scale as broadly time-equivalent. They also suggested that all adjacent lithologies within this group represent separate facies in one large environmental continuum, with the Borden Formation and Slade Formation, traditionally included in the Mississippian, representing marine units at one end of the Borden-Conemaugh continuum, and the uppermost Breathitt Formation (Fig. 2), traditionally Middle Pennsylvanian, representing alluvial-plain deposits at the other end. This view was based on field mapping, which suggested that the Pennington Group, Late Mississippian, and the Lee Formation, attributed to the Early Pennsylvanian age, had an intertonguing relationship, which is preserved in some areas (Englund and DeLaney, 1966; Ferm and others, 1971). Horne and others (1979, p. 390, fig. 2) also proposed interfingering relationship between the Borden Formation and the Pennington Group.

The Ferm and Cavaroc (1969) depositional model for the Carboniferous rocks of the Central Appalachian basin included strata deposited in open-marine at one extreme, and terrestrial at the other. Transitions between open-marine and terrestrial environments were interpreted to include barrier-bar, lagoonal, and lower delta-plain environments. The model attempted to explain the heterogeneous Carboniferous units of the Central Appalachian basin. Similar models previously had been developed by Ferm and others (1967) for the Southern Appalachian basin (cf. Wanless, 1969, fig. 2). These models, because they were based on actualistic comparisons of the various components, generated enthusiastic studies of Carboniferous rocks in the Appalachian Basin (Ferm and others, 1972; Horne and others, 1976; Horne and Levy, 1979, p. 671; Milici, 1979; Weisenfluh, 1979), and were developed to explain nearly all of the Carboniferous strata of the Appalachian Basin (e.g. Ferm and Weisenfluh, 1979, p. 517).

The terms "Mississippian" and "Pennsylvanian," are used by the proponents of the interpretation of Ferm and Cavaraoc (1969) as lithostratigraphic units only; that is, the term Mississippian represents the predominantly marine rocks, whereas the term Pennsylvanian represents the predominantly terrestrial rocks which may be partly or completely contemporaneous. Thus, in this interpretation, the terms Mississippian and Pennsylvanian become useless as chronostratigraphic units, because the rock facies represented by them are intergradational with each other and completely or partly time-transgressive. The interpretation of Ferm and Cavaroc (1969) is not the only available explanation for the Carboniferous succession and its lateral variability.

In contrast to the model of Ferm and Cavaroc (1969) which indicates a conformable contact between the rocks referred to as Mississippian and Pennsylvanian, there are two interpretations involving an unconformity between these rocks. One interpretation (Haney, 1979) suggests a local unconformity in structurally positive areas, whereas the other suggests that a regional unconformity exists.

Haney (1979) inferred an unconformable relationship based on the presence of paleochannels, paleokarst, and features representing subaerial weathering, in local, structurally positive areas in northeastern Kentucky (e.g. Woodward-Kentucky River fault zone). Elsewhere in eastern Kentucky, he noted that shallow-water shales of the Pennington Group commonly appear to be conformably overlain by the coal-bearing shales of the Breathitt Formation. Haney suggested that a conformable and gradational relationship between these rocks exists away from structurally positive areas.

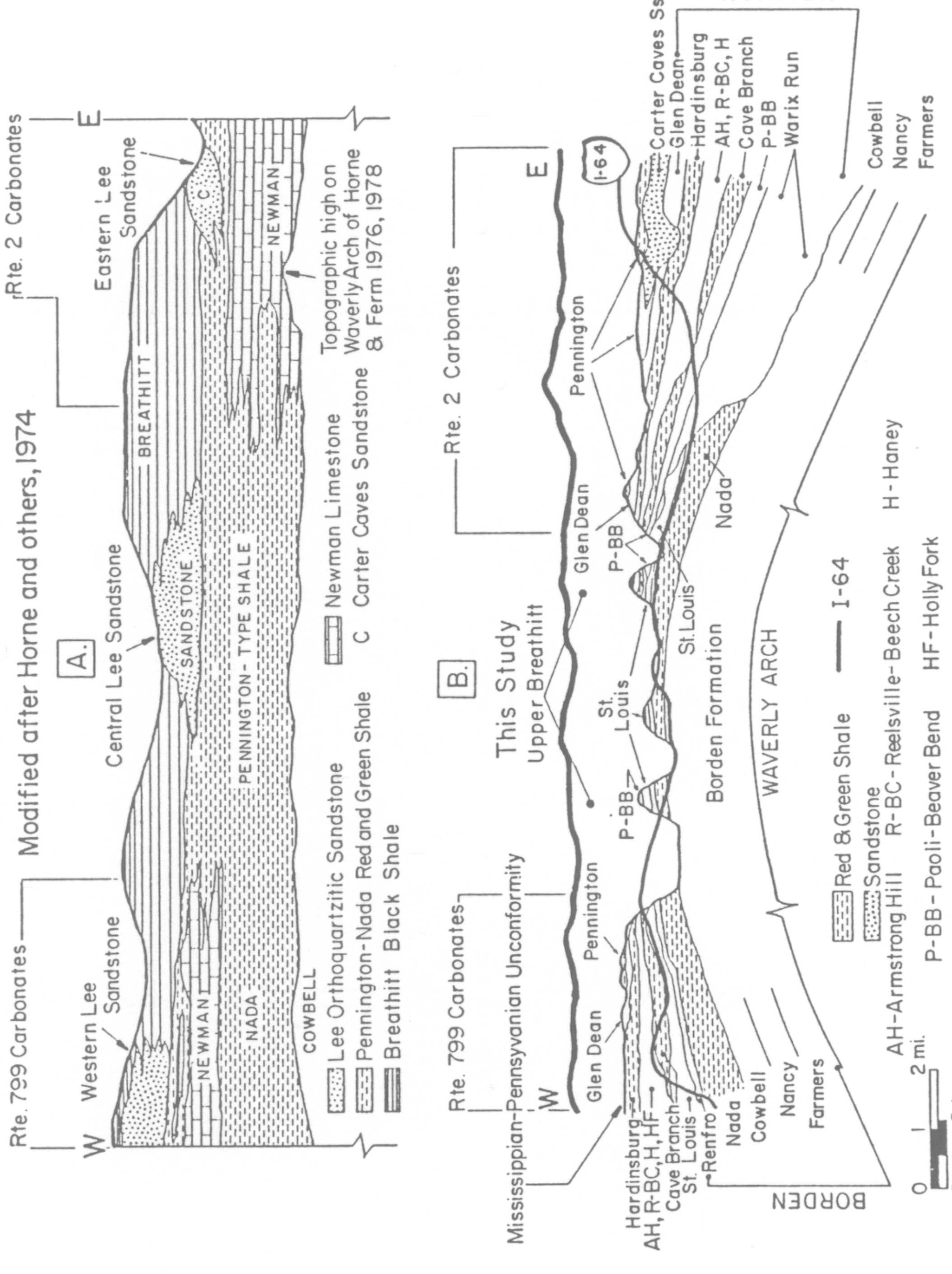
Many have long claimed that a regional unconformity separates Mississippian and Pennsylvanian strata in the central Appalachians and other regions (Miller, 1919; McFarlan, 1943; Wanless, 1946; Branson, 1962; Stearns and Mitchum, 1962; Wanless, 1962; Ettensohn, 1977; Rice and others, 1979)). A significant regional unconformity would necessarily interupt any of the suggested large-scale facies relationships between adjacent units on either side of it and would negate the wholesale application of Ferm and

Cavaroc's model. Features such as sequential regional overstep of part of the stratigraphic section, missing section, and erosional features such as scours, paleochannels, subaerial weathering, and paleokarst, were noted by Miller (1974). Donaldson and Shumaker (1979, p. 24-26), Chesnut (1983), Ettensohn and Chesnut (1985), and Englund and others (1985). They inferred an unconformable relationship between the Lee-Breathitt-New River formations and underlying units everywhere in the Central Appalachian basin except at the southeastern edge of the basin in Virginia and West Virginia, where they appear to be conformable.

Features previously interpreted to represent the interfingering of Mississippian and Pennsylvanian rocks were reinvestigated. In northeastern Kentucky, Ettensohn and Dever (1975), Ettensohn (1977, 1979, 1980, 1981), Ettensohn and Peppers (1979) provided evidence indicating that the suggested intertonguing relationship between these units could be reinterpreted in terms of a widespread unconformity. Figure 6 compares the interpretation of Ettensohn (1980) with that of Horne and others (1974).

Englund and DeLaney (1966) had originally proposed an intertonguing relationship between the Lee and the underlying Pennington Group in southwestern Virginia. However, Englund and Thomas (1985) recently revised their

Figure 6. Comparison between the (A.) Lee-Newman Barrier-Shoreline model interpretation (Horne and others, 1974) and (B.) the Tabular-Erosion model interpretation of outcrops along Interstate-64 in northeastern Kentucky (from Ettensohn, 1980).


Modified after Horne and others, 1974
A.
Rte. 799 Carbonates
Rte. 2 Carbonates
W
E
Western Lee Sandstone
Central Lee Sandstone
Eastern Lee Sandstone
BREATHITT
SANDSTONE
PENNINGTON - TYPE SHALE
NEWMAN
NADA
COWBELL
C
Topographic high on Waverly Arch of Horne & Ferm 1976, 1978
Lee Orthoquartzitic Sandstone
Pennington-Nada Red and Green Shale
Breathitt Black Shale
Newman Limestone
C Carter Caves Sandstone
B.
This Study
Mississippian-Pennsylvanian Unconformity
Upper Breathitt
Glen Dean
Pennington
P-BB
St. Louis
Borden Formation
WAVERLY ARCH
Nada
I-64
Carter Caves Ss.
Hardinsburg
AH, R-BC, H
Cave Branch
Warix Run
AH, R-BC, H, HF
Renfro
Cowbell
Nancy
Farmers
BORDEN
NEWMAN
Red & Green Shale
Sandstone
AH-Armstrong Hill
R-BC-Reelsville-Beech Creek
H-Haney
P-BB-Paoli-Beaver Bend
HF-Holly Fork
2 mi.
2 km.

correlations of measured sections and now suggest an unconformable contact between the two units. The revised correlation indicates that one of the sandstones interpreted to be the Lee Formation by Englund and DeLaney (1966) is actually the Pinnacle (Princeton) Sandstone and the dark shales above this sandstone, but below the true Lee Fm. are actually the Pride Shale Member of the Pennington Group and not a part of the Lee or Breathitt formations. Englund and Thomas (1985) suggested that an unconformity exists here since the Lee Fm. has an erosional base and the Bluestone and Pocahontas formations are absent. Conclusions similar to those of Englund and Thomas (1985), but derived independently, were suggested by Chesnut (1983).

Purpose

The purpose of this study is to provide a detailed lithostratigraphic and structural framework of the Carboniferous strata of the Central Appalachian Basin and to determine how it constrains the existing interpretations of depositional environments of the Carboniferous rocks and the development of the basin.

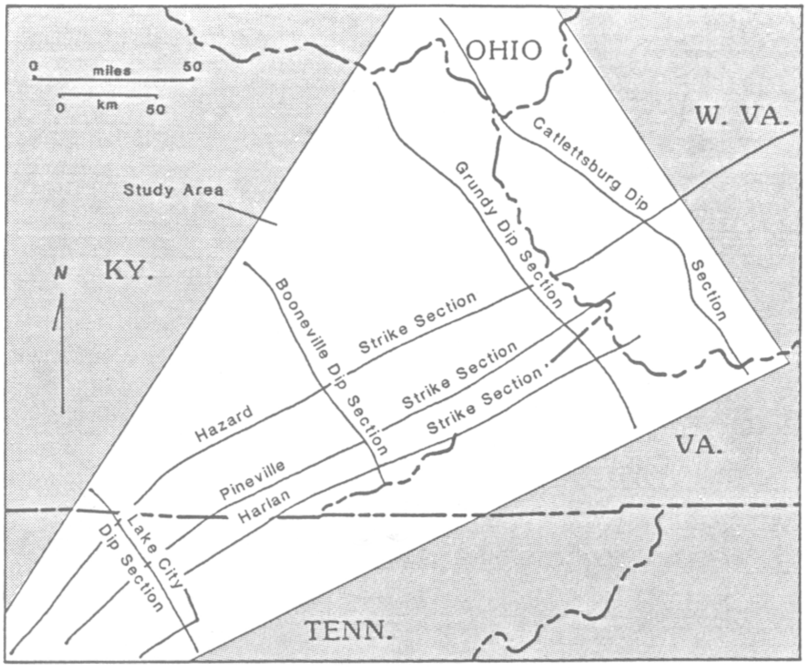
Procedures

In order to show the lithostratigraphic and structural framework of the Central Appalachian basin, detailed serial cross sections were constructed through the Carboniferous rocks (Fig. 7). The study was conducted over southernmost Ohio, southwestern West Virginia, eastern Kentucky, western Virginia, and part of northeastern Tennessee. Several hundred subsurface records were used in constructing the sections. Because of the large number, these records will not be listed in the Appendix, but are available at the Kentucky Geological Survey (open-file information in the Stratigraphy subsection of the Coal Section, Lexington Office). Likewise, the large number of geologic quadrangle maps used in making the cross sections, unless specifically mentioned in the text, precludes their inclusion in the bibliography.

The serial cross sections form a grid across the basin. This grid is oriented parallel and perpendicular to the general axis of the Appalachian basin, which is NE-SW. Sections perpendicular to the axis of the basin show best the variations from the center of the basin to the margins.

Because the correlation of Pennsylvanian strata is an important objective of this study, the cross sections were based on all available lines of evidence, including topography, surface geology, borehole descriptions, measured

Figure 7. Location of cross sections.



0 miles 50
0 km 50
OHIO
W. VA.
Study Area
KY.
N
Catlettsburg Dip Section
Grundy Dip Section
Booneville Dip Section
Strike Section
Hazard
Strike Section
Pineville
Strike Section
Harlan
VA.
Lake City Dip Section
TENN.

sections, and subsurface logs from studied parts of Kentucky, Tennessee, Virginia, and West Virginia.

Approximately 2,000 borehole descriptions were collected from coal companies, land companies, government agencies, published literature, and engineering reports. Oil and gas information available from the various state geological surveys, and one private source, Dr. Richard Bergenback (University of Tennessee at Chattanooga) was used. Where available, geophysical logs were employed, otherwise only drillers' logs were used.

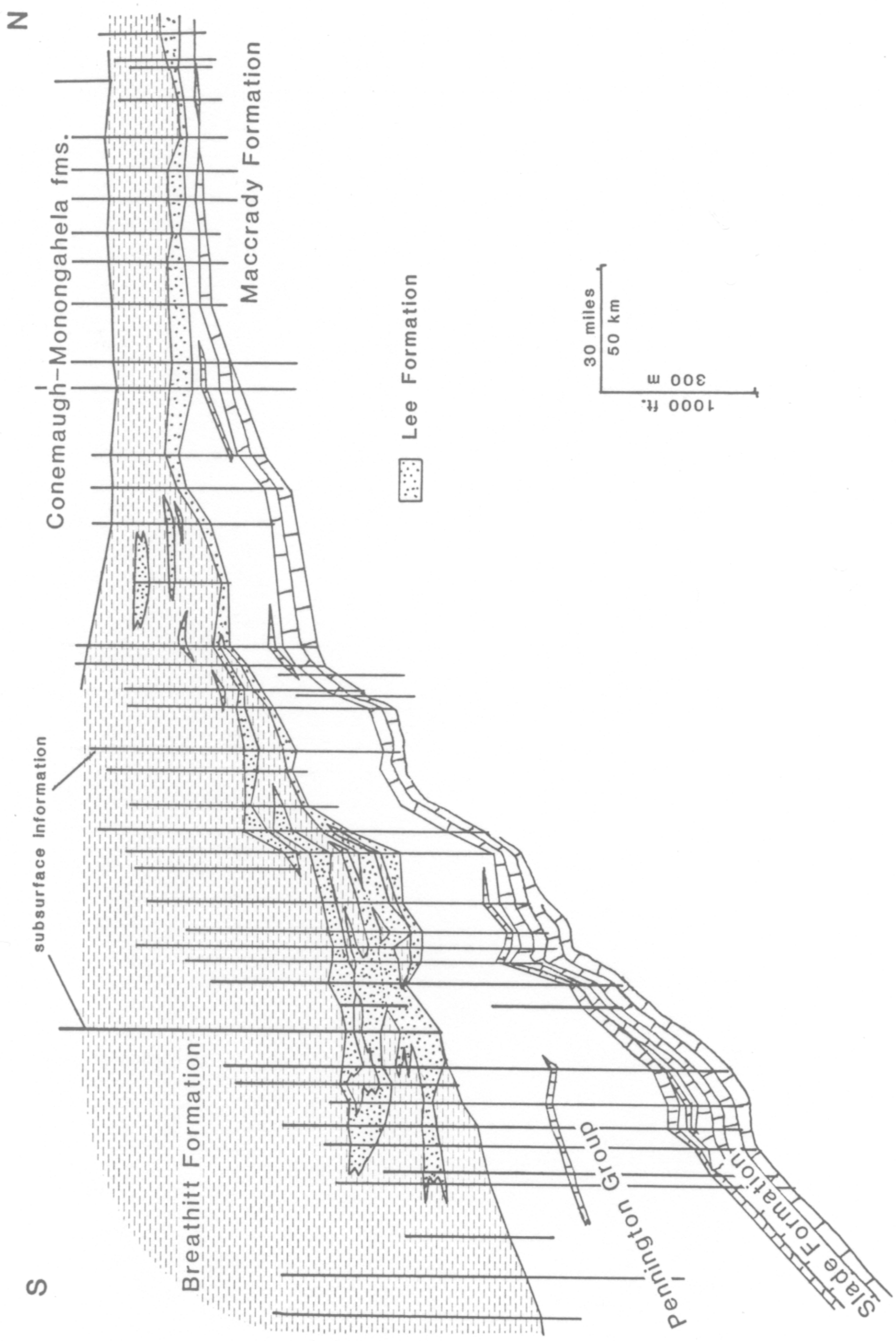
Subsurface data points, largely oil and gas logs, were selected at distances of about one mile (1.6 km) apart for the cross sections. Departures from the one-mile spacing exist, however, because of a lack of information from some areas in Kentucky or a lack of opportunity to gather information from other states. One of the cross sections (Grundy Dip Section) constructed in this study has an average density of about one well per 1.4 miles (2.25 km). Average data spacing in remaining sections are less dense than this.

Many of the drillers' logs for Pennsylvanian parts of the section are not very detailed, but this is compensated by the available geophysical logs. Geophysical logs, however, do not reflect such geologically important characteristics as color, important in some stratigraphic interpretations where the color of lithologies is the major distinguishing criterion. Both logs where used in conjunction when available. Cobb and Smath (1979) described in detail the use of geophysical logs in coal-bearing rocks.

Correlations within the cross sections were based on lithostratigraphy. Similar lithologies from adjacent logs were correlated if they occurred at the same relative position. This type of correlation contrasts with that used in the cross sections of Ferm and Cavaroc (1969, Fig. 4) and others described previously. Their cross sections apparently are based on the authors' interpretation of the facies relationships between the major rock units. The difference in the mode of construction of cross sections, and the result is illustrated in two examples below.

The outline of the cross section of Ferm and Cavaroc (1969, Fig. 4) was enlarged, leaving only drill-hole data. The density of the data averages one hole per five miles. New correlations based on lithostratigraphy were plotted in Figure 8. The precise lithological characters of some units are not known, because Ferm and Cavaroc described many of the lithologies in genetic terms, such as "upper delta facies" and "alluvial facies." However, the coal-bearing units can all be placed in the Breathitt Group, because coals of sufficient thickness to be reported in drillers' logs are not known in the Pennington. The Pennington Group

Figure 8. Lithostratigraphic recorrelation of Ferm and Cavaroc's (1969) cross section (Fig. 4).


N
S
Conemaugh–Monongahela fms.
Maccrady Formation
Lee Formation
30 miles
50 km
1000 ft.
300 m
subsurface information
Breathitt Formation
Pennington Group
Slade Formation

includes all the red-colored rocks between distinctive lithologies in the Slade Formation and in the Breathitt Formation. This new correlation indicates that Breathitt lithologies generally overlie Pennington lithologies. This type of lithostratigraphic framework is amenable to various genetic interpretations including that of Ferm and Cavaroc.

Another illustration is a regional cross section traversing the western belt of outcrop from northern Alabama through Tennessee to northern Kentucky (Fig. 9). This cross section (Fig. 9) by Ferm and others (1972, fig. 4) has been constructed with a facies interpretation of the rock data. Lithologies in the Pennsylvanian “Gizzard Group“ are shown intertonguing with lithologies of the Mississippian “Pennington Formation.” This cross section was enlarged, and facies correlations were removed, leaving only the drill-hole data. New lithostratigraphic correlations were introduced (Pig. 10), in which an apparent truncation of the Pennington Group rather than intertonguing is possible. In this interpretation, lithologies in the Breathitt Group and Lee Formation appear to have an unconformable and overlapping relationship with the underlying units. The two cross sections appear to be very different, yet were constructed from the same data.

Thus with sparse data, many interpretations can be made, depending on the hypothesis underlying the principles of

Figure 9. Facies-interpreted cross section in part of the Southern and Central Appalachian basins (adapted from Ferm and others, 1972).

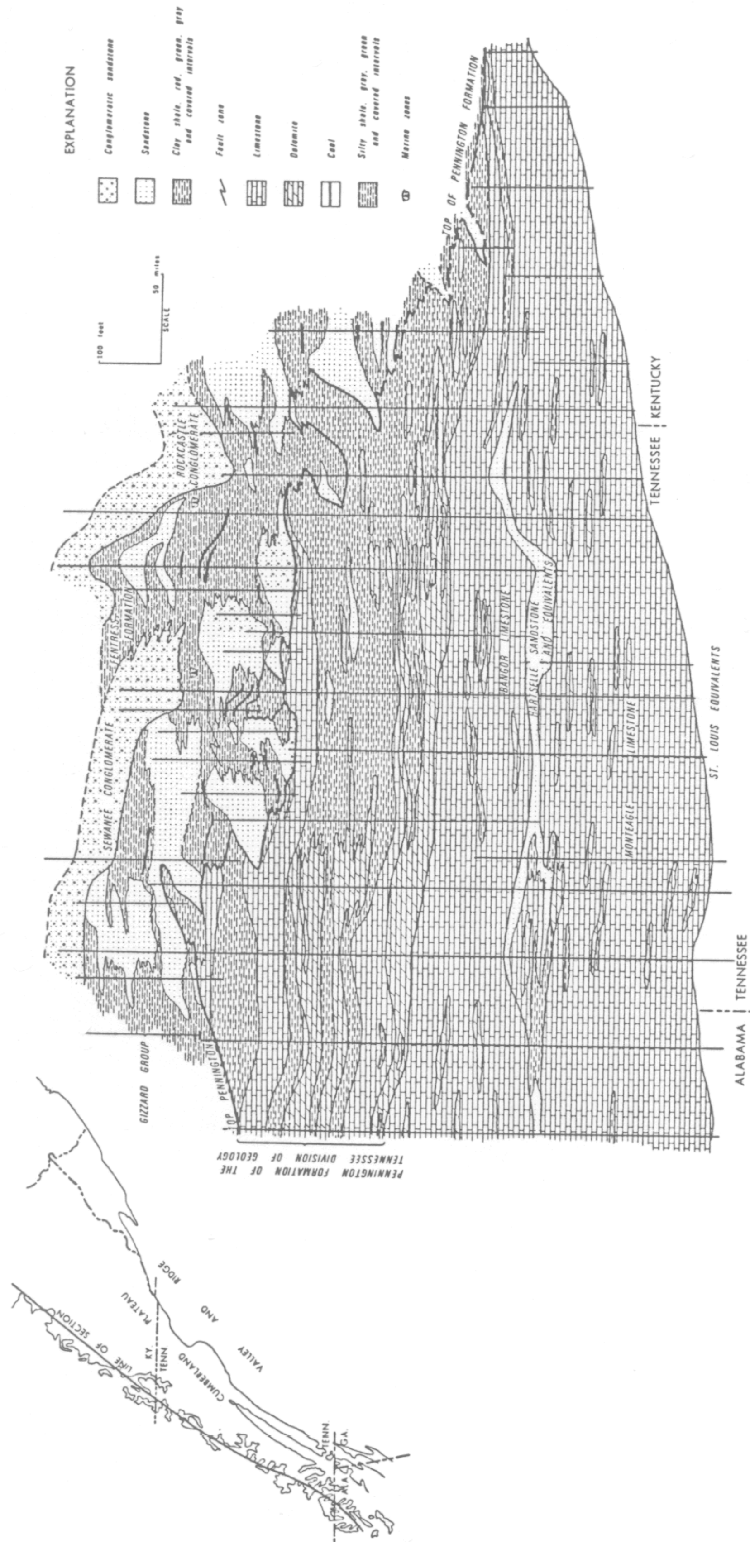
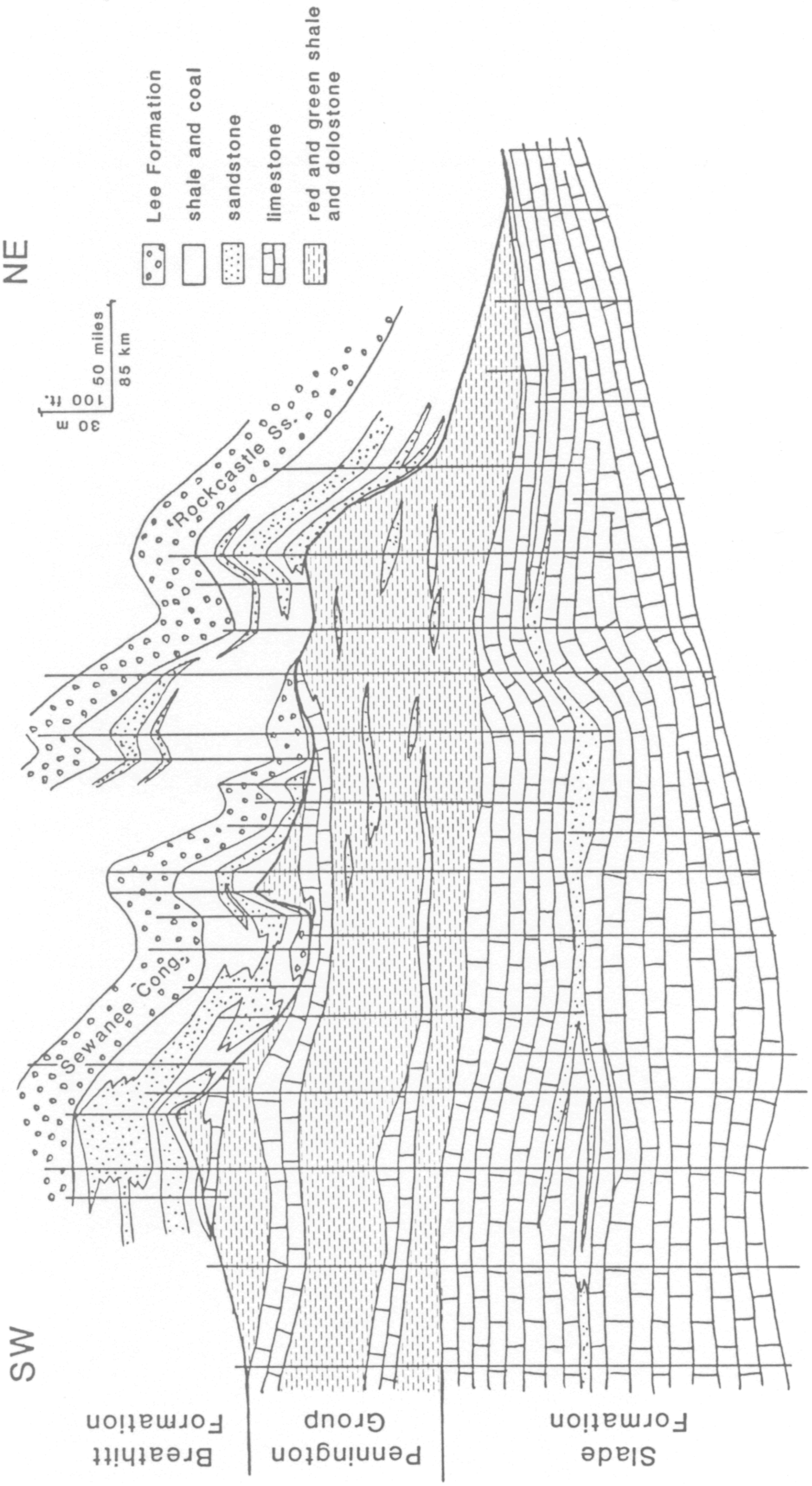
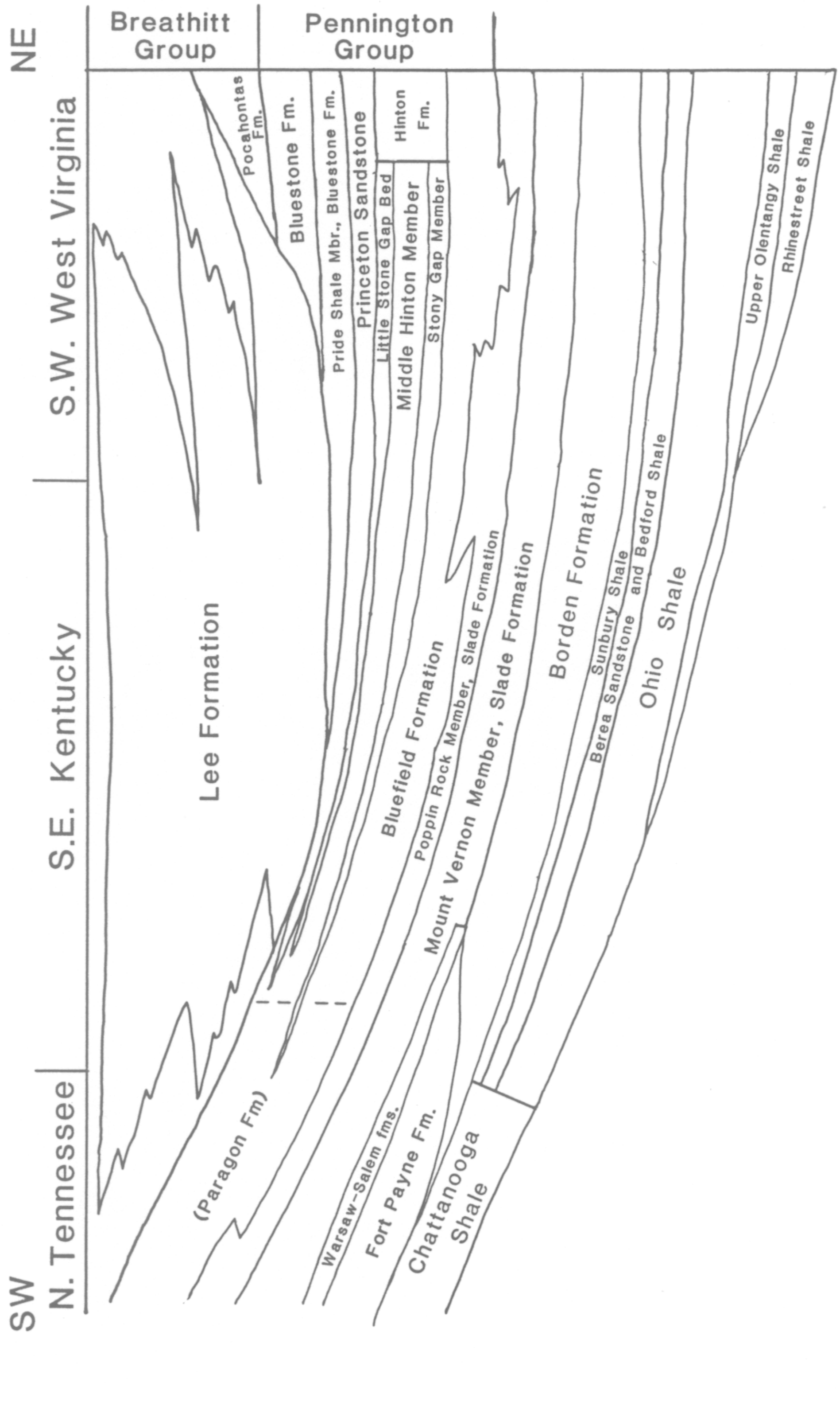

EXPLANATION
Conglomeratic sandstone
Sandstone
Clay shale, red, green, gray and covered intervals
Fault zone
Limestone
Dolomite
Coal
Silty shale, gray, green and covered intervals
Marine zones
100 feet
50 miles
SCALE
TOP OF PENNINGTON FORMATION
ROCKCASTLE CONGLOMERATE
TENNESSEE
KENTUCKY
FENTRESS FORMATION
BANGOR LIMESTONE
HARTSELLE SANDSTONE AND EQUIVALENTS
SEWANEE CONGLOMERATE
MONTEAGLE LIMESTONE
ST. LOUIS EQUIVALENTS
GIZZARD GROUP
TOP PENNINGTON
ALABAMA
TENNESSEE
PENNINGTON FORMATION OF THE TENNESSEE DIVISION OF GEOLOGY
PLATEAU
RIDGE AND VALLEY
CUMBERLAND
LINE OF SECTION
KY
TENN
GA
ALA

Figure *10.* Lithostratigraphic recorrelation of Ferm and others' (1972) cross section (Fig. 9).


SW
NE
Breathitt Formation
Pennington Group
Slade Formation
Sewanee Cong.
Rockcastle Ss.
30 m
100 ft.
50 miles
85 km
Lee Formation
shale and coal
sandstone
limestone
red and green shale and dolostone

correlation employed. The most widely published cross sections of the Appalachian Basin are actually interpretations of facies relationships. Using only lithostratigraphic correlations, however, the author has constructed seven cross sections through the study area. A description augmented by an analysis of these cross sections follows.

Figure 11. Stratigraphic framework of Mississippian-age rocks in the Central Appalachian basin. Overlying Pennsylvanian-age rocks are also illustrated.


NE
SW
S.W. West Virginia
S.E. Kentucky
N. Tennessee
Breathitt Group
Pennington Group
Pocahontas Fm.
Bluestone Fm.
Pride Shale Mbr., Bluestone Fm.
Princeton Sandstone
Hinton Fm.
Little Stone Gap Bed
Middle Hinton Member
Stony Gap Member
Lee Formation
Bluefield Formation
Poppin Rock Member, Slade Formation
Mount Vernon Member, Slade Formation
Borden Formation
Sunbury Shale
Berea Sandstone and Bedford Shale
Ohio Shale
Upper Olentangy Shale
Rhinestreet Shale
(Paragon Fm)
Warsaw-Salem fms.
Fort Payne Fm.
Chattanooga Shale