south created an intervening bay or lagoonal slough which was filled with dark silt.

The lowermost rocks in this exposure are dark, massive, graywacke sandstones which are overlain directly by a fossiliferous marine ironstone and grade downward into dark silty shales. The unwinnowed deposits are probably shore-face sands, which formed some distance seaward of the barrier but are now overlapped by it.

Retrace route to Interstate 59.

3.2	100.3	Junction; Alabama Highway 77. Continue on U.S. 431.
0.5	100.8	Junction; U.S. 278. Continue on U.S. 431.
1.8	102.6	Intersection. Bear left through Attalla on U.S. 278 and U.S. 431.
0.4	103.0	Turn right on U.S. 11. Follow U.S. 278 and 431.
0.05	103.05	Turn left, follow U.S. 278 and 431.
0.1	103.15	Turn right, follow U.S. 278 and 431.

0.65 103.8 Turn left, then right to I-59 North.

0.2 104.0 Turn left onto I-59 to Chattanooga.

0.3 104.3 Parkwood-Pennington (?) in cuts on right. Proceed north on I-59 to Alabama Highway 117.

47.6 151.9 Exit—Alabama 40, 117, Mentone, Valley Head, Henager, Hammondville. Leave Interstate.

0.2 152.1 Turn left onto Alabama 40, 117.

1.5 153.6 Junction; Alabama 40, 117. Turn right and follow Alabama Highway 117. Route crosses Sand Mountain in Pottsville strata.

6.6 160.2 Junction; Alabama Highway 75. Stop. Then proceed on Alabama 117.

5.5 165.7 Junction; Alabama Highway 71. Continue on Alabama 117.

6.6 172.3 STOP 2—NORWOOD COVE.

STOP 2

DEPOSITIONAL ENVIRONMENTS AT NORWOOD COVE, ALABAMA

Exposures at Norwood Cove, Alabama, are in the upper part of the Pennington Formation and the lower part of the Gizzard Group (fig. 8).

Environmentally, the rock units are barrier sandstones and tidal-channel deposits at the top of the outcrop; and lagoonal sediments, marine sandstones, and shales at the bottom. The upper sandstones have numerous sets of low-angle accretion beds (A). Most accretion beds are interpreted to be remnant barrier foreshores. They grade downward into festoon beds (B) and then into coarse conglomeratic lag accumulations which were probably deposited along the beach step by the advancing surf. Accretion beds are cut by massive channel-fill sandstones (F) which apparently are at random orientations. In one place near the northern end of the outcrop, dips of accretion beds flatten and then incline gently in the opposite direction. Accretion beds that reverse dip probably represent the berm line of the beach.

The base of the upper sandstone body scours into the upper of four lagoonal sequences, represented by clay and silt fills, each of which is capped by a coal. The upper lagoonal fill grades into coarser rippled beds, which probably reflects the development of tidal flats. Channels, perhaps scoured by tidal currents, are filled with slumped material near the top of the second lagoonal sequence. Within the second and third lagoonal sequences (from the top) are relatively thin lenses of sand. The coal that caps the third (down from the top) lagoon is a facies equivalent to the thin sideritic ledge exposed to the south across the covered interval. Brackish water and marine fossils are numerous, both in the sideritic ledge and in shales and siltstones below it. Lower lagoonal sediments lie upon a structureless sand ledge rich in clay, which passes downward into marine shale. This ledge interfingers with red shale to the south. This lower sand unit is probably a shore-face bar which accumulated offshore among marine shales. The rapid upward transition from marine shales and sands to lagoonal silts and clays suggests that the local environment was partially blocked from the open marine shelf, probably by the establishment of a barrier farther offshore. The history of lagoonal sedimentation seems to have been one of repetitive filling to a surface upon which peats (now coals) could develop, followed by subsidence. The irregular occurrence of isolated sand lenses within lagoonal fills probably reflects the influx of overwash or tidal-delta splays back into the lagoon.

Continue west on Alabama 117.

1.6 173.9 Mississippian limestones exposed to left (south) side of road. Descend into Browns Valley, which is formed above the Alabama part of the Sequatchie anticline, and is underlain mostly by Ordovician limestones.

1.6 175.5 Tennessee River.

1.0 176.5 Residual Knox chert along axis of Sequatchie anticline.

1.0 177.5 Junction; Alabama 117 and U.S. 72. Turn right (north) onto U.S. 72 East. Road follows the faulted side of Sequatchie anticline to Tennessee. In general, Knox is thrust on Mississippian limestones along the route.

4.3 181.8 Entrance to TVA Widows Creek steam plant.

4.4 186.2 Knox residuum exposed along road. Enter Bridgeport, Alabama.

3.6 189.8 Tennessee State line. Richard City quarry on left (west) is in Bangor Limestone.

1.1 190.9 South Pittsburg, Tennessee.

1.1 192.0 Junction; Tennessee Highway 156. Continue on U.S. 72.

0.4 192.4 Monteagle Limestone (Mississippian) exposed on left (west) of road.

1.6 194.0 Junction; U.S. 72 and I-24. Enter Interstate and return to Chattanooga. See road log for second day, miles 28.4 to 0.0, for description of route.

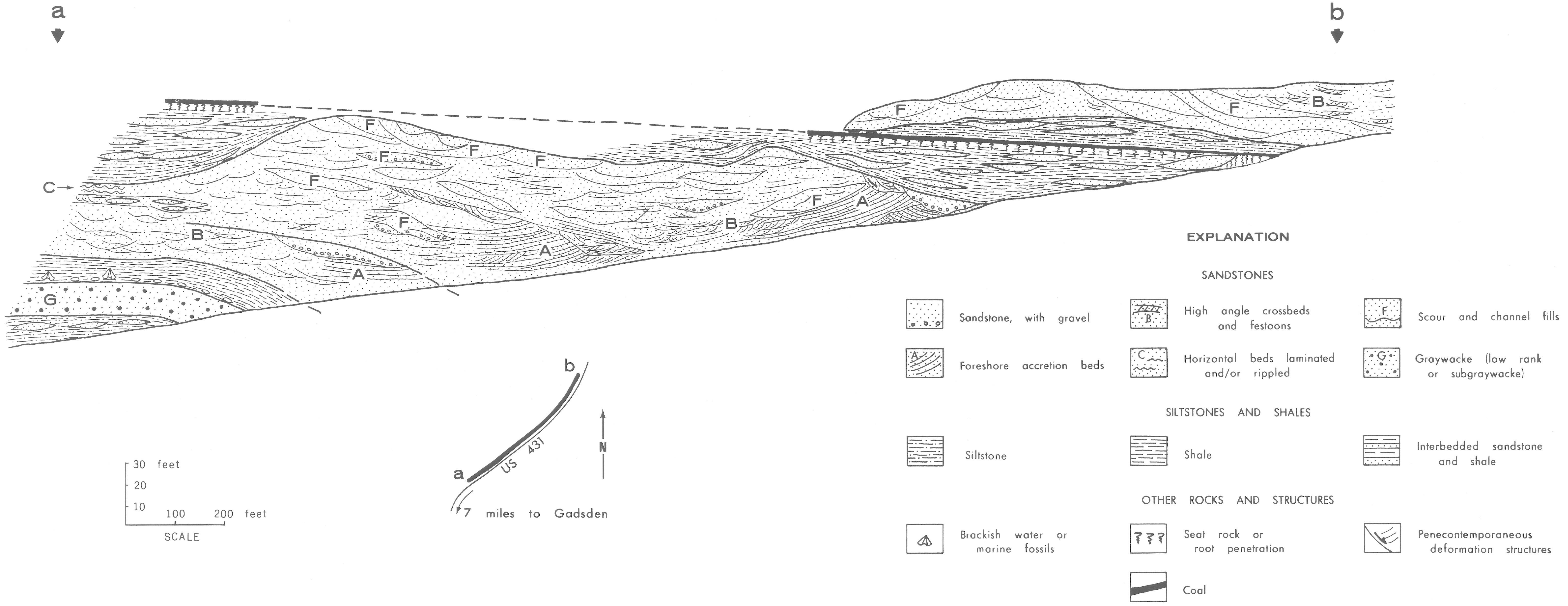


Figure 7—STOP 1: Beach foreshore, tidal-channel, back-barrier and offshore facies at Rockledge, Alabama. Left side of drawing is rotated to horizontal (modified from Hobday, 1969).

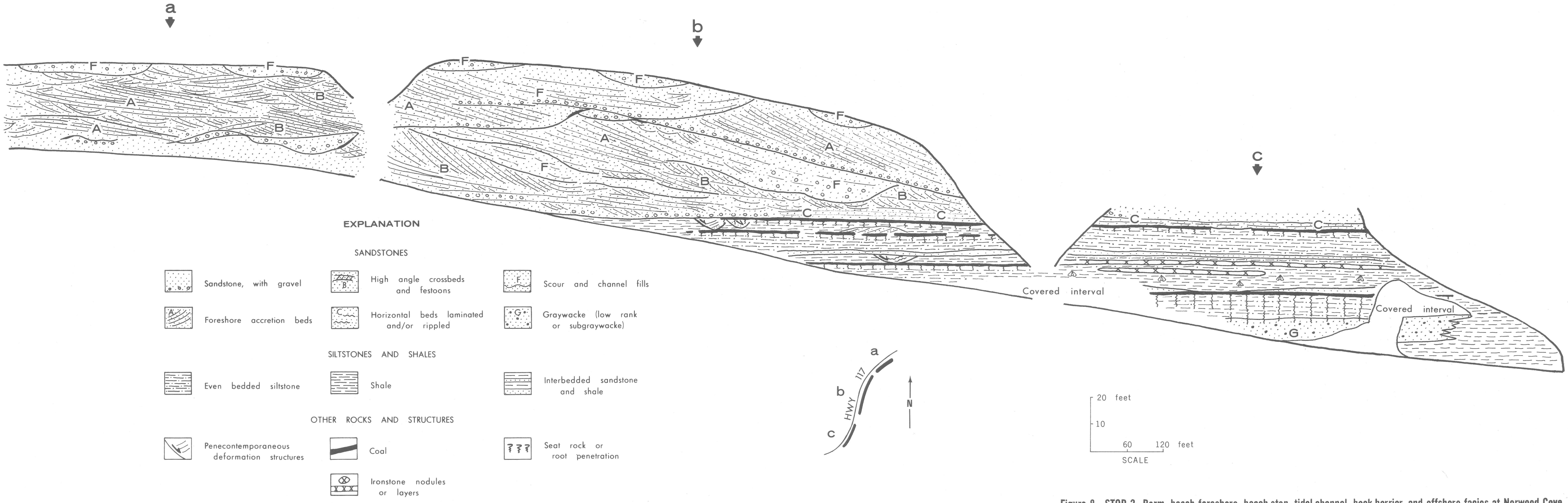


Figure 8—STOP 2: Berm, beach foreshore, beach-step, tidal-channel, back-barrier, and offshore facies at Norwood Cove, Alabama (modified from Hobday, 1969).

ROAD LOG—SECOND DAY

MILEAGE Inter-val	Cumu-lative	DESCRIPTION
0.0	0.0	Depart Read House 8:00 a.m. Proceed on West 9th Street under I-124.
0.2	0.2	Enter I-124 South ramp.
1.1	1.3	Intersection of I-124 and I-24. Enter I-24 West ramp to Nashville, Birmingham. Lookout Mountain is to the southwest and Moccasin Bend of the Tennessee River is on the right (north) side of road.
1.6	2.9	Lookout Mountain syncline; bluffs to the left (south) of road are Monteagle Limestone (Mississippian).
0.1	3.0	Entering Lookout Valley and Lookout Valley anticline. Mountains of the Cumberland Plateau in the background. Elder Mountain is on the right (north) and Raccoon Mountain on the left. Raccoon Mountain is the site of a TVA pump-storage power project.
1.2	4.2	Roadcuts in the Fort Payne Formation.
0.3	4.5	Chattanooga Shale exposed on right (north) side of Interstate.
0.1	4.6	Browns Ferry exit. Continue on Interstate.
0.5	5.1	Interstate crosses Lookout Valley anticline axis, then turns and follows the Valley south into Georgia.
0.6	5.7	Rockwood Formation, with thin beds of hematite.
0.2	5.9	Tiftonia exit. Continue on Interstate.
0.3	6.2	Hill on right is underlain by the Fort Payne, Chattanooga, and Rockwood Formations.
1.5	7.7	Rockwood Formation on right (west) side of Interstate contains beds of hematite.
0.1	7.8	Quarry on mountainside on right side of Interstate is in Mississippian limestones (Fort Payne, St. Louis, and Monteagle).
0.4	8.2	Rockwood Formation exposed on right (west) side of road for the next mile.
0.9	9.1	Georgia State line.
0.5	9.6	Quarry to left (east) of Interstate contains the upper part of the Inman Formation, the Leipers Limestone, and the lower part of the Shellmound Formation (Upper Ordovician).
0.1	9.7	Exit 32. Continue on Interstate.
0.1	9.8	Shellmound Formation with Fernvale Member exposed along entrance ramp on right (north) side of Interstate. The Shellmound Formation with seams of chamosite and hematite is exposed along the Interstate for 1.2 miles.
1.2	11.0	Shellmound-Rockwood contact on right (west) side of Interstate.
0.4	11.4	Junction I-59 and I-24. Bear right on I-24 West toward Nashville. Chattanooga and Fort Payne exposed on right (west) side of road.
1.2	12.6	Mississippian limestones are in cuts along Interstate for next three-quarters of a mile.
0.8	13.4	The Pennington Formation is exposed along the Interstate for the next 4.4 miles.
4.4	17.8	Pennington-Bangor contact exposed in cuts to right (north) of Interstate.
0.9	18.7	Haletown exit. Continue on Interstate.
2.7	21.4	Tennessee Highway 28, Jasper, Nickajack Dam exit. Continue on Interstate. Monteagle Limestone exposed in cuts along Interstate.
0.7	22.1	Anderson Ridge—a hogback of Fort Payne chert; Chattanooga Shale exposed at base. Entering Sequatchie Valley.
0.2	22.3	Shellmound type section exposed along south side of Interstate, west lane; Leipers and Inman Formations at base of cut.
0.8	23.1	Entering the East Valley division of Sequatchie Valley. East Valley is underlain by Middle Ordovician limestones.
0.4	23.5	Ridge underlain by cherty Knox residuum.
1.0	24.5	Sequatchie River.

0.5	25.0	West Valley, the faulted side of Sequatchie anticline.
3.4	28.4	U.S. 72, Jasper, South Pittsburg exit. Continue on Interstate west along Battle Creek Valley.
1.8	30.2	Quarry to right (north) side of Interstate is in the Monteagle Limestone.
4.8	35.0	St. Louis and Monteagle limestones exposed in cuts on right (north) side of Interstate. The St. Louis is exposed intermittently for the next 5 miles.
2.4	37.4	Martin Springs Road exit. Continue on Interstate.
2.9	40.3	Division of lanes; Monteagle Mountain. Exposure No. 1 (fig. 10). St. Louis - Monteagle contact in cut on left (west) side of lane.
0.1	40.4	Exposure 2. Monteagle Limestone.
0.1	40.5	Exposure 3. Monteagle Limestone.
0.3	40.8	STOP 3. Exposure 4. Monteagle Limestone; oolite mounds of several orientations.
0.2	41.0	Exposure 5. Monteagle Limestone; subaerial crust.
0.7	41.7	Exposure 6. Hartselle Formation.
0.2	41.9	Exposure 7. Bangor Limestone.
0.5	42.4	Exposure 8. Bangor-Pennington contact.
0.2	42.6	STOP 4. Exposure 9. Micrite channels.

Construction of Interstate Highway 40 across Monteagle Mountain has provided an almost unparalleled series of exposures of Carboniferous littoral and shore-face deposits. Cuts on three sides of the mountain illustrate the same stratigraphic interval and make possible the creation of a three-dimensional picture for this series of sedimentary rocks. However, because of the size of the exposures, it is often difficult for the observer not only to grasp what is immediately visible but to relate this to exposures on other parts of the mountain. Figure 9 shows a regional cross section of the entire mountain indicating the location of each stop. The first two stops illustrate the characteristics of the carbonate sequences on the east side of the mountain, whereas Stop 5 shows the uppermost shore face and lowermost back barrier dominated by upper tidal flats. Stop 6 illustrates the tidal-delta sequences on the top of the east side of the mountain. Stop 7 on the west side of the mountain shows the same stratigraphic position as Stop 5, but at Stop 7 the facies is that of the lower tidal flat.

STOPS 3 AND 4—DEPOSITIONAL ENVIRONMENTS OF MISSISSIPPIAN CARBONATE ROCKS AT MONTEAGLE, TENNESSEE

By

Richard E. Bergenback, John C. Horne and Richard F. Inden

An almost complete sequence of Mississippian formations from the middle of the St. Louis Limestone to the top of the Pennington Formation is exposed along Interstate 24 between Martin Springs and Monteagle, Tennessee (figs. 10 and 11). Rock models were constructed from studies of grain types and sizes, bedforms and sedimentary structures, lateral and vertical variations of rock units, and faunal content of these exposures. By comparing sedimentary characteristics of the rocks with depositional features of Recent sediments, interpretations of depositional environments for this Mississippian carbonate sequence were formulated. In this way, models for two carbonate depositional environments were developed: (1) a carbonate platform model and (2) a tidal-flat model. The two stops selected for this field trip best illustrate the main components of these carbonate depositional models.

STOP 3—Monteagle Formation, Carbonate Platform Model

The Monteagle Formation at this stop (figs. 10 and 11, exposure 4; fig. 12a) is composed of carbonate sands which were deposited in shoal and interior-platform environments. Local, episodic

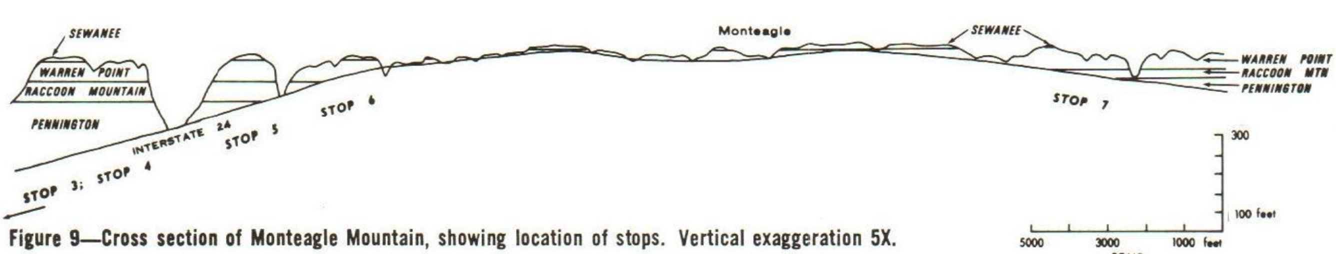


Figure 9—Cross section of Monteagle Mountain, showing location of stops. Vertical exaggeration 5X.

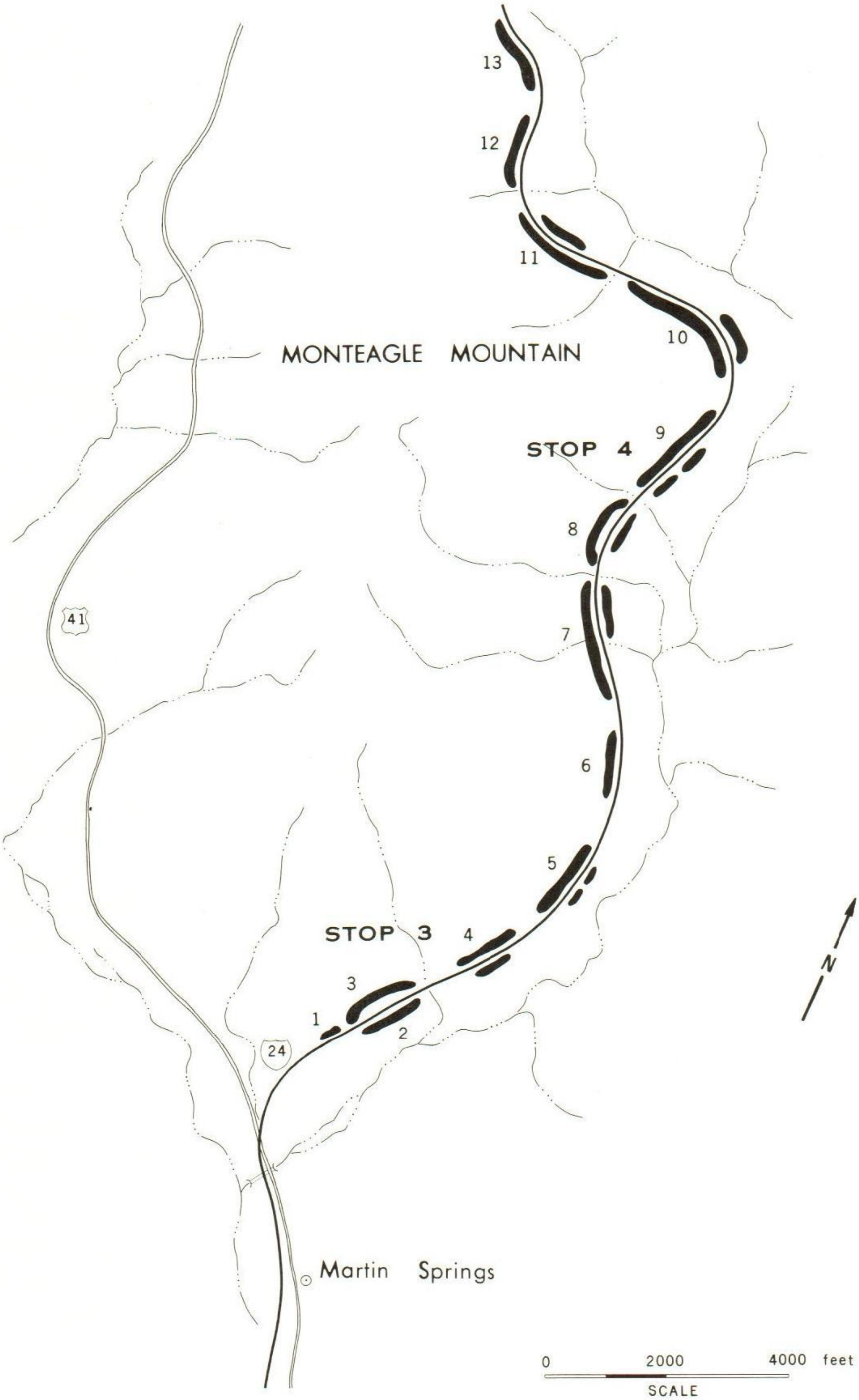


Figure 10—Road map and location of exposures along I-24 on the east side of Monteagle Mountain.

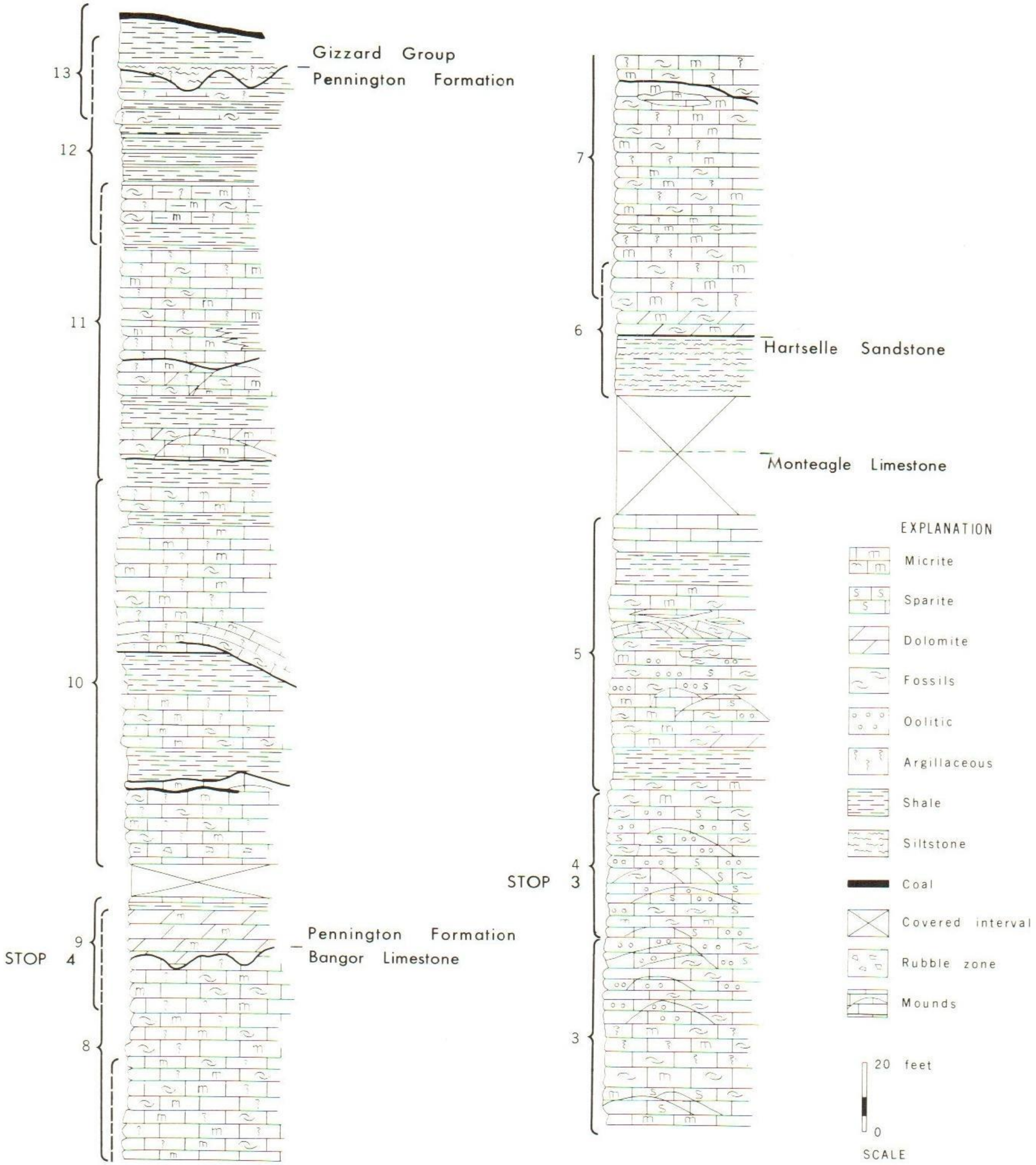


Figure 11—Stops 3 and 4. Stratigraphic column of carbonate rocks along I-24, on the east side of Monteagle Mountain.

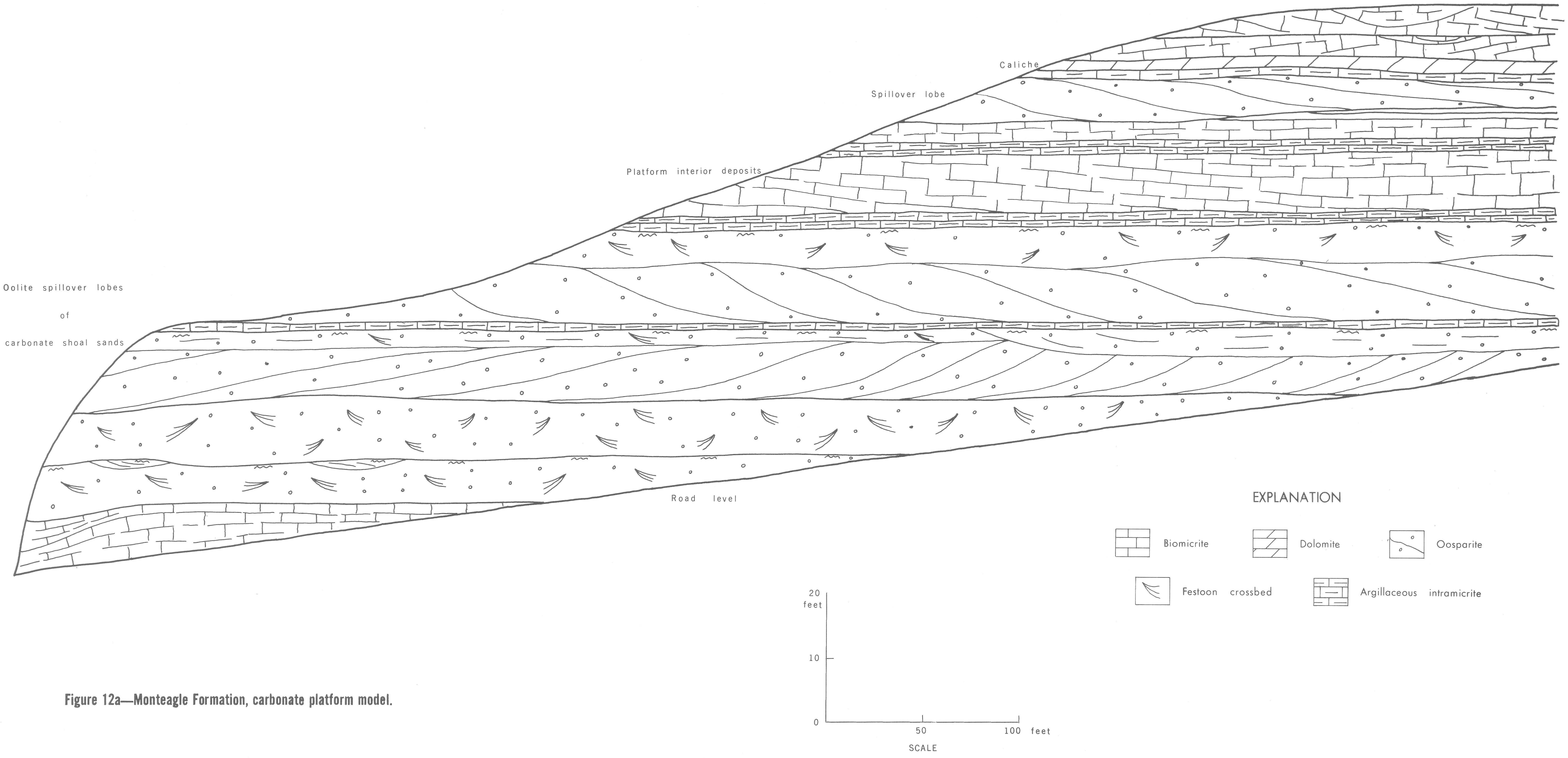


Figure 12a—Monteagle Formation, carbonate platform model.

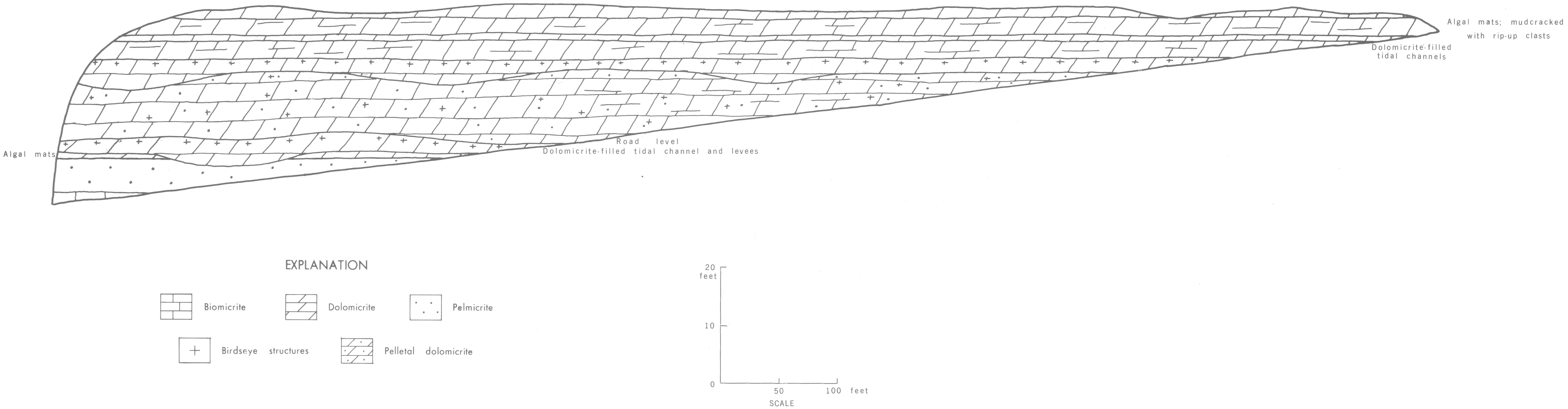


Figure 12b—Pennington Formation, tidal-flat model.

emergence of these shoals gave rise to islands on which early cementation, gross dissolution, and the formation of caliche sol horizons took place. Upon submergence the sediment and soil veneers of these islands were reworked into thin sheets of sand, which in turn were covered by succeeding shoal deposits.

The lowermost unit at this stop consists of poorly sorted, burrowed, pelletoidal and oolitic sparry biomicrites which represent the lowest energy deposits in the sequence. The strata overlying this unit consist mostly of well-sorted, medium to coarse intraclastic oosparite or fossiliferous, oolitic intrasparite. Also, some less well-sorted zones contain abundant rounded crinoids, bryozoans, and brachiopods. Sparite layers are festoon crossbedded or accretion bedded; festoon crossbed sets indicate current directions parallel to the depositional strike of accretion units. The accretion beds (large foresets) extend from the top to the base of a layer, coarsen upward, and merge tangentially with the subjacent unit. Two horizontally bedded, fossiliferous, burrowed oosparites occur above the bench.

The composition, sedimentary structures, and vertical changes seen in these carbonate sand bodies indicate that they were deposited in an environmental setting similar to that of the present-day Bahamian Platform. Ball (1967) describes platform-edge, well-sorted, oolitic marine sand belts and tidal-bar belts which contain festoon crossbeds and accretion foresets. In sand bars of the marine sand belts, storm-induced large-scale tabular foresets predominate and foreset dips denote sediment transport toward platform interiors. Spillover lobes formed during intense storms extend landward onto the platform from these belts; accretion beds in these lobes indicate current directions normal to strike of the marine sand belt. The tops of both the spillover lobes and sand bars are covered with medium-scale tabular and festoon crossbeds which formed during smaller storms, and larger spillover lobes commonly have axial channels through which sand is transported onto the platform. Tidal-bar belts, on the other hand, consist of a series of accretion-bedded sand bars oriented perpendicular to the shelf edge; channels separate the tidal sand bars and are floored with festoon crossbedded sedments which indicate current directions parallel to the strike of the accretion beds. During localized storms or transgressive phases, the well-sorted, oolitic sands of the tidal and marine sand belts were deposited, and grade downward into poorly sorted, burrowed, pelletoidal and bioclastic sands that accumulated in the lee of the shoals on the interior platform. During local or regional progradations, however, interior platform sands overlap the high-energy shoal deposits.

The essentially continuous shoal sequence seen at this stop is interrupted by three subaerial exposure crusts and a caliche paleosol; these localized weathering zones developed on shoals which built up to sea level during storms or during slight regressive phases. The subaerial crusts are thin, dark-brown, dense micrite beds and veins displaying fenestral fabrics and laminae; the crusts either parallel or cut across bedding planes. The caliche paleosol is a brecciated, nodular bed of micrite and dolomicrite; many of the breccia cracks are oriented horizontally and are filled with calcite spar and breccia clasts. Below this caliche zone is a bed of greenish-gray, nodular calcareous mudstone, and some of this may be an insoluble residue formed during calichification. Clasts of caliche and subaerial crust are found in overlying zones of argillaceous, oolitic intramicrites (either thin transgressive sands or storm deposits), attesting to the penecontemporaneous formation of the weathering zones. A channel, filled with graded beds of intraclastic oosparite, cuts out the uppermost part of an accretion-bedded unit on the north side of the outcrop; this channel fill in turn is overlain by a subaerial crust.

The laminated subaerial crusts (i.e., duricrusts, calcrete, laminated caliche) described here have been reported from the Florida Keys (Multer and Hoffmeister, 1968), Permian of Texas (Kendall, 1969), and Carboniferous of Kentucky (Ferm and others, 1971); in all instances the crusts occur at or near the surfaces of slightly emergent islands. Reeves (1970) points out that caliche crusts only form at the tops of plugged (impermeable) nodular caliche zones, or when an impermeable weathering zone is exposed at the surface. The nodular, brecciated zone near the top of this outcrop represents a mature caliche in which all original depositional textures and fabrics have been destroyed. The spar-filled cracks and breccia clasts are the result of expansion and dessication in the upper soil zone during the late stages of calichification. Caliches developed on limestone bedrock form through dissolution of bedrock material by downward-percolating water, followed by upward removal of water during intense evaporation (Blank and Tynes, 1965).

STOP 4—Pennington Formation, Tidal-Flat Model

The lower part of the Pennington Formation exposed at this stop (figs. 10 and 11, exposure 9; fig. 12b) is composed of carbonate sediments deposited on a tidal flat. Tidal channels scoured into the subjacent deposits, and levees which formed adjacent to the channels are separated by ponds. In areas of longer continuous exposure (e.g., levees), dolomitized birdseye pelmicrites, algal mats and rip-up clasts formed, while burrowed, pelletal micrites were accumulating in areas of more continual submergence (e.g., ponds, channels).

Two periods of tidal channeling are evident at this stop. Characteristics of these tidal channels are basal scours and fills of massive dolomicrite. Lateral to these channels are supratidal levees of laminated, intraclastic dolomicrites deposited over burrowed pelletal micrites that formed in intra-levee ponds. The laminations dip gently away from the channels and represent deposits that formed during flood stages. The intraclasts resulted from reworking of the dessicated mudcracked sediments during floods and by burrowing. Similar characteristics were noted by Shinn and others (1969) on the high intertidal to supratidal flats on the west side of Andros Island, Bahamas. Capping these channel-levee sequences are birdseye dolomicrites. Shinn (1968) noted that birdseye structures form in Recent supratidal deposits as a result of dessication and/or gas release.

Near the top of the exposure are laminated to crenulated, dessication-cracked dolomicritic algal mats. In a few places bedding has been disrupted by burrowing organisms. Intercalated with these laminated units are zones of intraclastic flat-pebble conglomerates composed of clasts of algal mats which were ripped up and reworked by storms. Similar sedimentary features were observed by Shinn (1968) and Laporte (1967) in Recent intertidal deposits.

0.7	43.3	Exposure 10. Bars, rubbly zone, cut-and-fill channel.
0.4	43.7	Exposure 11.
0.5	44.2	STOP 5. Exposure 12; Pennington-Gizzard boundary.

STOP 5

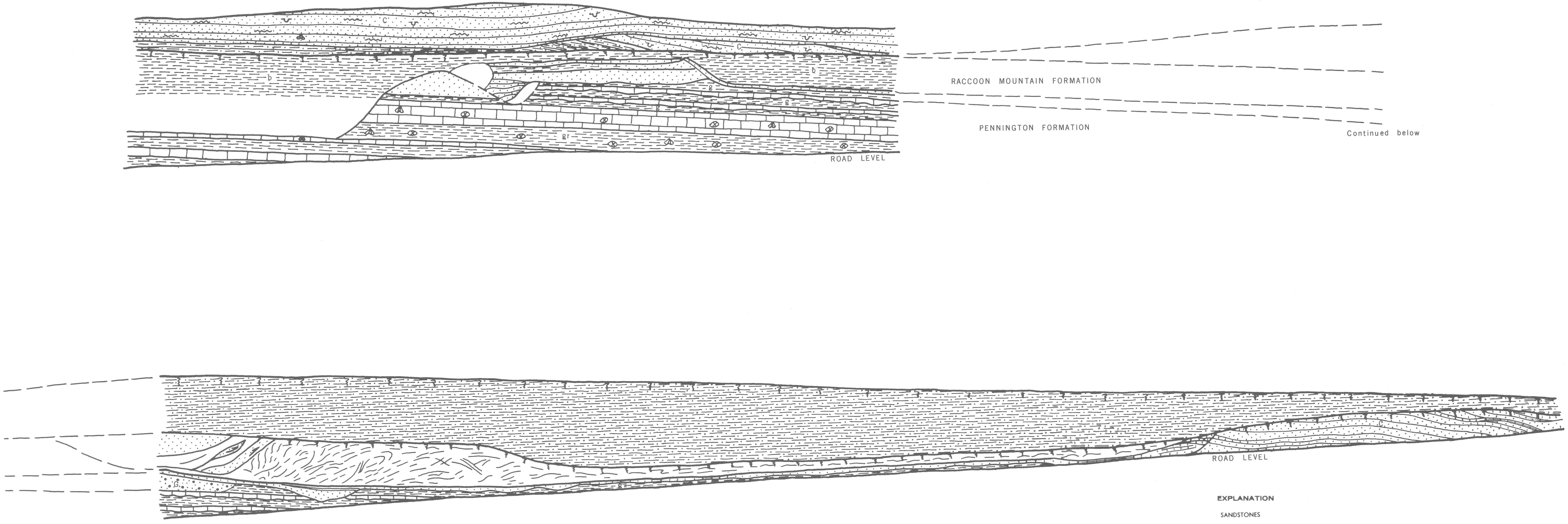
SHORE-FACE AND BACK-BARRIER ENVIRONMENTS ON THE EASTERN SIDE OF MONTEAGLE MOUNTAIN, TENNESSEE

Rocks exposed at Stop 5 include the upper part of the Pennington Formation and the lower part of the Raccoon Mountain Formation, and represent a suite of environments ranging upward from shallow offshore carbonate mud flats through a back-barrier lagoon and tidal-flat sequence into tidal deltas.

Gray shales with interbedded micrite and ironstone near the base of the outcrop (fig. 13) were deposited in a progressively shallowing offshore flat. The bedded micrite was probably a barlike mound which accumulated where influx of detrital material was not sufficient to preclude carbonate deposition. For the most part, marine fauna in the micrite mound occurs as shell hash in discrete, isolated layers, which suggests deposition by storm tides. The quartzose ledge above the micrite is thought to have formed as a shore-face bar. Green shales interbedded with rubbly, exposure-crusted micrites seem to interfinger with the sandstone along its north edge. The shales and carbonates probably represent high intertidal to supratidal flats which formed contemporaneously with the bar. The supratidal carbonates become progressively more argillaceous toward the quartzose sandstone, probably reflecting mixing of fine material from the flanks of the bar with the tidal-flat sediments. Overlying both quartzose sandstone and shaly carbonates is a series of sandstone wedges which are well winnowed in some places but contain abundant clay matrix in others. Their purity and relatively structureless appearance suggests that these sandstones, like the sand in the carbonates and shales upon which they lie, were derived from the quartzose sand body.

The sequence that follows the accumulation of the shore-face bar suggests a rapid change in depositional environment, perhaps by the establishment of a barrier island farther offshore. The relatively dirty channel sand that lies upon and truncates the shore-face bar to the north and south of the outcrop is interpreted to be a tidal-channel deposit. Eventually, a marsh was established upon which a thin, discontinuous coal developed. Black shale overlies this coal and represents the continued filling of a protected back-barrier lagoon. The next overlying coal represents the establishment of a second marsh. Slumped blocks of sand appear to have distorted the shale and presumably accumulated in tidal channels which reworked the surface of the marsh. This marsh was in turn drowned and once again a lagoon, represented by the silty shale, was established. Silt-sized material in this lagoon may have been derived from reworking of nearby tidal deltas and washover deposits. The lagoon eventually filled and a third marsh was established, as evidenced by the third coal. Toward the southern end of the outcrop, there is evidence of deep scouring of this last marsh surface. Above the upper coal are intensely burrowed flaser-bedded sandstones, which may have formed somewhere in the high intertidal zone of a tidal flat.

0.2	44.4	Exposure 13. Gizzard Group.
0.4	44.8	STOP 6 (by Garrett Briggs). Enter rest area.



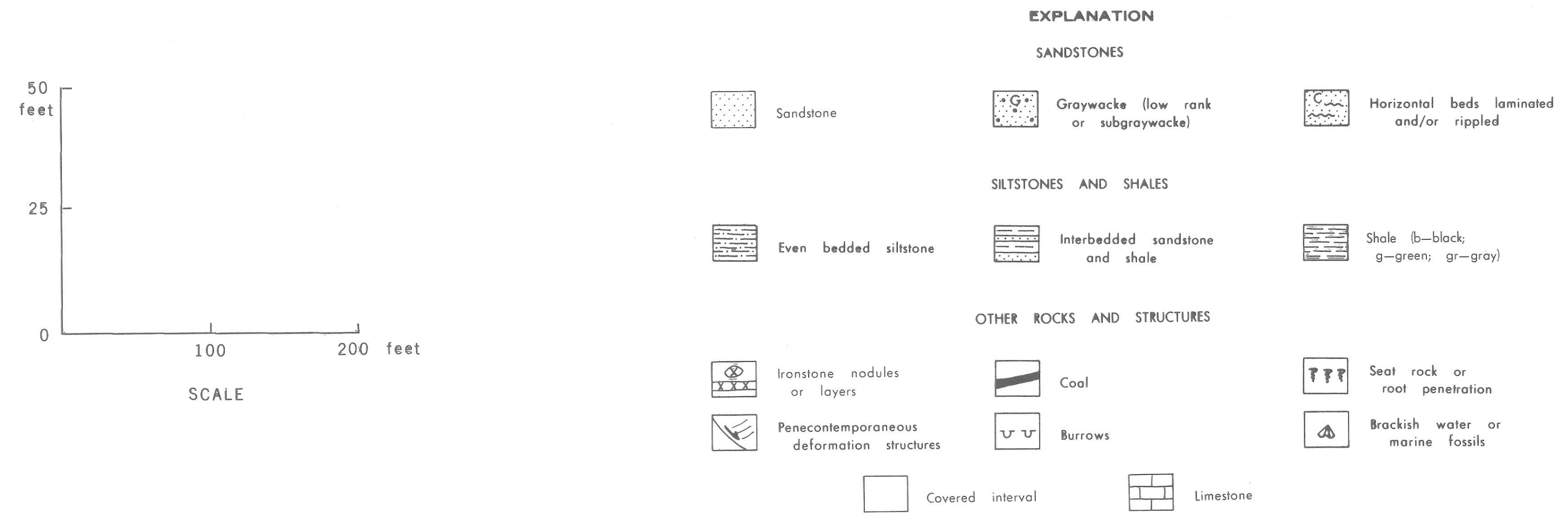


Figure 13—STOP 5: Shore-face and lowermost back-barrier tidal flats and tidal deltas of the Pennington Formation and lower part of the Raccoon Mountain Formation.

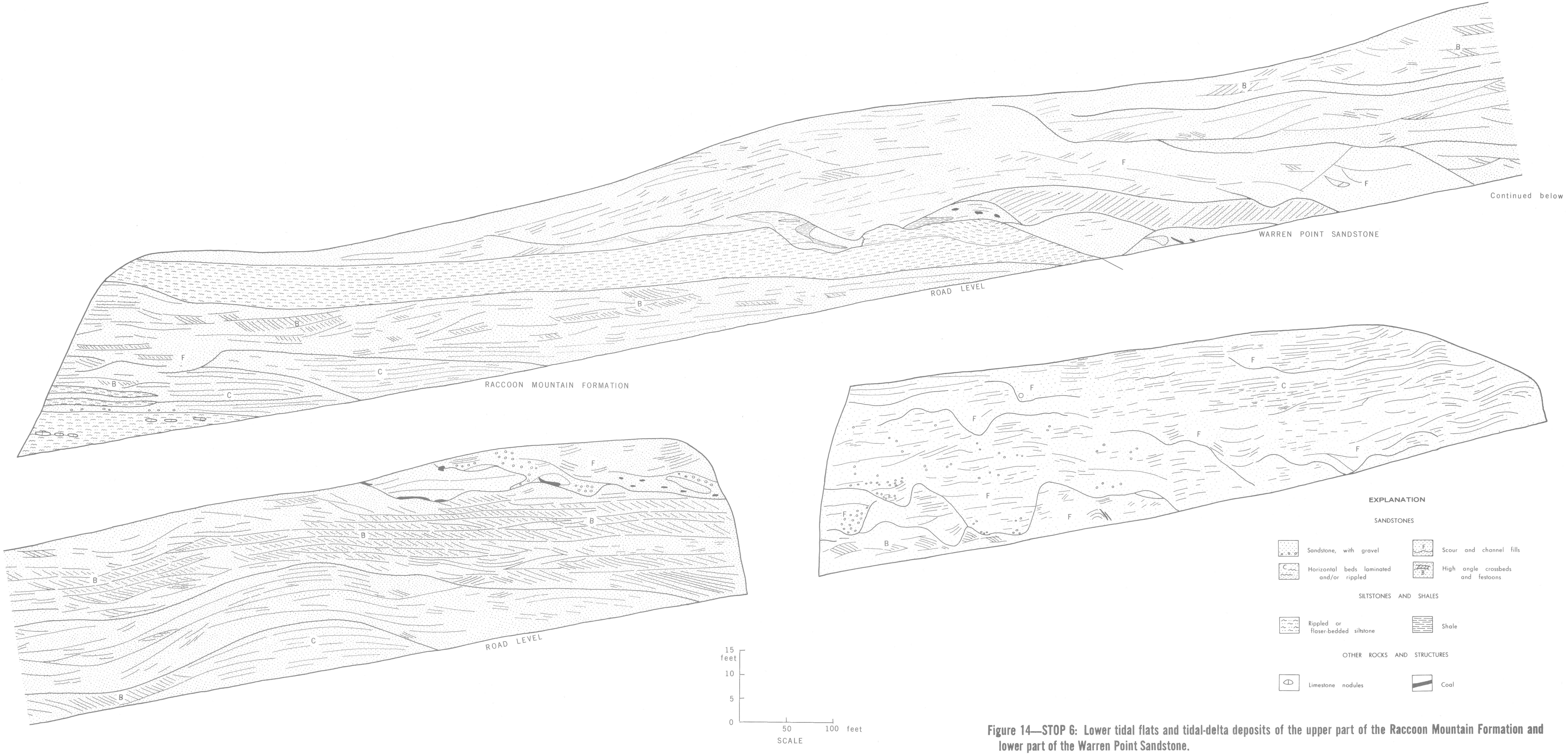


Figure 14—STOP 6: Lower tidal flats and tidal-delta deposits of the upper part of the Raccoon Mountain Formation and lower part of the Warren Point Sandstone.

STOP 6

TIDAL-DELTA DEPOSITS ON THE EASTERN SIDE OF MONTEAGLE MOUNTAIN, TENNESSEE

Garrett Briggs

The upper section east of Monteagle consists of the top of the Raccoon Mountain Formation and the lower two-thirds of the Warren Point Sandstone (fig. 14). The boundary between the two formations is at the base of a prominent scoured surface above rippled and flaser-bedded sandy siltstone and shales about one-fourth of the way up the exposure. Rocks of the upper part of the Raccoon Mountain Formation are interpreted as low tidal-flat and tidal-delta environments. Low tidal-flat environments are flasered, burrowed siltstones and shales and are in two sequences separated by tidal-delta deposits. The burrowed lower flaser-bedded deposit includes two horizons marked by discoidal nodules of fine-grained, dark-gray limestones as much as a foot long. The lower flasered beds are a continuation of extensively burrowed strata in the roadcut below, and toward the top of the sequence they are interbedded with tidal-delta sandstones. The lowest tidal-delta sandstone tongue contains lenses of rock-pebble conglomerates which were apparently deposited by the first accelerated currents of the tidal-delta phase. The main body of the Raccoon Mountain tidal-delta consists of fine-grained, planar crossbedded sandstone (B) and massive channel fills (F). The upper body of flaser-bedded strata records a diminution of current and sand supply, and the sand-starved ripples may have formed in low intertidal shoals and sand flats.

The Warren Point Sandstone is the main tidal-delta at this stop. The basal contact records the sudden increase of current flow when sand-laden waters ripped up and redeposited flasered deposits. Channel fills and high-angle crossbedded planar beds at the base of the formation give way to low-angle wedges which appear to have formed as a large mound of sand accumulated. Long lenses of sandstone built over the top of the mound, and these in turn are overlain by strata dominated by planar crossbeds and then by many massive channel fills with abundant lag gravel deposits.

Above the rocks of figure 14 an additional 20 feet includes the upper part of the Warren Point and the basal sands of the Sewanee Conglomerate. The top of the Warren Point is a continuation of the massive channels and lag gravels that mark the top of the section in figure 14. The channel-fill and lag gravels grade upward into more massive channel-fill sandstones which are overlain by a thin sequence of dark-gray carbonaceous shales, siltstones, and transported coals (washover). Coarse-grained, pebbly Sewanee sandstones rest on top of the dark shaly sequence. The Sewanee is interpreted as the initiation of a higher energy environment of a tidal-delta phase characterized by massive channel fill (F), steep planar crossbeds, and longer, more gently inclined crossbeds (B).

The succession of bedforms probably records both the filling of a relatively small lagoon by a tidal delta, and the progressive restriction of tidal currents from sheet flow and small channels in an open lagoon to the large confined channels of a restricted tidal inlet.

1.0	45.8	Top of mountain is capped by Sewanee Conglomerate.
0.1	45.9	Exit 135 to Monteagle. Continue on Interstate, down through STOP 7 to the Tennessee Highway 50, Altamont, Winchester exit.
8.3	54.2	Leave Interstate at Tennessee 50, Altamont, Winchester exit; then left over bridge and enter I-24 East ramp.
1.3	55.5	Elk River.
1.1	56.6	Mississippian limestone section on right (south) side of Interstate; type section of the Monteagle Limestone. See Appendix for measured section.
2.1	58.7	Base of Pennington Formation.
1.5	60.2	Pennington-Gizzard contact.
0.2	60.4	Base Warren Point Sandstone.
0.2	60.6	STOP 7. Enter rest area; walk down through section.

STOP 7

SHORE-FACE, LOWER TIDAL-FLAT AND TIDAL-DELTA DEPOSITS ON THE WESTERN SIDE OF MONTEAGLE MOUNTAIN, TENNESSEE

Stratigraphically the rock units exposed at Stop 7 range from sandstones assigned to the Pennington Formation at the base through sandstones of the Warren Point at the top (fig. 15).

The environmental units to be seen here include marine shore-face bars, lower tidal-flat deposits and tidal-delta sandstones with channels. The lowest shore-face sandstones are massive bars rich in clay which are interbedded with green shales near the bottom. Burrowing has destroyed any earlier formed sedimentary structures. Toward the bottom of the outcrop, the sandstone bars are scoured and overlain by channeled and slumped wedges of flat, interbedded, rippled and burrowed sandstones and siltstones which contain numerous bands of ironstone. The surface of these deposits is again truncated, leaving an irregular surface upon which the upper sandstones were deposited.

The upper sandstone body, the Warren Point Sandstone, consists of numerous wedges of both high-angle and broad, low-angle festoon beds (B). Crossbedded sets are difficult to trace because their surfaces are commonly scoured and overlain by similar features. High-angle festoons (B) may be observed grading laterally into both broad, shallow festoons and flat-lying beds. At the top of the outcrop, massive channel-fill (F) sandstones truncate the lower sandstones.

The burrowed sandstones with interlaminated green shales are thought to have been deposited as shore-face bars atop the marine shales. The scoured and slumped interbedded siltstones and sandstones represent tidal-flat deposits which were cut by migrating tidal channels. The degree of scouring, the conspicuous lack of clay-sized material, and the relatively minor occurrence of bioturbation of these strata suggest that they were deposited as low intertidal flats. The upper sandstones were deposited as tidal-delta sands filled across the scoured tidal flats.

0.8	61.4	Junction U.S. 41A and 67. Continue on Interstate.
1.2	62.6	Exit 135. Continue on Interstate.
0.1	62.7	Division of lanes.
1.0	63.7	Base Sewanee Conglomerate; Warren Point Sandstone below consists of several channel sandstone deposits.
0.6	64.3	Raccoon Mountain Formation; rippled sandstones, and lagoon and marsh deposits (shales, siltstones, and coals).
0.2	64.5	Slump in Raccoon Mountain Formation.
0.1	64.6	Pennington-Gizzard boundary.
1.1	65.7	Bangor Limestone on left (north) side of road.
0.5	66.2	Hartselle Formation, both sides of road.
0.4	66.6	Monteagle Limestone on left (north) side of road.
0.7	67.3	St. Louis Limestone on left side of road.
2.6	69.9	Martin Springs exit. Continue on Interstate.
9.2	79.1	Exit Interstate, U.S. 41, 64, 72; Jasper, South Pittsburg exit.
0.2	79.3	Turn left on U.S. 72, cross median and proceed under Interstate toward Jasper.
0.3	79.6	Junction U.S. 72, 41, 64. Proceed east (straight ahead). Exposures at intersection are Monteagle.
0.1	79.7	Kimball.
2.4	82.1	Cross Sequatchie Valley fault; Fort Payne thrust on Hartselle.
0.3	82.4	Leave Fort Payne hanging wall; continue on footwall of Mississippian limestones.
1.0	83.4	Enter divided highway on outskirts of Jasper.
0.5	83.9	Junction, U.S. 41, 64, 72 and Tennessee Highway 27. Turn left (north) onto Tenn. 27 East at stop light.
1.3	85.2	Junction Tenn. 27 and Tenn. 150. Continue on Tenn. 27 toward Whitwell. Rock on top of mountain to left front is Castle Rock Point and is formed from Gizzard quartzose sandstones.
0.2	85.4	Mississippian limestones exposed to left (west). Road follows the Monteagle-Hartselle-Bangor interval to Whitwell.
0.2	85.6	Hills of Pleistocene (?) terrace deposits mixed with colluvium. Road continues through the surficial deposits to Sequatchie.
1.7	87.3	Sequatchie.
0.7	88.0	Blowing cave in park on left (west) side of road is in the Bangor Limestone.
0.8	88.8	Little Sequatchie River. This is one of the few clear-water streams remaining in this part of the State. The stream emerges from several limestone springs in the uninhabited upper reaches of the gorge.
0.2	89.0	Hartselle shales exposed in cut behind house to left (west) of road.
0.3	89.3	Pleistocene(?) terrace deposits mantle Mississippian limestones to Whitwell.
1.7	91.0	Victoria. The Victoria coal mine on the mountain to the left (west) is in the Sewanee seam and was opened about the time of the Civil War. The seam has since been mined-out generally along the mountain to Whitwell. Coal

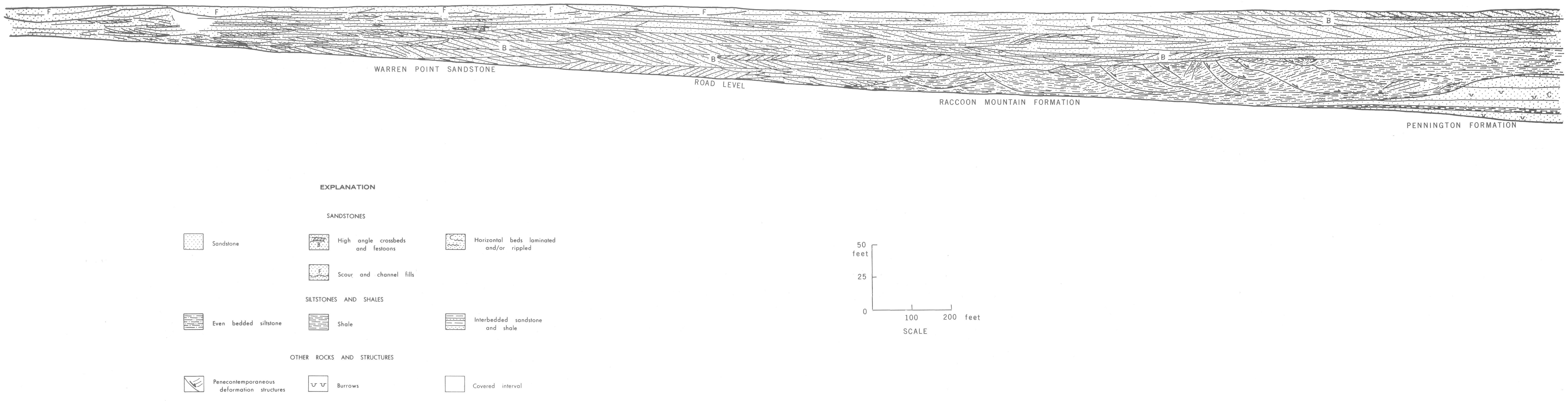


Figure 15—STOP 7: Slumped lower tidal flats of the Raccoon Mountain Formation and Warren Point tidal-delta deposits.

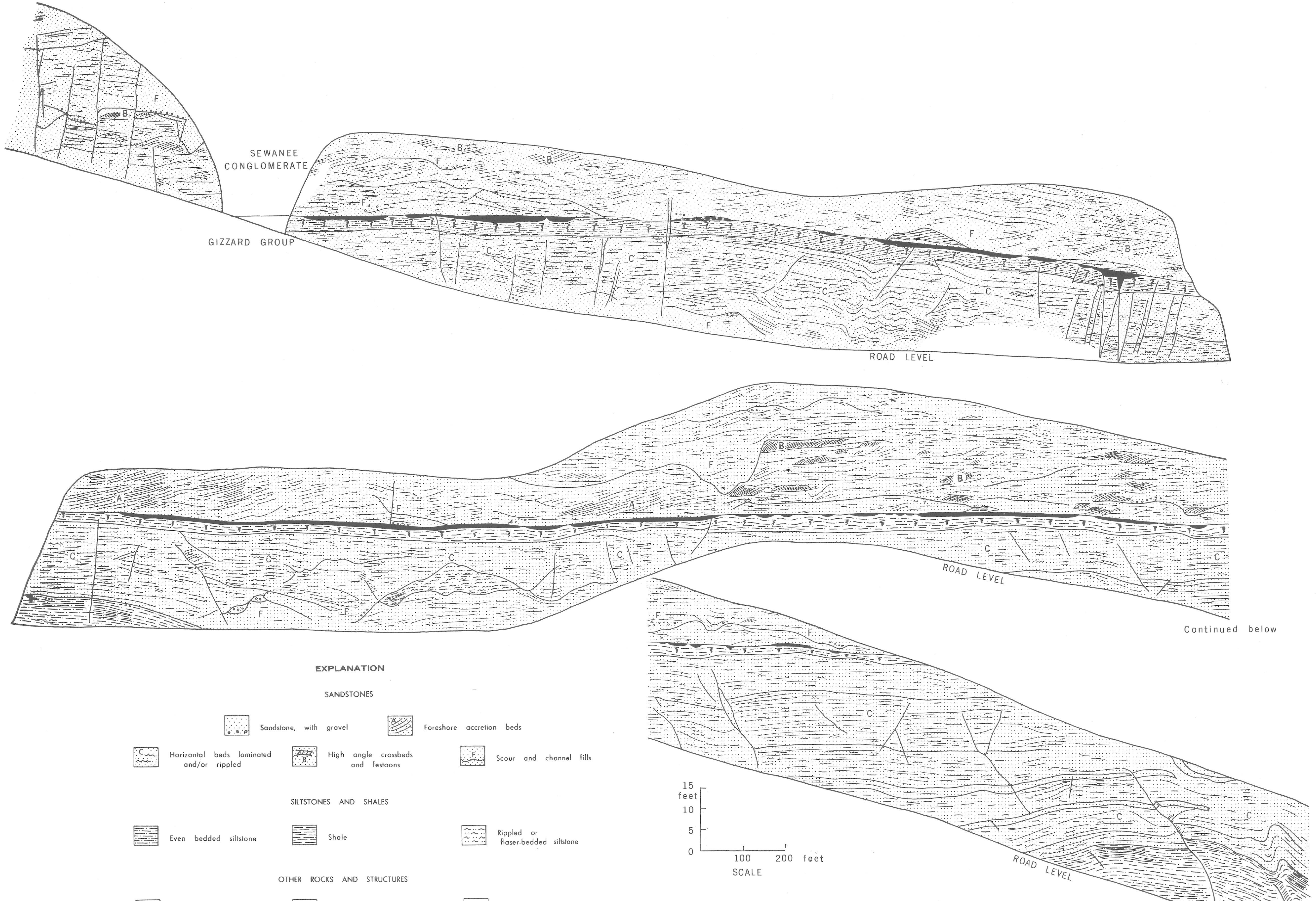


Figure 16—STOP 8: Beach foreshore, tidal-channel, bar and marsh facies in the Gizzard Group and Sewanee Conglomerate.

remains and is extensively mined to the west toward Palmer.

0.8 91.8 Exposures of Mississippian limestone on the left (west) side of road are in the footwall of the Sequatchie Valley fault.

1.5 93.3 Rock bluffs along the mountain on left (west) side of the road are Gizzard capped by Sewanee.

0.8 94.1 Junction, Tenn. 27 and Tenn. 108. Turn left onto 108 to Whitwell.

0.1 94.2 Whitwell. Springs along road are in Mississippian limestones about at the Hartselle interval.

1.3 95.5 Stop, 4-way; Spring and Main streets; Junction Tenn. 108 and rural road. Proceed straight ahead (north) on rural road.

0.2 95.7 Whitwell Elementary and High schools. Terrace and colluvial deposits mantle Mississippian limestones between Whitwell and Dunlap.

4.9 100.6 Mississippian limestone ledges exposed in woods to left (west) of road.

1.8 102.4 Cartwright.

0.3 102.7 Hill to front is Knox thrust over Bangor.

0.1 102.8 Bangor in footwall of Sequatchie Valley fault; road closely follows the trace of the Sequatchie Valley fault from here to Dunlap.

2.9 105.7 Daus.

2.6 108.3 Dunlap Stone Company quarry in upper Bangor.

1.4 109.7 Junction of rural road with U.S. 127. Stop, turn left (north) onto 127 North; proceed into Dunlap.

1.4 111.1 Middle Ordovician limestones along road on left (west) are on the hanging wall of the Sequatchie Valley fault, and are thrust over Bangor.

1.3 112.4 Junction, U.S. 127 and Tenn. Highway 8. Turn left (west) onto Tenn. 8 North. Promontory to right front is Savage Point.

1.2 113.6 Enter 3-lane road. Landslide on right (north) side of road is in colluvium above the Pennington. The construction of the road has undercut the toe of a stabilized slope and initiated the slide. Road construction has triggered Pennington, colluvium slides throughout the Cumberland Plateau.

0.8 114.4 Pennington sandstones and shale on right (north) side of road.

0.2 114.6 Pennington limestone on right (north) side of road.

0.1 114.7 Gizzard sandstones folded along the Cumberland Plateau overthrust.

0.1 114.8 Deformed Gizzard sandstone and shale in the Cumberland Plateau overthrust zone. Is this tectonic or slump?

0.4 115.2 STOP 8—Dunlap. Disembark at falls; walk east along road to crest of hill and then down to deformed zone.

STOP 8

FORESHORE, TIDAL-CHANNEL, BACK-BARRIER AND MARSH ENVIRONMENTS AT DUNLAP, TENNESSEE

Strata of the Gizzard and nearly all formations of the Crab Orchard Mountains Group (Sewanee, Whitwell, Newton and Vandever) are exposed almost continuously for 2 miles along Tennessee Highway 8 west of Dunlap. Except for structurally deformed zones at the base and in the middle of the exposure, formations are approximately horizontal and bedforms are oriented nearly as they were when formed. Exposures at Dunlap show a complete range of barrier and back-barrier environments. The lower units—Gizzard, Sewanee, Whitwell and Newton —seem to represent barrier foreshores, tidal deltas and some fine-grained back-barrier deposits; whereas, the Vandever seems to be dominated by marsh, lagoonal and subordinate tidal-delta elements.

The Gizzard Group is divisible into three formations in the Chattanooga-Monteagle area—the Raccoon Mountain Formation, Warren Point Sandstone, and Signal Point Shale. At Dunlap the Signal Point Shale is missing, and Sewanee lies on Gizzard sandstones (fig. 16). Sewanee-Gizzard stratigraphy has not yet been mapped into this area, but the base of the Sewanee is probably at the prominent deformed coal and rooted seat rock exposed along Tennessee Highway 8 west of Dunlap (fig. 16).

Downward from the base of the Sewanee upper Gizzard strata consist of gray siltstones capped by thick rippled sandstones (C beds) with a few small channel-filled (F) beds. These rocks presumably formed during the filling of a back-barrier lagoon which became progressively coarser and then rippled at the top. The coal and seat rock completed the episode of lagoonal fill.

Strata lying directly above the Gizzard coal on figure 16 differ markedly from those below. The sandstones (probably basal Sewanee) are fine-grained and are dominated by low-angle accretion beds, high-angle crossbeds, and massive channel-fill sandstones (A, B, and F beds). The sequence is interpreted as the foreshore of a barrier beach, most of which has been reworked and replaced by tidal-delta deposits.

The upper part of the Sewanee Conglomerate is too much deformed here to be interpreted genetically, but in adjacent areas it consists of low-angle accretion beds, high-angle crossbeds, and massive channel fills. It thus appears to represent the same types of environments as the lower beds at Dunlap —mostly the subtidal portion of a barrier reworked by migrating tidal inlets.

2.0	117.2	Proceed to top of cut. Turn around at intersection.
0.1	117.3	STOP 9—DUNLAP. Disembark, walk down through upper sandstones and shale beds.

STOP 9

TIDAL-DELTA, LAGOON, MARSH AND TIDAL-CHANNEL ENVIRONMENTS AT DUNLAP, TENNESSEE

The upper Vandever consists of two sandstone bodies separated by about 20 feet of marsh and lagoonal deposits (fig. 17a). These sandstones are dominated by massive channel-fill sandstones and planar crossbeds (F and B beds). Horizontal and rippled beds are subordinate, but each sandstone contains one thin zone of this type of strata. Massive channel fills dominate the lower sandstone body; in contrast, the upper sandstone body is composed mostly of planar (B) crossbeds. Both sandstones are interpreted to be tidal-delta deposits built by unconfined megaripples and sand waves (crossbeds) which were fed and cut by tidal currents. Horizontal and rippled beds are perhaps parts of tidal deltas which accumulated in low intertidal regions, or in subtidal regions above wave base.

The lower part of the Vandever Formation is almost entirely channel fill with abundant evidence of local scour. The channel deposits represent only an isolated though spectacular event in the midst of a large tidal-delta marsh. The great number of channels, the lower ones filled with conglomeratic sandstones and the upper ones abandoned and filled with shale, is indicative of episodic invasion of the marsh by diminishing tidal currents. Immediately after the channeling episode the area remained relatively shallow, permitting a thin succession of marsh and shallow lagoonal clays. These in turn are overlain by a thick succession of lagoonal muds with limestone and a siltstone with marine fossils near the top. Such successions in other parts of the coal field are commonly transitional with landward delta-plain strata.

The Newton Sandstone consists almost entirely of fine sandstone in the form of planar high-angle crossbeds as well as some festoons (B beds). The absence of channel-fill sandstones (F) suggests that, unlike similar deposits at Monteagle, these strata were not formed directly in the tidal-pass area of the tidal delta but more probably in the flared edge farther back in the lagoon. Sandy crossbedded units in the upper part of the formation grade into laminated and rippled sandstones, which are in turn overlain by interlaminated sandstones, shales (flaser), rooted siltstones, and coal. These deposits probably reflect abandonment of the tidal delta as an area of active current activity and its gradual fill and replacement by marshes.

The Whitwell Formation (fig. 17b), composed mostly of siltstone, four coal seams, and a few feet of shale, is interpreted as barrier-back lagoonal and marsh deposits.

1.1	118.4	Board buses at the base of the Whitwell Formation.
3.7	122.1	Junction, U.S. 127 and Tenn. Highway 8. Stop, turn right (south) onto U.S. 127.
0.6	122.7	Dunlap city limit. Proceed on U.S. 127 through Dunlap to Chattanooga.
2.4	125.1	Highway climbs ridge of residual Knox chert; the ridge divides Sequatchie Valley into east and west strike valleys.
1.9	127.0	Sequatchie River.
0.4	127.4	East Valley, underlain by formations of the Stones River and Nashville

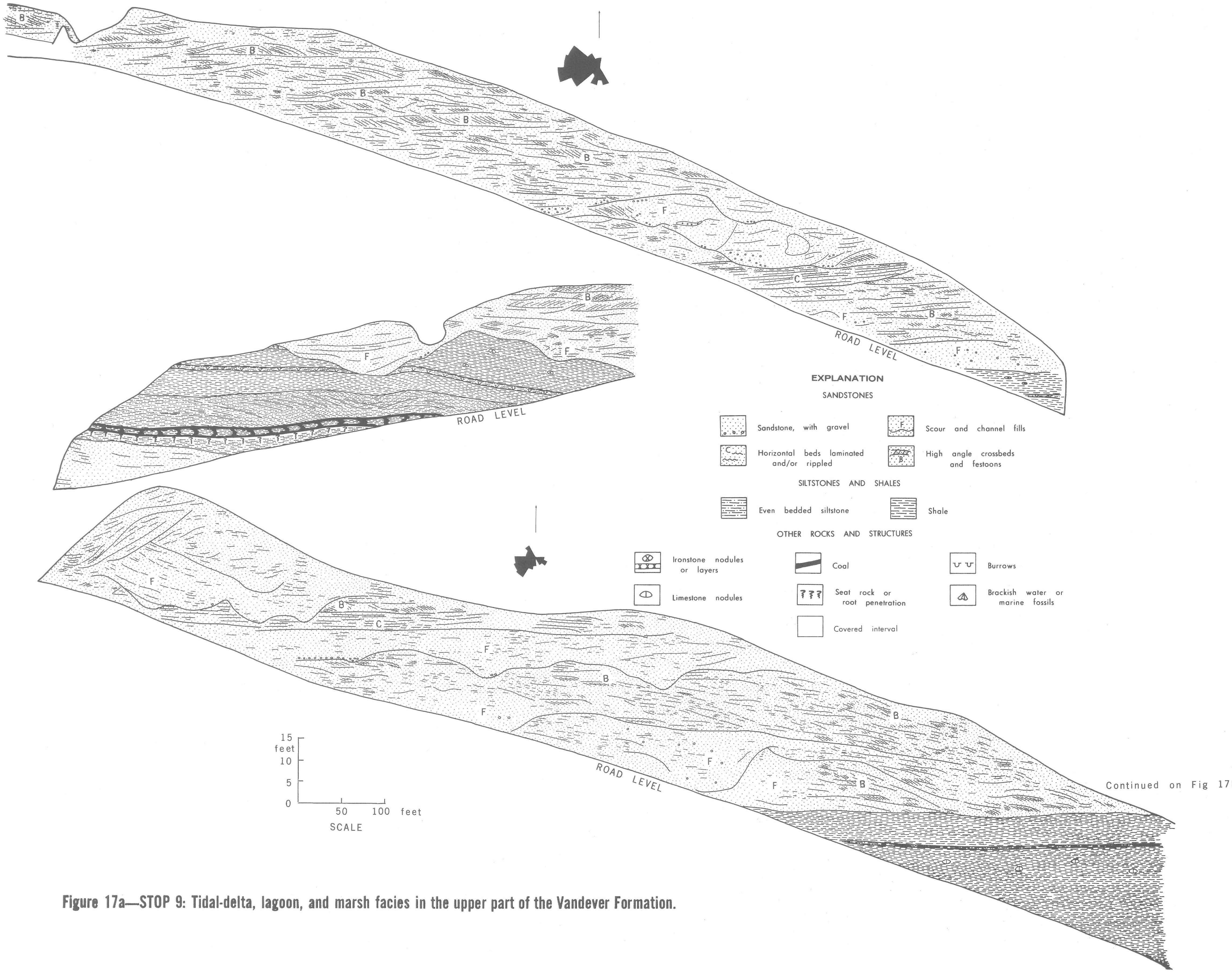


Figure 17a—STOP 9: Tidal-delta, lagoon, and marsh facies in the upper part of the Vandever Formation.

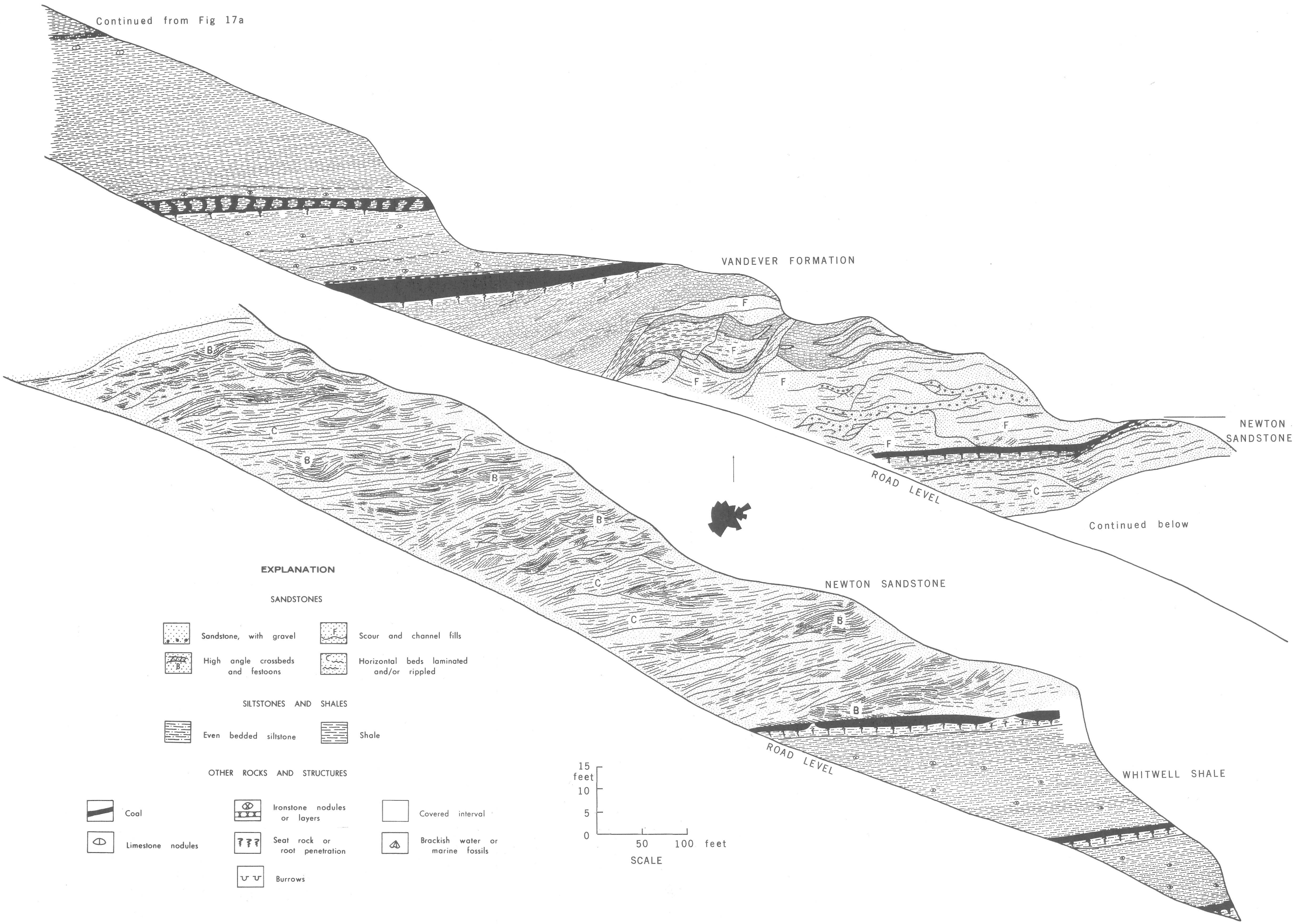


Figure 17b—STOP 9: Tidal-delta, lagoon, marsh, tidal-channel, and upper tidal-flat facies in the lower part of the Vandever Formation, the Newton Sandstone, and the upper part of the Whitwell Shale.

		Groups (Middle Ordovician), extends throughout the length of Sequatchie Valley. Beds dip east at 20°-35°; the dip flattens eastward across the valley to about 10° at the base of the mountain.
0.7	128.1	Junction, U.S. 127 and Tenn. 28. Continue on U.S. 127. Carters Limestone, with bentonites T-3 and T-4, is exposed along left (east) side of highway.
0.9	129.0	Shellmound Formation (Upper Ordovician), exposed on left (east) side of road.
0.1	129.1	Rockwood Formation (Silurian), exposed on left (east) side of road.
0.1	129.2	Chattanooga, Maury, and Fort Payne Formations exposed on left (east) side of road.
0.3	129.5	Warsaw Formation (Mississippian) exposed on left (east) side of road.
0.1	129.6	St. Louis Limestone in quarry on left (east) side of road.
0.2	129.8	Monteagle Limestone exposed on left (east) side of road.
0.3	130.1	Mississippian Limestone, probably Bangor, exposed on left (east) side of road. The quadrangle has not been mapped, and the position of the Hartselle has not been determined.
1.9	132.0	Pennington-Gizzard boundary. Gizzard is back-barrier marsh, tidal-flat, storm-delta and lagoon deposits. The Warren Point Sandstone is poorly defined in this section and probably is not a mappable unit in this area.
0.4	132.4	Storm delta.
0.1	132.5	Signal Point Shale; interpreted environments are lagoon and tidal flat.
0.5	133.0	Base of Sewanee Conglomerate.
0.9	133.9	Whitwell Shale, Sewanee seam.
0.1	134.0	Newton Sandstone. Exposures between here and Signal Mountain are in formations of the Crab Orchard Mountains Group.
2.6	136.6	Vandever Formation.
1.0	137.6	Needleseye Member of Vandever Formation.
1.1	138.7	Lone Oak School on left (east) side of road.
6.2	144.9	Signal Mountain. Proceed through town on U.S. 127 South.
1.5	146.4	Sewanee Conglomerate.
0.1	146.5	Signal Point Shale.
0.1	146.6	Warren Point Sandstone; the great thickness is interpreted to represent a large barrier sandstone.
2.8	149.4	Junction, U.S. 127 (south) and Tenn. 27. Continue on U.S. 127.
0.1	149.5	Enter Lookout Valley. West limb of Lookout Valley anticline. Fort Payne, Chattanooga, and Rockwood Formations are exposed along road and railroad cut to right (west) of road.
0.1	149.6	Chattanooga City Limits.
0.2	149.8	Approximate axis of Lookout Valley anticline. Ridge to east is underlain by Fort Payne cherts and is the east limb of the Lookout Valley anticline.
1.0	150.8	Red Bank City Limits. Rockwood, Chattanooga and Fort Payne Formations exposed in cuts on left.
0.2	151.0	Bear right.
0.1	151.1	Enter ramp to Interstate 124; Chattanooga City Limits.
0.3	151.4	Chattanooga Shale and Fort Payne Formation at top of ramp.
0.7	152.1	Rockwood Formation exposed on hillsides along Interstate.
0.9	153.0	Tennessee River.
0.3	153.3	Cameron Hill. Fort Payne, Chattanooga, Rockwood, and Shellmound Formations exposed on hill to right (west).
0.4	153.7	Right lane; exit 9th Street East, downtown. Turn right on West 9th Street and proceed to Read House.
0.6	154.3	Read House.

LITTORAL PALEOCURRENTS IN GIZZARD AND CRAB ORCHARD MOUNTAINS GROUPS, SOUTHERN CUMBERLAND PLATEAU AND WALDEN RIDGE, TENNESSEE

Michael L. Jones

Introduction

The purpose of this study is to present an analysis of paleocurrents of Pottsville sandstones in the southern Cumberland Plateau of Tennessee.

Several crossbed studies have been made of the Pottsville in the southern Appalachians. Each study showed that the vast majority of crossbeds dip into the southwest hemicircle. Schlee (1963) measured 1222 crossbed dip directions in Tennessee, Alabama, and Georgia and postulated a generally arcuate pattern of sediment transport ranging from southerly and southwesterly in Tennessee and Georgia to more westerly in Alabama. A study in northern Alabama by Metzger (1965) is in general agreement with Schlee's arcuate pattern. Mitchum (1954) studied 1000 crossbeds in Tennessee, eastern Kentucky, and southwest Virginia, and using an iso-azimuth map, he noted local areas of divergent current direction. Chen and Goodell (1964) related crossbed directions within their Sewanee Sandstone (probably a Gizzard sandstone) to sand-grain orientations in the Lookout Mountain area, Alabama and Georgia. The results of their study indicate southerly-moving paleocurrents in this area.

The area of this study includes thirty-five 7½-minute quadrangles in the southern Cumberland Plateau and Walden Ridge in Tennessee, and data are from outcrops in the Gizzard and Crab Orchard Mountains Groups.

Within the study area dip directions (azimuth) and amounts of dip of 1054 cross-stratified cosets were measured for the Gizzard Group, Sewanee Conglomerate, Newton Sandstone, Vandever Formation, and Rockcastle Conglomerate. Directional data were summarized on a formational basis by using equiareal circular histograms with 20° classes (fig. 18).

Analysis of Data

Gizzard, Sewanee, Newton, and Vandever sandstones exhibit vector means (Curray, 1956) with mutually overlapping confidence limits (Potter and Pettijohn, 1963; Dennison, 1962), as shown in table 2. Rockcastle crossbeds alone have a vector mean that is significantly different from the means of the other formations (S. 43° W. ± 9°, as opposed to S. 72° W. to S. 80° W.). The grand sample histogram indicates a generally normal distribution with a large standard deviation (fig. 19). Polymodal distributions are evident in the Gizzard, Newton, and Rockcastle histograms (fig. 18). Sewanee and Vandever crossbed azimuths have apparently normal distributions.

The amount of dip of crossbeds was measured to determine relationships between dip angle and

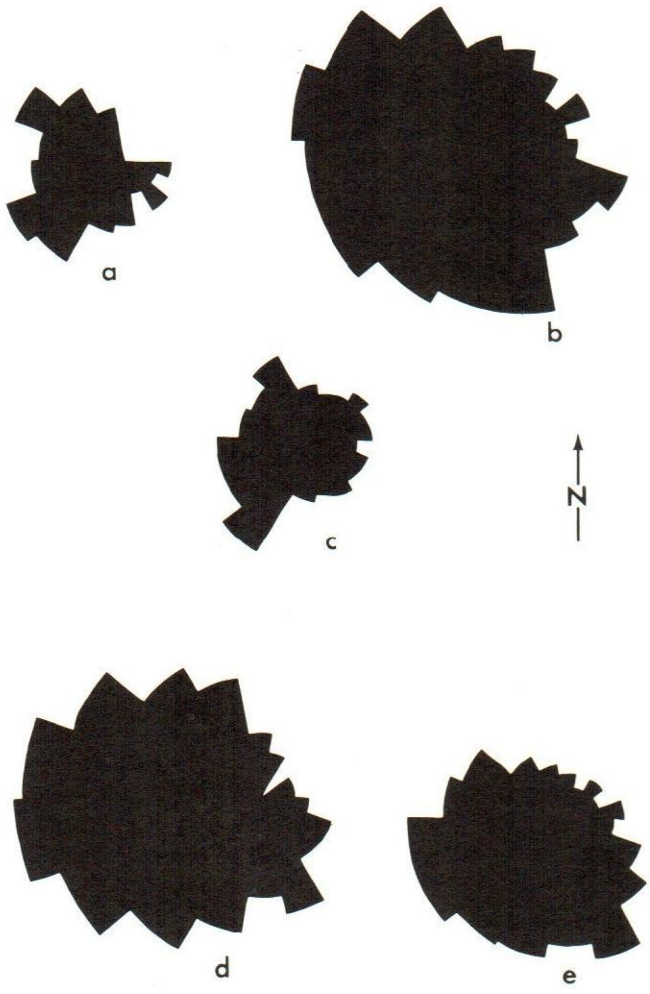


Figure 18—Equiareal circular histograms of crossbeds in southern Tennessee—(a) Gizzard, (b) Sewanee, (c) Newton, (d) Vandever, (e) Rockcastle.

Table 2—*Statistical results of crossbed measurements*

Unit	Observations	Vector mean	95% Conf. on mean	Probability of uniformity (Rayleigh test)
Gizzard	82	S. 72° W.	±13°	$< 10^{-15}$
Sewanee	366	S. 72° W.	± 7°	$< 10^{-20}$
Newton	90	S. 74° W.	±14°	$< 10^{-5}$
Vandever	326	S. 80° W.	± 7°	$< 10^{-20}$
Rockcastle	190	S. 43° W.	± 9°	$< 10^{-20}$
Grand sample	1054	S. 70° W.	± 4°	$< 10^{-20}$

azimuth. For the grand sample 401 western sector (classes N. 60° W., N. 80° W., S. 80° W.) cross-strata average 20° dip, as compared to a 17° average dip for the 162 southern sector cross-strata (classes S. 20° E., S., S. 20° W.). The distribution of dips in the southern sector is significantly different (>99 percent confidence) from those of the western sector (Kolmogorov-Smirnov statistic, Miller and Kahn, 1962). Furthermore, the average southern sector dip for each formation is 3°-5° less than their respective western sector dip averages.

The grand sample of 1054 readings was subsampled on the basis of dip angle (fig. 20). High-angle cross-strata tend to dip predominantly westward (fig. 20). However, low-angle beds tend to dip in a southerly direction.

The average dip of crossbeds within each formation is 19°-20°, except for the Newton which has an average dip of 16°. The dip frequency distribution of the Newton, however, is significantly different (>95 percent confidence) from the dip frequency distribution of other formations (Kolmogorov-Smirnov statistic).

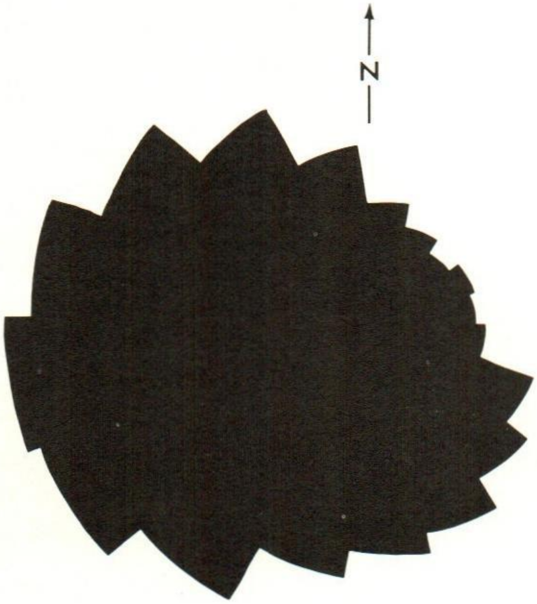


Figure 19—Grand histogram, representing 1054 measurements.

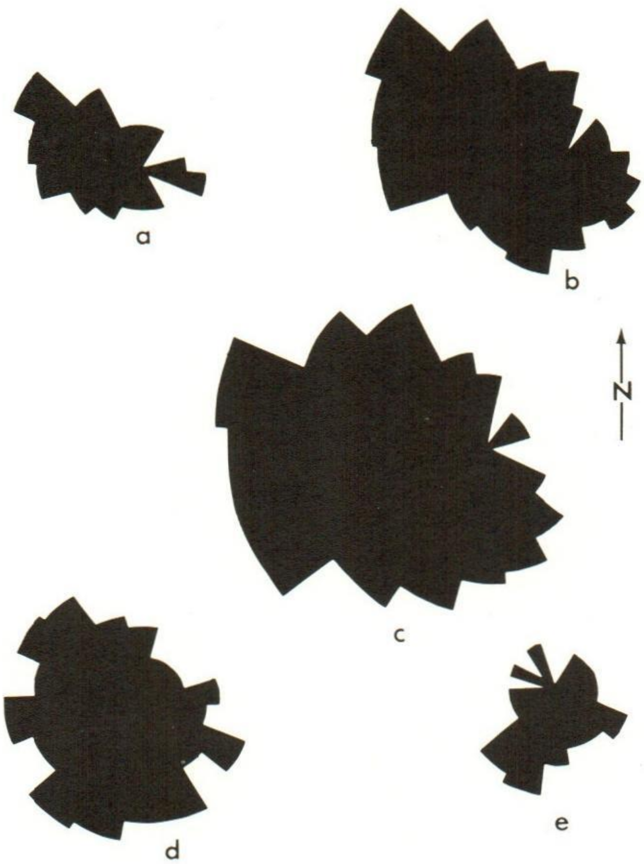


Figure 20—Equiareal circular histograms of (a) very high dips (≥ 28°), representing 41 measurements; (b) high dips (≥ 22°), representing 121 measurements; (c) mid-dips (17°-21°), representing 213 measurements; (d) low dips (≤ 10°), representing 102 measurements; and (e) very low dips (≤ 7°), representing 24 measurements.

Conclusions and Interpretations

Five characteristics of Pottsville crossbeds seem significant from a paleoenvironmental and paleogeographic viewpoint. (1) Vector means are consistent from one formation to another. (2) Crossbed azimuths alone cannot reliably be used to differentiate between formations. (3) The distribution of azimuths is commonly polymodal. (4) Dip angles are related to modal directions and vector means. (5) A systematic relationship exists between dip azimuth and average dip angle within each unit studied.

The consistency of vector means for different crossbedded sandstones is compatible with a fluvial origin. However, in contrast with unimodal distributions of fluvial crossbed azimuths (Allen, 1965), most crossbed patterns in the southern Plateau of Tennessee are polymodal. Crossbed patterns in southern Tennessee are analogous to polymodal distributions in shallow-marine coarse clastic rocks (Shelley, 1967; Tanner, 1955, 1963), in Mississippian carbonates (Adams, 1970; Schlee, 1963), and in recent marine sediments (Boothroyd, 1969; Hoyt, 1967; Land, 1964).

The crossbed data support an hypothesized coastal-marine environment of deposition for the Gizzard and Crab Orchard Mountains Groups, and general stratigraphic evidence indicates that Pottsville littoral strata prograded south and southwest into Tennessee from eastern Kentucky, (Ferm, Milici and Eason, this volume).

Azimuth and dip angle data can be interpreted in the context of the littoral model (fig. 20). The bimodal distribution of high dips (fig. 20 a, b) records the "fossilization" of bedforms oriented approximately parallel and perpendicular to the inferred shoreline that are interpreted to have formed in tidal channels and tidal deltas. The mid-dip histogram (fig. 20c) indicates the averaging of crossbed components of inferred tidal and longshore origin. The result is a "normalized" histogram much like a grand sample histogram of all observations. Most low-angle beds are probably fossilized beach foreshores (Hobday, 1969) and exhibit a pronounced S 20° W. dip direction mode with secondary east-west modes (fig. 20d). The extremely low angle crossbed histogram (fig. 20e) illustrates probable beach foreshore beds dipping dominantly S. 20° W., with an E.S.E. mode which perhaps reflects foreshores of recurved spits. The southwesterly-directed vector means (table 2) may reflect the combined effects of tidal currents and littoral drift.

Thus the data not only yield information on the directions of sediment transport but also can be interpreted in the context of littoral depositional environments for Pottsville strata in southern Tennessee.

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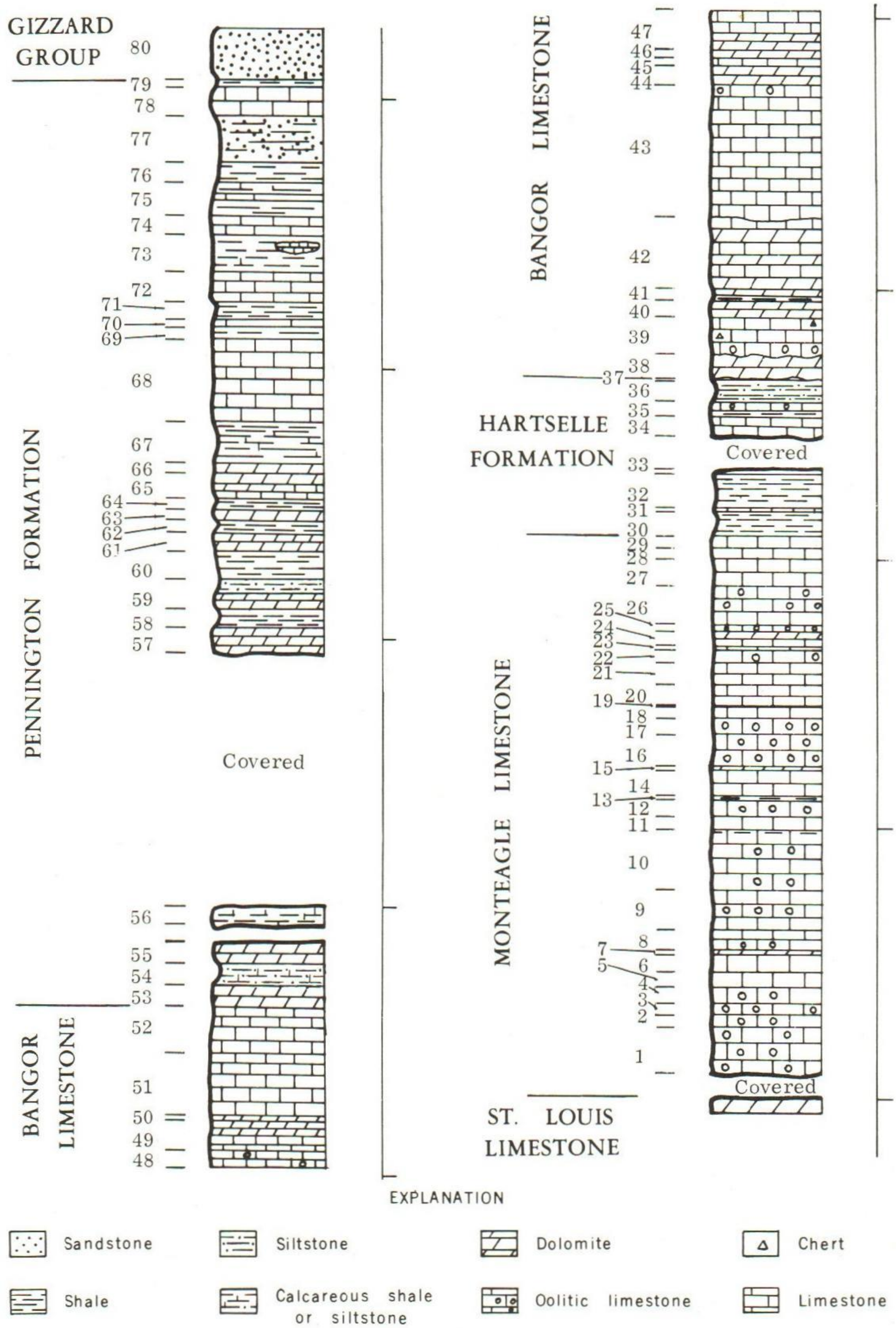

Section along Interstate 24 near Monteagle, Tennessee. Modified from figure 34 in Alabama Geological Society Guidebook, Fifth Annual Field Trip, 1967.

APPENDIX

Reference section of Upper Mississippian Formations in Southern Tennessee, located along Interstate Highway 24, just west of Monteagle, Grundy County. Tennessee Coordinates 321,300N., 2,032,500E. to 307,800N., 2,040,100E.).[1] Section measured by Carl C. Ferguson and Richard G. Stearns (in *Ala. Geol. Soc. Guidebook, Fifth Ann. Field Trip, 1967*)

Unit No.	Thick-ness	Interval	DESCRIPTION
			PENNSYLVANIAN SYSTEM
			Gizzard Group
80	...	...	Sandstone, light brownish-gray, with some limonite staining, very fine-grained, thin- to medium-bedded, few siderite spheroids.
			MISSISSIPPIAN SYSTEM
			Pennington Formation
79	2.0	804.1-806.1	Shale, variegated, grayish-yellow, greenish-gray, and olive-gray, laminated.
78	10.4	793.7-804.1	Limestone, pale yellowish-brown and olive-gray with traces of grayish-green and grayish-orange, medium- to very coarse-grained, thin- to medium-bedded, abundant fossil fragments (crinoids, bryozoa, brachiopods); shale zone at top with lenses of limestone.
77	17.0	776.7-793.7	Claystone, sandy, grayish-red, with grayish-orange, fine-grained sand, soft; grades into limestone down the cut.
76	7.5	769.2-776.7	Shale, very calcareous, light olive-gray, abundant fossil fragments; pinches out down the cut.
75	12.0	757.2-769.2	Claystone, grayish-red with some grayish-yellow, soft, contains thin beds of limestone; entire unit pinches out down the cut.
74	6.7	750.5-757.2	Limestone (sandy at top); upper part is moderate yellowish-brown, very fine-grained, and sandy; lower part is light olive-gray, medium- to very coarse-grained dolomitic limestone with abundant crinoid and brachiopod fragments, and some oolites; entire unit is medium-bedded. Unit thickens down the cut.
73	13.8	736.7-750.5	Claystone, dark greenish-gray and olive-gray to yellowish-brown, soft, contains stringers and nodules of limestone.
72	11.0	725.7-736.7	Limestone, olive-gray, very fine-grained, argillaceous, silty, medium-bedded, fossiliferous.
71	6.5	719.2-725.7	Shale, medium-gray, with thin dark yellowish-brown dolomite blebs (concretions).
70	3.1	716.1-719.2	Limestone, dark yellowish-brown, fine- to medium-grained, thin-bedded, contains scattered pyrite and chalcopyrite (?), abundant fossil fragments (bryozoa and foraminifers?).
69	4.0	712.1-716.1	Claystone, olive-gray, slightly calcareous; contains a thin bed of limestone in upper part, abundant fossil fragments (**Fenestella, Archimedes,** corals, brachiopods, crinoids, and gastropods).
68	31.3	680.8-712.1	Limestone, dark yellowish-brown to moderate yellowish-orange and olive-gray, fine- to very coarse-grained, medium- to very thick-bedded; grades from a fossil-fragmental limestone at top to an oolitic limestone at base; upper beds contain traces of pyrite and glauconite; fragments of brachiopods, crinoids, gastropods, foraminifers (?) and corals. A thrust fault with approximately 4-5 feet of throw can be seen in this unit.
67	15.1	665.7-680.8	Claystone, pale green and greenish-gray, slightly calcareous, soft; contains finely disseminated pyrite.
66	4.0	661.7-665.7	Dolomite, pale green to light olive-gray, microcrystalline, irregular nodular dolomite becoming thin-bedded at base, interbedded with shale; contains relic fossils, oolites, secondary calcite, and pyrite.
65	9.5	652.2-661.7	Dolomite (at top), dull yellowish-brown, microcrystalline; dolomitic limestone (at base), pale yellowish-brown, very fine-grained, some oolites; entire unit is thin- to thick-bedded and contains shale partings.
64	4.1	648.1-652.2	Shale, grayish-green, soft, contains a thin (1") bed of limestone near the top.
63	3.7	644.4-648.1	Dolomite, mottled grayish-red and grayish-pink, microcrystalline, thin- to medium-bedded, with shale partings.
62	4.6	639.8-644.4	Shale, pale reddish-brown and medium-gray, mottled; contains thin beds of dolomite, pale yellowish-brown, microcrystalline.
61	7.5	632.3-639.8	Dolomite, dull yellowish-brown and very pale orange, microcrystalline to very finely crystalline, medium-bedded.
60	10.5	621.8-632.3	Shale, olive-gray and grayish-orange, soft; and dolomite, olive-gray and moderate yellowish-brown, mottled, very finely crystalline.
59	11.1	610.7-621.8	Upper unit is siltstone (dolomitic), grayish-orange, few fossil fragments; middle unit is claystone, light olive-gray, soft,

[1]The base point for the Tennessee Coordinate System, near Scottsboro, Alabama, is assigned the values 2,000,000 feet east and 100,000 feet north. Reference ticks at 10,000-foot intervals are printed along the margins of topographic quadrangle maps.

			pinches out up the cut; lower unit is dolomite, light olive-gray, very finely crystalline, contains black chert, thickens up the cut. All units contain geodes of pink calcite.
58	6.5	604.2-610.7	Shale, light olive-gray; upper part contains siliceous and calcareous nodules; lower part has thin lenses of silty dolomite.
57	9.5	594.7-604.2	Dolomite, pale yellowish-orange to light olive-gray and grayish-orange, microcrystalline to very fine-crystalline, medium-bedded, interbedded with shale; lower part contains a few relic oolites; upper part contains geodes filled with calcite and lined with siliceous material (chalcedony?).
	95.0	499.7-594.7	Covered, slumped red and greenish shale and Pennsylvanian sandstone boulders.
56	5.0	494.7-499.7	Claystone, yellowish-gray, calcareous, argillaceous; alternating with dolomite, olive-gray, very finely crystalline, thin- to medium-bedded; contains trace of finely disseminated pyrite.
	6.0	488.7-494.7	Covered.
55	7.5	481.2-488.7	Dolomite, olive-gray, argillaceous, very finely crystalline, thin- to medium-bedded, trace of finely disseminated pyrite; and claystone, grayish-yellow, slightly calcareous.
54	8.5	472.7-481.2	Siltstone, olive-gray, argillaceous, thick-bedded, finely disseminated mica; shale, yellowish-gray, calcareous, some limonite staining, zone 8"-10" thick; dolomite, olive-gray, argillaceous, very finely crystalline, thick-bedded.
53	8.1	464.6-472.7	Dolomite, olive-gray and pale yellowish-brown, argillaceous, microcrystalline to very finely crystalline, very thin- to medium-bedded, trace of limonite.
			Bangor Limestone
52	18.0	446.6-464.6	Limestone, slightly dolomitic, light olive-gray and pale yellowish-brown to yellowish-gray, micrograined to very fine-grained, medium- to very thick-bedded, some relic structures (fossil?); upper 4 feet covered.
51	23.3	423.3-446.6	Limestone, yellowish-gray and pale yellowish-brown, fine- to medium-grained, medium- to very thick-bedded, upper part very oolitic; some fossil fragments (brachiopods, crinoids), scattered gypsum geodes. At base is dolomite, dark yellowish-brown, very finely sucrose, stylolitic.
50	2.5	420.8-423.3	Dolomite, dark yellowish-brown, very finely sucrose, thin-bedded, stylolitic.
49	10.8	410.0-420.8	Upper part is dolomite, dark yellowish-brown, carbonaceous, very finely sucrose, thin- to medium-bedded. Lower part is limestone, very dolomitic, dark yellowish-brown, very fine-grained, thin- to medium-bedded, some fossil fragments (crinoids, brachiopods). Entire unit contains scattered gypsum geodes as much as 5 inches in diameter.
48	6.5	403.5-410.0	Limestone, dark yellowish-brown with dark yellowish-orange specks, dolomitic, fine- to coarse-grained, medium- to thick-bedded with some shale partings, oolitic, fossil-fragmental (crinoids, brachiopods), trace of limonite staining.
47	14.8	388.7-403.5	Upper part is limestone, yellowish-gray and pale yellowish-brown, very fine- to coarse-grained, thin- to medium-bedded with shale partings and shale zone at top that pinches out, very oolitic, trace of fossil fragments, trace of limonite. Lower part is dolomite, dark yellowish-brown, calcareous, slightly argillaceous, very finely sucrose to microcrystalline, thin- to medium-bedded, slightly fractured (with secondary calcite), abundant limonite staining.
46	3.1	385.6-388.7	Dolomite, pale yellowish-brown, very finely crystalline, medium-bedded with irregular lower surface, some limonite staining.
45	2.7	382.9-385.6	Limestone, pale yellowish-brown with some grayish-red mottling, lithographic, thin-bedded with irregular upper surface (vugs of secondary calcite and relic fossil fragments).
44	6.3	376.6-382.9	Dolomite, dark yellowish-brown, very calcareous, very finely crystalline, thin- to medium-bedded, with subconchoidal fracture, finely disseminated pyrite.
43	48.3	328.3-376.6	Limestone, pale to dark yellowish-brown and light olive-gray to olive-gray, fine- to very coarse-grained, medium- to massive-bedded, jointing prominent, grades from very oolitic at top to fossil-fragmental at base. Some beds in lower half are dolomitic; stylolites present; fossil fragments include brachiopods, crinoids, bryozoa, corals, ostracod (?), blastoid (?).
42	25.5	302.8-328.3	Alternating limestone and dolomite. Limestone, slightly dolomitic, pale yellowish-brown and grayish-orange with medium-red and pale yellowish-orange specks (limonite), very fine- to coarse-grained; lower limestone very oolitic, with some fossil fragments. Dolomite, pale yellowish-brown to grayish-orange with some moderate reddish-brown specks, calcareous, argillaceous, stylolitic, some fossil fragments (crinoids, brachiopods). Bedding is thin to medium with a massive lenticular bed at top separated from Unit 43 by thin shale. Lower part extremely vuggy.
41	4.8	298.0-302.8	Upper part is dolomite, light olive-gray to olive-gray, very finely crystalline, medium-bedded, separated from Unit 42 by 4'-6' shale zone. Lower part is shale, pale olive, silty, some limonite staining, slightly bentonitic.
40	6.0	292.0-298.0	Dolomite, yellowish-gray, calcareous, argillaceous, massive-bedded, soft, mineralization (calcite) along vertical fractures, exfoliated weathering.
39	14.6	277.4-292.0	Limestone, pale to dark yellowish-brown, medium- to coarse-grained, thin- to very thick-bedded with a few thin

			shale zones, lower surface irregular; upper part is fossil-fragmental, scattered black chert blebs, conglomeratic, slightly pyritic, grades into color-laminated zone which contains traces of dolomite; lower part is very oolitic, limonite staining.
38	8.7	268.7-277.4	Dolomite (upper part argillaceous), pale grayish-yellow and light olive-gray, very finely crystalline, medium- to thin-bedded with shaly appearance, irregular upper and lower surfaces.
37	1.0	267.7-268.7	Limestone, olive-gray, medium-yellow and pale yellowish-orange (mottled), argillaceous, very coarse-grained, medium-bedded with scalloped upper surface, abundant fossil fragments (crinoids, bryozoa), some fossil fragments replaced with moderate yellow calcareous silt.

Hartselle Formation

36	7.3	260.4-267.7	Siltstone, grayish-orange, calcareous, argillaceous, thin- to massive-bedded with crossbedding; upper part contains traces of glauconite; lower part has brachiopods.
35	5.6	254.8-260.4	Upper part is limestone, light olive-gray, medium- to very coarse-grained, thick-bedded, oolitic and fossil-fragmental, some limonite staining. Lower part is claystone, light olive-gray, calcareous, sandy, bentonitic, slightly fossiliferous; base covered.
34	7.4	247.4-254.8	Limestone, light grayish-orange and pale yellowish-brown with moderate reddish-orange specks in upper part, fine- to coarse-grained, medium- to thick-bedded with some shale in upper part; upper part is very oolitic; lower part is dolomitic and very fossil-fragmental (crinoids, brachiopods, spines).
	14.0	233.4-247.4	Covered.
33	1.6	231.8-233.4	Limestone, pale yellowish-brown, medium- to very coarse-grained, medium-bedded, very oolitic, with some fossil fragments (crioids, brachiopods, bryozoans).
32	12.5	219.3-231.8	Shale, light olive-gray and pale yellowish-orange, bentonitic, soft; with a few thin zones of limestone, pale yellowish-brown, cryptocrystalline to micrograined, pelletal.
31	1.2	218.1-219.3	Limestone, light olive-gray, fine- to coarse-grained, small fossil fragments (crinoids, brachiopods).
30	9.3	208.8-218.1	Shale, calcareous, light olive-gray, fissile; with thin (as much as 1") beds of limestone, light olive-gray, silty, very fine-grained, abundant pellets in upper beds.

Monteagle Limestone

29	4.5	204.3-208.8	Limestone, pale yellowish-brown and light olive-gray, very fine-grained, thin- to medium-bedded, pelletal, trace of fossil fragments.
28	4.1	200.2-204.3	Limestone, light olive-gray with black specks, medium- to very coarse-grained, thin- to medium-bedded, abundant fossil fragments (brachiopods, crinoids, bryozoa?).
27	10.3	189.9-200.2	Limestone, pale yellowish-brown with some pale yellowish-green, argillaceous, silty in upper part, fine- to coarse-grained, thin- to medium-bedded, fossil fragments (crinoids, brachiopods), some oolites, some pellets (flowstone on surface).
26	14.2	175.7-189.9	Limestone, pale yellowish-brown and yellowish-gray, medium- to coarse-grained, thick- to very thick-bedded, very oolitic; with a zone of dolomite, yellowish-gray, very finely crystalline, with vugs of drusy calcite in the middle; contains shale zone as much as 4 inches thick.
25	2.3	173.4-175.7	Limestone, pale yellowish-brown, medium- to coarse-grained, medium-bedded, very oolitic, some fossil fragments (crinoids, brachiopods), some pellets, zone of reworked calcareous material (bits of this material scattered throughout unit) 7" above base.
24	5.3	168.1-173.4	Upper part is dolomite, greenish-gray, argillaceous, microcrystalline. Lower part is limestone, olive-gray, argillaceous, silty, fine- to medium-grained, thin- to medium-bedded, some fossil fragments (brachiopods, ostracods?).
23	1.4	166.7-168.1	Limestone, pale yellowish-brown, coarse- to very coarse-grained, medium-bedded, very oolitic, some fossil fragments (brachiopods, crinoids).
22	5.7	161.0-166.7	Limestone, pale yellowish-brown and light olive-gray, fine- to coarse-grained, medium- to thick-bedded, oolitic, some fossil fragments (brachiopods, crinoids); upper part slightly fractured, with vein calcite.
21	8.1	152.9-161.0	Limestone, yellowish-gray and light olive-gray, fine- to coarse-grained, medium- to thick-bedded, abundant fossil fragments (crinoids, brachiopods), some pellets, trace of secondary calcite.
20	7.5	145.4-152.9	Limestone, light olive-gray and pale yellowish-brown, medium- to very coarse-grained, massive-bedded, very oolitic, some fossil fragments (crinoids, brachiopods).
19	0.6	144.8-145.4	Shale, calcareous, pale olive and yellowish-gray, soft, fossiliferous (crinoids, etc.); interbedded with thin stringers of limestone, dark yellowish-brown, argillaceous, coarse-grained, abundant fossil fragments (crinoids).
18	4.5	140.3-144.8	Limestone, pale yellowish-brown, fine- to very coarse-grained, thin- to medium-bedded, shale partings toward top, pelletal, slightly oolitic, fossil fragments (crinoids, brachiopods, bryozoa?).
17	5.5	134.8-140.3	Limestone, pale yellowish-brown, medium- to coarse-grained, thick-bedded, very oolitic.

16	12.1	122.7-134.8	Limestone, dark yellowish-brown, medium- to coarse-grained, medium- to massive-bedded, very oolitic, some fossil fragments (crinoids, brachiopods), trace of dolomite.
15	1.4	121.3-122.7	Dolomite, pale yellowish-brown, microcrystalline, medium-bedded, lower surface irregular and shaly, relic oolites and fossil fragments.
14	9.5	111.8-121.3	Limestone, pale to dark yellowish-brown, fine- to very coarse-grained, medium- to thick-bedded, some oolites, fossil fragments (crinoids, coral, brachiopods), some pellets. Upper part has bands of dolomite, yellowish-gray, very finely crystalline, slightly oolitic and pelletal, fossil fragments.
13	1.5	110.3-111.8	Shale, pale olive-gray; with limestone stringers, pale olive, micrograined, argillaceous, nodular; irregular upper surface.
12	6.1	104.2-110.3	Limestone, pale yellowish-brown, medium- to coarse-grained, very thick-bedded, very oolitic.
11	5.0	99.2-104.2	Limestone, pale olive and greenish-gray, argillaceous and silty, very fine- to fine-grained, nodular, few fossil fragments and pellets, disseminated fine pyrite in lower part.
10	21.5	77.7- 99.2	Limestone, pale yellowish-brown and yellowish-gray to light olive-gray, very fine- to very coarse-grained, thick- to massive-bedded, with 10-inch shale zone; thin limestone beds at top, oolites, fossil fragments (brachiopods, crinoids, bryozoans), some pellets.
9	14.7	63.0- 77.7	Limestone, light olive-gray and yellowish-gray, medium- to coarse-grained, thick- to massive-bedded, some cross-bedding, oolitic, fossil fragments (crinoids, brachiopods, bryozoans), some pellets.
8	8.0	55.0- 63.0	Limestone, light olive-gray and yellowish-gray, medium- to coarse-grained, thick-bedded, fossil fragments, lower part oolitic.
7	1.5	53.5- 55.0	Dolomite, yellowish-gray, very finely sucrose, medium-bedded.
6	6.1	47.4- 53.5	Limestone, yellowish-gray, medium- to coarse-grained, thick-bedded, lenticular, very oolitic, trace of fossil fragments.
5	6.0	41.4- 47.4	Limestone, pale yellowish-brown, very fine-grained, thick-bedded, a few fossil fragments, pellets (?).
4	6.0	35.4- 41.4	Limestone, yellowish-gray, coarse-grained, very thick-bedded, very oolitic.
3	4.1	31.3- 35.4	Limestone, slightly dolomitic, pale yellowish-brown and light olive-gray, very fine- to medium-grained, thick-bedded, a few fossil fragments (bryozoans, crinoids, brachiopods, spicules), pellets (?). This is the horizon that weathers to Lost River Chert, which outcrops around the hill from the roadcut.
2	5.0	26.3- 31.3	Limestone, pale yellowish-brown, medium- to coarse-grained, medium- to thick-bedded, oolitic, fossil fragments (crinoids, brachiopods), trace of limonite staining in lower part.
1	17.3	9.0- 26.3	Limestone, yellowish-gray, very fine- to coarse-grained, medium- to thick-bedded, oolitic, fossil fragments (bryozoa, crinoids), pellets (?), trace of secondary calcite.
	9.0	0- 9.0	Covered.

St. Louis Limestone

Across I-24—dolomite, dull yellowish-brown, very finely sucrose, medium-bedded.

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