Figure 15. Lake City dip section. Vertical lines represent subsurface data; jagged lines represent topography; datum is sea level.

LAKE CITY DIP SECTION

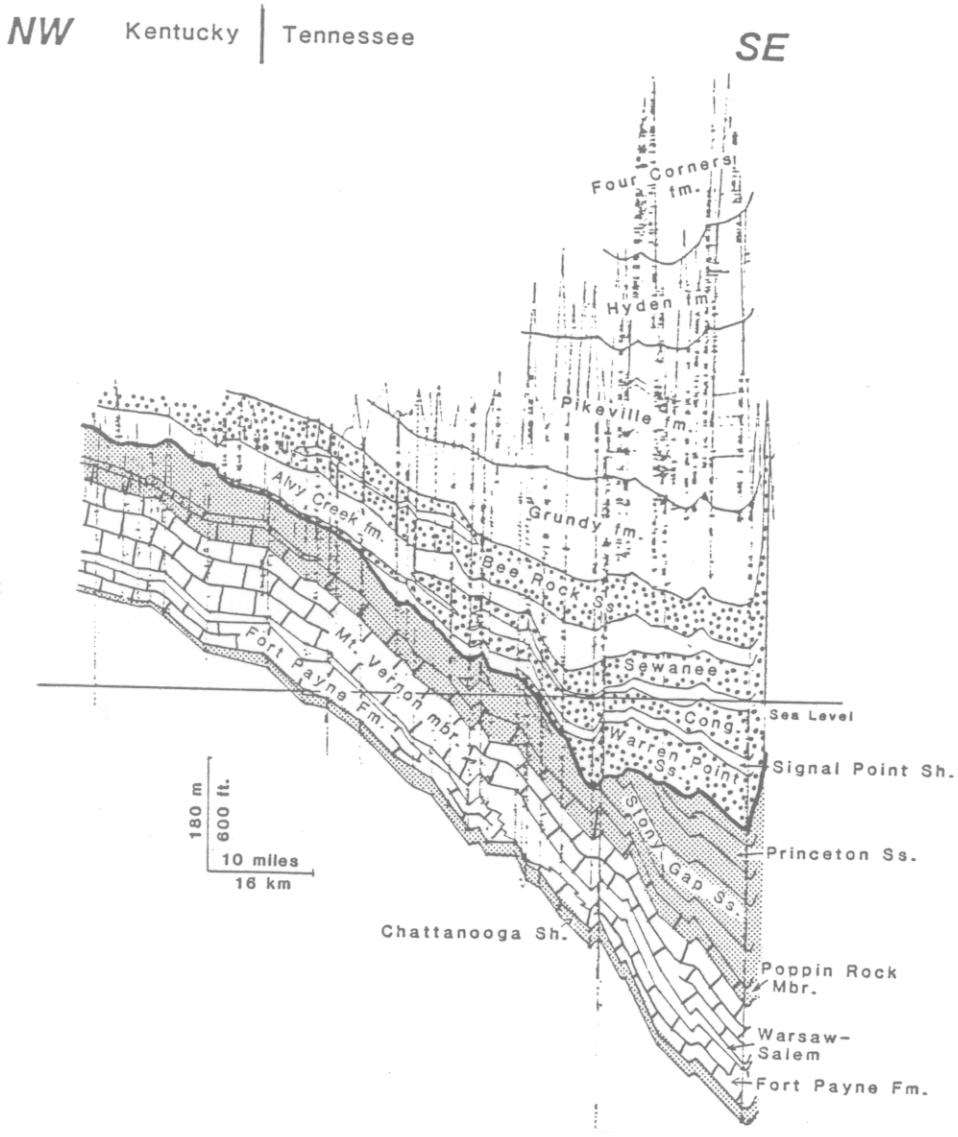

Figure 16. Hazard strike section. Vertical lines represent subsurface data: jagged lines represent topography; datum is sea level.

See dissertoversize325.pdf

Figure 17. Pineville strike section. Vertical lines represent subsurface data; jagged lines represent topography; datum is sea level.

See dissertoversize326.pdf

Figure 18. Harlan strike section. Vertical lines represent subsurface data; jagged lines represent topography: datum is sea level.

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DESCRIPTIONS OF CROSS SECTIONS

Seven cross sections were constructed to determine the stratigraphic (Fig. 11) and structural framework of part of the Central Appalachian Basin. Only lithostratigraphic correlations are shown in these sections. Figure 7 shows the locations of cross sections (Figs. 12-18), which are named for towns through which they run.

Stratigraphic Framework

Construction of the cross sections was undertaken to develop a framework into which the various lithologic units could be placed. Much of the lithologic nomenclature used herein was developed during the course of the study based on subsurface information, such as drillers and geophysical logs, and is used informally. Hence, nomenclature in this study may not include all formally designated units recognized on the surface, and some units do not necessarily bear any relationship to mapped units at the surface (see Table 1).

Only the dominant lithologies in each unit are described in the sections below. Features observed in outcrops which are important for environmental interpretations are included in a later section.

Chattanooga Shale

Throughout most of the region, the dominant lithology in the Chattanooga Shale is black, organic-rich shale (e.g., Rhinestreet, Ohio, and Sunbury Shale members). Black-shale members, however, are separated by gray shales such as the upper Olentangy and Bedford Shale members, and sandstones like the Berea Sandstone Member. Other lithologies are present in all the units, but are minor components. In eastern parts of the study area, the black shale gives way progressively to abundant interbedded black and gray shales, and eventually to gray shales. The Chattanooga Shale is easily recognized in drillers' logs by its color (black, dark brown, "coffee") and in gamma-ray logs by its high radioactivity.

In this study, the Chattanooga Shale (Fig. 11) is divided into six members, which, in ascending order, are the Rhinestreet Shale, the upper Olentangy Shale, the Ohio Shale, the Bedford Shale, the Berea Sandstone, and the Sunbury Shale. Where the units are too thin to differentiate, the Chattanooga Shale is shown as undifferentiated.

The Rhinestreet, upper Olentangy, and Ohio Shale members are traditionally placed in the Upper Devonian (Shaver, 1984). The Bedford Shale, Berea Sandstone, and Sunbury Shale members are considered to be Lower Mississippian

(Kinderhookian) (Patchen and others, 1984). The base of the Berea-Bedford interval is assumed to be the base of the Carboniferous.

The Rhinestreet is observed only in the eastern half of the Hazard strike section (Fig. 16), but probably occurs in the eastern quarter of the Pineville strike section (Fig. 17) and the southeastern half of the Grundy (Fig. 13) and Catlettsburg (Fig. 12) dip sections where the deeper strata are not recorded on the sections. The Rhinestreet apparently thickens to the east.

The upper Olentangy occurs in the eastern halves of the Hazard and Pineville strike sections and throughout the Grundy and Catlettsburg dip sections. The upper Olentangy also thickens to the east.

The Ohio Shale is dominantly a black shale in the western part of the study area. However, in the eastern thirds of the Hazard and Pineville strike sections and the southeastern two-thirds of the Grundy and Catlettsburg dip sections the Ohio is interbedded with gray shales and in the extreme eastern part of the study area, the stratigraphic level of the Ohio is dominated by gray shales.

The Berea-Bedford interval can be recognized in the eastern halves of the Pineville and Harlan (Fig. 18) and the central part of the Hazard strike sections as well as the Grundy and northwestern part of the Catlettsburg section.

In the extreme eastern part of the study area where the level of Ohio Shale is dominated by gray shale, the Berea-Bedford interval is not recognized due to similarity of lithology. The Berea-Bedford interval thickens to the east, except for the extreme eastern part of the Pineville strike section, where, after thickening to the east, it starts to thin.

The Sunbury Shale occurs throughout the study area, but in the extreme western part of the study area, it can only be recognized by its high radioactivity gamma ray signature in geophysical logs. The Sunbury thickens toward the east except for the eastern third of the Hazard strike section where the Sunbury begins to thin toward the east near the Kentucky-West Virginia border.

The cross sections indicate that the Chattanooga is very thin in the extreme western part of the study area, but thickens to the east. In the eastern part of the study area, the members are easily recognized. In the western part, the members are not illustrated because they are too thin, or the driller's logs did not differentiate the members. However, geophysical logs indicate that in the western area, the Chattanooga can be divided into the Sunbury, Berea-Bedford, and the Ohio.

Borden Formation

The Borden Formation (Fig. 11) is composed of gray, interbedded shales, siltstones, some sandstones, and a few limestones. Some beds near the top of this interval may contain red and green shale, siltstones, and carbonates.

The Borden Formation is absent in the Lake City dip section (Fig. 15) and in the extreme western parts of all the strike sections (Figs. 16-18), where it is replaced by the Fort Payne and Warsaw-Salem formations. Elsewhere, the Borden gradually thickens to the east. Locally the Borden appears to thin in the vicinity of the Warfield .anticline in the Catlettsburg section (Fig. 12), and the Paint Creek uplift in the Grundy section (Fig. **13),** and to thicken north of the Rockcastle uplift.

Fort Payne Formation

The Fort Payne Formation (Fig. 11) occurs above the Chattanooga Shale and below the Warsaw-Salem formations in the southwestern part of the study area. It consists of limestones which are commonly cherty, biostromal, crinoidal, or siliceous, and also contains cherty dolostones, and calcareous, cherty siltstones. The Fort Payne pinches out to the north and east, and is replaced laterally by the Borden Formation.

The Fort Payne Formation is recognized throughout the Lake City section (Fig. 15), except for a small area about 25 mi (40 km) from the southeastern end, where it thins and vanishes. It is replaced by a thick shaley unit recognized here as the Warsaw-Salem Formation. The Fort Payne occurs only in the southwestern quarters of all the strike sections (Figs. 16-18); elsewhere, it is absent.

Warsaw-Salem Formations

The Warsaw-Salem formations (Fig. 11) are recognized as one unit composed of gray shales and fossiliferous, locally dolomitic, limestones occurring between the Fort Payne Formation and the massive limestones of the Mount Vernon member of the Slade Formation (described below). Where the Fort Payne is absent, the shales of the Warsaw-Salem become indistinguishable from the shales of the Borden Formation in subsurface logs. Along the western belt of outcrop, limestones of this interval are equivalent to the basal dolomitic unit in the Mount Vernon member. The Warsaw-Salem formations are recognized only in the southwestern part of the study area.

The Warsaw-Salem formations in the Lake City section (Fig. 15) are present throughout the section. The unit is fairly thin everywhere (generally about 50 ft or 16 meters),

except for one area about 25 mi (40 km) from the southeastern end of the section, where the Fort Payne disappears and the Warsaw-Salem(?) is as thick as 270 ft (84 m).

The Warsaw-Salem is present only at the southwestern ends of the Hazard, Pineville, and Harlan strike sections (Figs. 16-18). Data are insufficient to trace its northeasternmost contact with the Borden Formation.

Slade Formation

The Slade Formation (Fig. 11) is a massive limestone sequence composed of two subunits, which are, in ascending order, the informally designated Mount Vernon member and the formally designated Poppin Rock Member. The Slade was previously mapped as the Newman Limestone (Ettensohn and others, 1984).

MOUNT VERNON MEMBER

The Mount Vernon member is composed of dominantly gray limestone with minor thin shale beds. This member is named for outcrops near Mt. Vernon, Kentucky, exposed as roadcuts along Interstate Highway 75 (Dever and others, 1979). The Mount Vernon member is generally easily recognized in drillers' logs as the Big Lime or as the thick limestone

sequence above the Chattanooga Shale and Borden Formation. The informally designated Mount Vernon member includes up to 8 formally designated members in the western belt of outcrop in east-central and northeastern Kentucky (Ettensohn and others, 1984).

The Mount Vernon member in the Catlettsburg (Fig. 12). Grundy (Fig. 13), and Booneville (Fig. 14) dip sections thins progressively to the northwest. In the extreme northwestern part of the Catlettsburg and Grundy sections, the Slade is locally absent, and isolated occurrences of Slade are present between lense-shaped bodies of Lee sandstone. The upper part of the Mount Vernon is absent in the northwestern part of the Booneville dip section. The Poppin Rock is undifferentiated from the Mount Vernon member in the northwestern quarters of the Catlettsburg and Grundy sections, perhaps because drillers omitted thin units on their logs. The Mount Vernon member is thicker in the northwestern part of the Lake City dip section (Fig. 15), a trend opposite that found in the other dip sections, which show this member thickening to the southeast. The Mount Vernon is thinner in the central parts of the Hazard, Pineville, and Harlan strike sections (Figs. 16-18) compared to the northeastern and southwestern parts.

POPPIN ROCK MEMBER

The Poppin Rock Member, a dark-gray, fossiliferous limestone, is the uppermost member of the Slade Formation. The Poppin Rock in Kentucky is generally distinguishable in outcrop by its darker color compared to the Mount Vernon member. It is commonly separated from the Mount Vernon member by sandstones and shales of the Hartselle Sandstone in Tennessee and south-central Kentucky, and by shales of the Maddox Branch Member (Hardinsburg Sh.) in northeastern and east-central Kentucky (Ettensohn and others, 1984). Locally, these shales may have red and green coloration (Ettensohn, 1975, 1981). The Maddox Branch-Hartselle shales of Kentucky are known as the Pencil Cave in drillers' terms. Neither the Hartselle Sandstone nor the Maddox Branch Member are thick enough to indicate on the reduced sections. Several shale beds may occur in the upper part of the Mount Vernon member, which can be mistaken for the Maddox Branch and, therefore, mistakingly used to separate the Poppin Rock from the Mount Vernon members. Drillers refer to the Poppin Rock as the Little Lime.

The Poppin Rock Member thickens to the south in Tennessee and to the southeast in Virginia and West Virginia. Some of this thickening is due to the inclusion in the Poppin Rock (Bangor Limestone in Tennessee) of limestone beds that interfinger with and laterally replace

part of the overlying Pennington Group, especially to the south in Tennessee. Thickening may also occur to the south in Tennessee and Alabama, because the Hartselle Sandstone in these areas may not be the same unit as described to the north and may in actuality include beds much lower in the section.

The Poppin Rock is undifferentiated from the Mount Vernon member in the northwestern quarters of the Catlettsburg (Fig. 12) and Grundy (Fig. 13) dip sections and the central part of the Harlan strike section (Fig. 18) due to the quality of the data. Elsewhere, the Poppin Rock is generally easily recognized. The Hartselle Sandstone Member occurs below the Poppin Rock in the western part of the Hazard (Fig. 16) and Pineville (Fig. 17) strike sections. The Poppin Rock is locally absent in the northwestern parts of the Catlettsburg, and Grundy sections where the entire Slade Formation is absent, and in the extreme northwestern part of the Booneville dip section (Fig. 14).

The Poppin Rock Member shows the same thickness trends as the Mount Vernon member: it is thinner in the central parts of the strike sections, thickens toward the southeast in the Catlettsburg, Grundy, and Booneville dip sections, and thickens toward the northwest in the Lake City dip section (Fig. 15). Local limestone bodies in the overlying Pennington Group in the southwestern parts of the Pineville

and Harlan (Fig. 18) strike sections, and in the southeastern part of the Grundy dip section appear to be associated with the Poppin Rock and are included as bodies of the Poppin Rock in this study.

Pennington Group

The Pennington Group (Fig. 11) is a heterogeneous unit characterized by red and green shales, gray shales, sandstone, limestone, and dolostone. Rarely, thin coals occur in all the formations of this group (Wilpolt and Marden, 1959). The presence of red and green shales commonly distinguishes the Pennington from overlying clastic units and from the massive limestones of the Slade Formation below. The Pennington Group in ascending order includes: the Bluefield Formation, the Hinton Formation, the Princeton Sandstone, and the Bluestone Formation.

BLUEFIELD FORMATION

This unit (Fig. 11) consists of calcareous shales interbedded with limestones, sandstones, dolostones, and some red and green shales. It overlies the Poppin Rock Member of the Slade Formation, and may be partially equivalent to parts of it.

HINTON FORMATION

Red and green shales interbedded with limestones and sandstones constitute most of this unit (Fig. 11). Where sandstones of the Hinton Formation are quartz-rich, gamma-ray signatures may be similar to those of sandstones from the Lee Formation. The Hinton is separated from the underlying Bluefield by its basal member, the Stony Gap Sandstone Member, which is a sandstone that varies from silicious to calcareous, and in places is interbedded with shales. It is commonly called the Maxon or Maxton Sand by drillers, although other sandstone units in the Pennington and Hinton Formation may be similarly designated by drillers. The Little Stone Gap Member (Avis Limestone), an argillaceous limestone or calcareous shale, occurs near the top of the Hinton Formation. This limestone has been used as a stratigraphic marker by Wilpolt and Marden (1959) and by Miller (1974). Some drillers in West Virginia have mistakenly called the Little Stone Gap Member the "Little Lime" even though the "true" Little Lime (the Poppin Rock) is much lower in the section. Red shales and siltstones in the Hinton Formation are commonly called Red Rock by drillers.

PRINCETON SANDSTONE

The Princeton Sandstone (Fig. 11) varies from silicious to calcareous, and in places is interbedded with shale. Where quartz-rich, it commonly has a gamma-ray signature similar to sandstones in the Lee Formation. This sandstone has been used as a stratigraphic marker by Wilpolt and Marden (1959) and Miller (1974). It is similar to the Stony Gap Sandstone Member of the Hinton Formation, but separates the underlying Hinton Formation from the Bluestone Formation above. The Princeton is commonly called the Ravencliff, Maxon, or Maxton Sand by drillers.

BLUESTONE FORMATION

Red and green shales, gray and dark gray shales, siltstones, sandstones, minor calcareous beds, and thin coals compose this unit (Fig. 11). The Pride Shale Member, at the base of the Bluestone Formation, is a distinctive unit of dark-gray shale and siltstone. The gamma-ray signature for the Pride Shale has proven useful for correlation in Letcher and Pike counties in Kentucky and in adjacent areas of Virginia. The gamma-ray signature is unique in that the unit is a sequence of moderately radioactive shales that lacks the variability found in other units. The rest of the Bluestone is similar to the Hinton Formation in lithology and lithologic variability. Red

shales and siltstones in the Bluestone Formation also are referred to as Red Rock by drillers. The Bluestone is reported to be gradational with the overlying Pocahontas Formation in southwestern Virginia and southern West Virginia (Englund and others, 1979).

CROSS SECTIONS

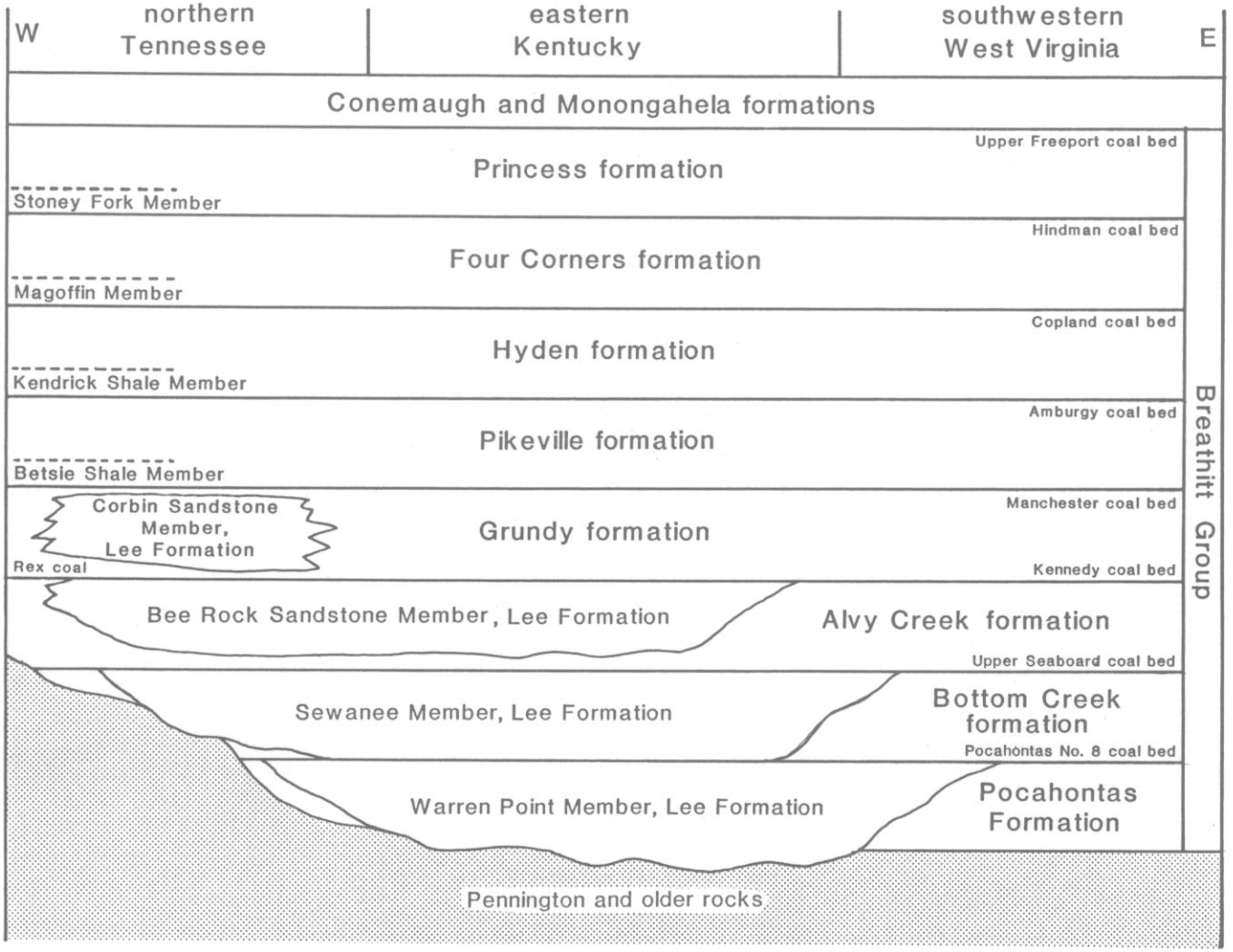
The Pennington Group is thickest in the southeastern part of the study area where it is as much as 2,500 feet (762 meters) thick at the southeastern end of the Catlettsburg dip section (Fig. 12), but thins to the northwest where it is completely missing at the nortwestern parts of the Catlettsburg, Grundy (Fig. 13), and Booneville (Fig. 14) dip sections. The Hazard (Fig. 16) and Pineville (Fig. 17) strike sections indicate a gradual thickening of the Pennington toward the northeast in these sections. The Harlan strike section (Fig. 18), however, shows a more accelerated thickening in this direction. Useful stratigraphic markers in the southeastern part of the study area include the Stony Gap Sandstone, the Little Stone Gap Member, the Princeton Sandstone, and the Pride Shale Member. These units are more difficult to recognize elsewhere in the study area, but the Stony Gap Sandstone can be recognized in all the sections. However, in the northern and western

parts of the study area, the Stony Gap is less continuous, and occurs as isolated lenses. The Pennington Group may be conformable with the overlying Pocahontas Formation (described below) in the southeastern ends of the Catlettsburg and Grundy dip sections, and in the northeastern end of the Harlan strike section: however, these marker units are progressively absent down-section to the northwest in all the dip sections and, to a lesser extent, to the southwest in the strike sections. The Bluestone Formation above the Pride Shale Member is absent in the Booneville and Lake City (Fig. 15) dip sections, and in the Pineville strike section. Both the Princeton Sandstone and the Bluestone Formation appear to be entirely absent from the Hazard strike section. Where marker beds become progressively absent down-section, the Pennington is overlain by the Lee Formation. The Stony Gap Sandstone may occur as separate lenses to the north.

The Lee Formation

The Lee Formation (Fig. 19) consists of several thick sandstone members separated by shales, coals, and sandstones of the interfingering Breathitt Group. The Lee Formation is composed dominantly of thick beds of quartzose sandstone and quartz-pebble conglomerate. Most sandstones of the Lee

Figure 19. Stratigraphic framework of the Pennsylvanian-age rocks of the Central Appalachian basin.


W
northern Tennessee
eastern Kentucky
southwestern West Virginia
E
Conemaugh and Monongahela formations
Upper Freeport coal bed
Princess formation
Stoney Fork Member
Hindman coal bed
Four Corners formation
Magoffin Member
Copland coal bed
Hyden formation
Kendrick Shale Member
Amburgy coal bed
Pikeville formation
Betsie Shale Member
Corbin Sandstone Member, Lee Formation
Manchester coal bed
Grundy formation
Rex coal
Kennedy coal bed
Bee Rock Sandstone Member, Lee Formation
Alvy Creek formation
Upper Seaboard coal bed
Sewanee Member, Lee Formation
Bottom Creek formation
Pocahontas No. 8 coal bed
Warren Point Member, Lee Formation
Pocahontas Formation
Pennington and older rocks
Breathitt Group

Formation are distinct from those that characterize the Breathitt Group in that the Lee sandstones are generally quartz-rich, may contain quartz pebbles, and are light in color. These sandstones, compared to those of the Breathitt Group are generally thicker, more massive, and many have a blocky, very low-radioactivity gamma-ray signature. These massive sandstone beds have scoured bases and may contain large-scale crossbeds. These Lee sandstones are commonly called the Salt, or White-Hard Sands by drillers. Other drillers' terms are less commonly used (~~see~~ McFarlan, 1943, p. 297).

The sandstones of the Lee Formation are interbedded with shale, coal, seat rock, siltstone, and sandstone. The various members of the Lee Formation occur as lenses within the Breathitt Group and are separated from each other by shale, sandstone, and coal units (described below) of the Breathitt Group: but otherwise the members of the Lee generally cannot be lithologically distinguished from each other. Some of the members interfinger with the Breathitt Group to the northwest and to the southeast. Several members recognized in this study include in ascending order: the Warren Point, the Sewanee, the Bee Rock and the Corbin members. The members are described in the following sections. In some places the Lee Formation could not be divided into members.

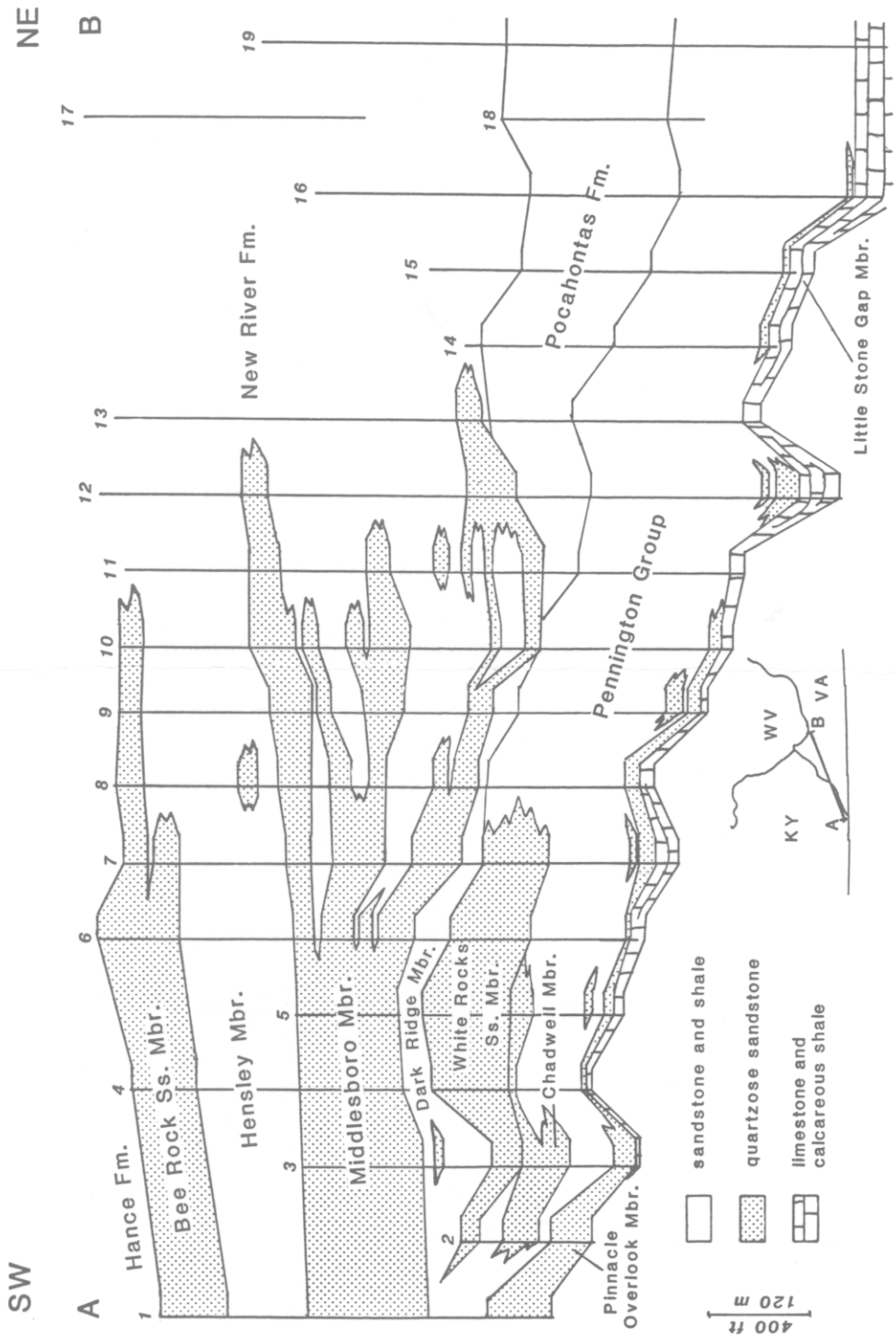
WARREN POINT MEMBER

The Warren Point Member (Fig. 19), the stratigraphically lowest member of the Lee Formation, is a sandstone member recognized in the southwestern part (in Tennessee) and in the eastern part (in West Virginia and Virginia) of the study area. This sandstone is overlain by Breathitt lithologies including shale, sandstone, and coal of the Bottom Creek formation (described below) in these areas. Elsewhere, the Bottom Creek becomes thin or absent, and the Warren Point is overlain by similar sandstones of the Sewanee Member of the Lee Formation. Where the Bottom Creek is absent, both sandstone members are combined as the Warren Point-Sewanee member. Strike sections in this study show that the Warren Point-Sewanee member is equivalent to the Middlesboro Member as mapped on the Pine Mountain thrust sheet. The strike sections also indicate that the Warren Point-Sewanee member and the overlying Bee Rock member and laterally equivalent units are mapped as the New River Formation in Virginia and West Virginia. The Warren Point was previously recognized only in Tennessee. The possibility exists that several different sandstone units in Tennessee have been locally correlated in the past with the Warren Point Sandstone, therefore, further stratigraphic studies between the study area and the rest of the coal-bearing rocks of Tennessee are warranted in the future.

The White Rocks Sandstone and Chadwell members of the Lee Formation were thought by Englund and DeLaney (1966) to occur below the Middlesboro Member (Fig. 20). However, reinterpretation of their sections (Fig. 21) indicates that the White Rocks and the Chadwell are equivalent to the Warren Point.

The Warren Point Sandstone occurs in all the cross sections except the Hazard strike section; however, an isolated lense of quartzose sandstone outside the study area in the northeastern quarter of this section (Fig. 16) may be either the Warren Point, or a sandstone in the Pennington Group. The Warren Point is largely restricted to a downthrown block of the newly recognized Dorton-Hellier subsurface fault, described elsewhere, in the northeastern part of the Pineville strike section (Fig. 17). The Warren Point is recognized in the southern parts of all the dip sections. In the Catlettsburg (Fig. 12), Grundy (Fig. 13), and Booneville (Fig. 14) dip sections, the northwestern extent of the Warren Point is difficult to discern because the intervening shale of the Bottom Creek formation become thin or absent and the overlying Sewanee Member is in direct contact with the Warren Point. Where this occurs, the contact is estimated by following isolated shale breaks and by extrapolating the northwestward thinning trend of the Warren Point. The intervening shale unit is present

Figure 20. Cross section of mid-Carboniferous units along Cumberland Mountain redrawn from Englund and (1966).


SW
NE
A
B
Hance Fm.
Bee Rock Ss. Mbr.
Hensley Mbr.
Middlesboro Mbr.
Dark Ridge Mbr.
White Rocks Ss. Mbr.
Chadwell Mbr.
Pinnacle Overlook Mbr.
New River Fm.
Pocahontas Fm.
Pennington Group
Little Stone Gap Mbr.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
KY
WV
VA
A
B
sandstone and shale
quartzose sandstone
limestone and calcareous shale
400 ft
120 m