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EUSTATIC AND TECTONIC CONTROL OF SEDIMENTATION IN THE PENNSYLVANIAN STRATA OF THE CENTRAL APPALACHIAN BASIN, USA

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ARSTRACT. Analysis of the Breathitt Group (Lower and Middle Pennsylvanian) of the Central Appalachian Basin reveals three orders of depositional cycles or trends. The Breathitt coarsening-upward trend (20 miillion years (Ma)) represents increasing intensity of the Alleghanian Orogeny. The major marine trangression cycle (2.5 Ma) was controlled by an unknown eustatic or tectonic mechanism. The major coal beds and intervening strata make up the coal-clastic cycle (= Appalachian cyclothem), which has an 0.42 Ma periodicity. This periodicity supports an eustatic control of sedimentation moduladed by an orbital periodicity. Extensive coastal peats deposited at lowstand (coal-clastic cycle) were preserved as coals, whereas highstand peats were eroded during the subsequent drop in sea level. Autocyclic processes such as delta switching and avulsion occurred within coal-clastic cycles. Distribution of strata shows that the Early Pennsylvanian foreland basin was underfilled (i.e., the forebulge had not been crested). Alluvial deposits (Breathitt Formation) derived from the highlands were transported to the northwest toward the forebulge. During lowstand (major-marine transgression cycle), the only outlet available to further sediment transport (Lee Formation) was toward the southwest (Ouachita Trough), along the Black Warrior-Appalachian foreland basins. This transport was periodically interrupted by northeastward transgression (major-marine transgression cycle), from the trough through the foreland basins. The Middle Pennsylvanian marks a period of intermittent overfilling of the foreland basin and cresting of the forebulge. Marine transgressions (coal-clastic cycle) entered through the foreland basins and across saddles in the forebulge. After the Ouachita Trough was destroyed during the late Middle Pennsylvanian, marine transgressions migrated across saddles in the forebulge. In the Late Pennsylvanian, marine waters entered the basin only across the diminished forebulge north of the Jessamine Dome.

INTRODUCTION

The Central Appalachian Basin is one of the most important bituminous coal basins in the world (Fig.1). The Pennsylvanian coal-bearing rocks in the basin are composed of about 100 mineable coal beds separated stratigraphically by sandstones and shales. Basin analyses of these coal-bearing rocks support eustatic and tectonic control over sedimentation within the basin.

STRATIGRAPHIC CYCLES AND TRENDS

Stratigraphic analysis of the Breathitt Formation (Lower and Middle Pennsylvanian) (Fig. 2) reveals one overall trend and two orders of cycles. The Breathitt coarsening-upward trend (Fig. 2) can be seen as a general coarsening upward of the whole formation (disregarding the coarse sands of the Lee Formation, which derive from a different provenance). The Breathitt Formation is subdivided by several major marine strata into eight subequal formats (Fig. 2) representing the major-marine transgression cycle. The formats contain an average of six coal-clastic cycles, each made up of a major coal bed and overlying strata (Fig. 2). The average coal-clastic cycle (Fig. 3)

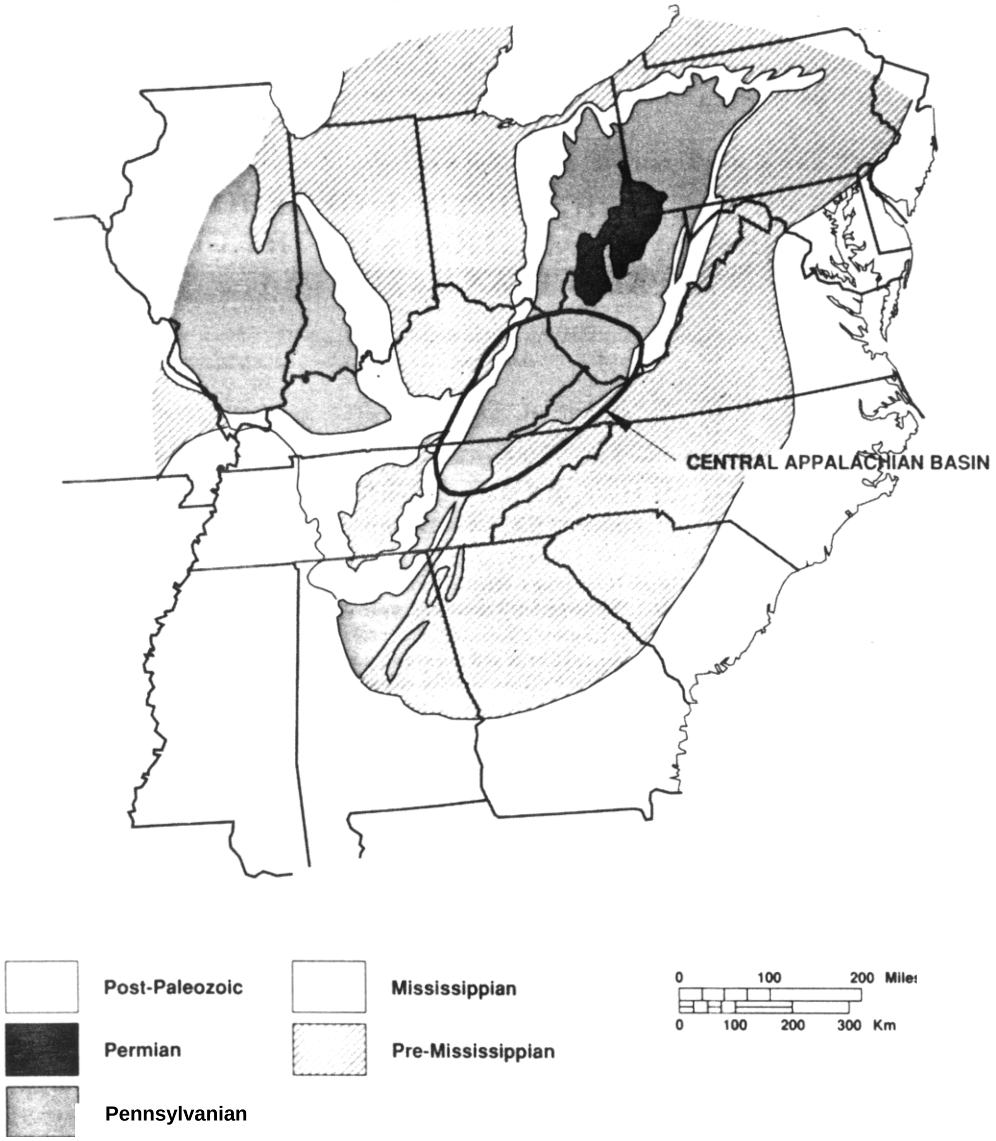
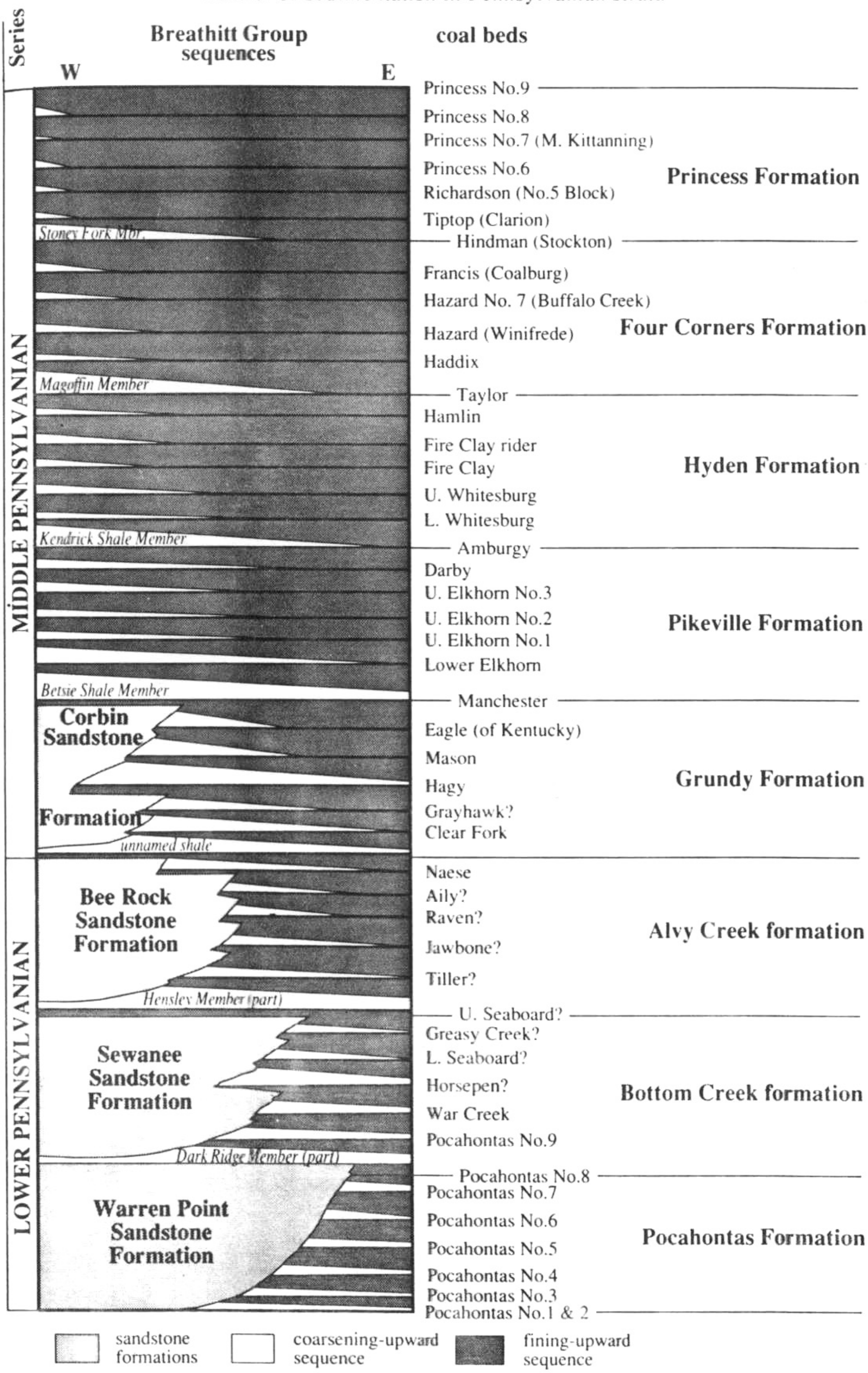


Figure 1. Location map of the Central Appalachian Basin

is composed of a coal bcd overlain by a marine or brackish-water coarsening-upward scquence of shale and sandstone. The coarsening-upward sequence is truncated and overlain by a fining-upward sequence of sandstone, which, in turn, is capped by seatrock and another coal bed. The coa1-clastic cycle is equivalent to the Appalachian cyclothem.

Figure 2. Schematic lithologic column of the Lower and Middle Pennsylvanian strata showing the Breathitt coarsening-upward trend, the major marine transgression cycle,. and the coal-clastic cycle. The Breathitt coarsening-upward trend reflects the general coarsening-upward grain size of the entire section (disregarding the Lee sandstone members, which represent a different provenance). The major-marine transgression cycles are equivalent to the eight mappable formats shown to the right. The major-marine transgression cycle is subdivided into an average of six coal and clastic units called Appalachian cyclothems, which represent the coal-clastic cycle.


Series
Breathitt Group sequences
coal beds
W
E
MIDDLE PENNSYLVANIAN
LOWER PENNSYLVANIAN
Princess No.9
Princess No.8
Princess No.7 (M. Kittanning)
Princess No.6
Richardson (No.5 Block)
Tiptop (Clarion)
Princess Formation
Stoney Fork Mbr.
Hindman (Stockton)
Francis (Coalburg)
Hazard No. 7 (Buffalo Creek)
Hazard (Winifrede)
Haddix
Four Corners Formation
Magoffin Member
Taylor
Hamlin
Fire Clay rider
Fire Clay
U. Whitesburg
L. Whitesburg
Hyden Formation
Kendrick Shale Member
Amburgy
Darby
U. Elkhorn No.3
U. Elkhorn No.2
U. Elkhorn No.1
Lower Elkhorn
Pikeville Formation
Betsie Shale Member
Manchester
Corbin Sandstone Formation
unnamed shale
Eagle (of Kentucky)
Mason
Hagy
Grayhawk?
Clear Fork
Grundy Formation
Bee Rock Sandstone Formation
Hensley Member (part)
Naese
Aily?
Raven?
Jawbone?
Tiller?
Alvy Creek formation
Sewanee Sandstone Formation
Dark Ridge Member (part)
U. Seaboard?
Greasy Creek?
L. Seaboard?
Horsepen?
War Creek
Pocahontas No.9
Bottom Creek formation
Warren Point Sandstone Formation
Pocahontas No.8
Pocahontas No.7
Pocahontas No.6
Pocahontas No.5
Pocahontas No.4
Pocahontas No.3
Pocahontas No.1 & 2
Pocahontas Formation
sandstone formations
coarsening-upward sequence
fining-upward sequence

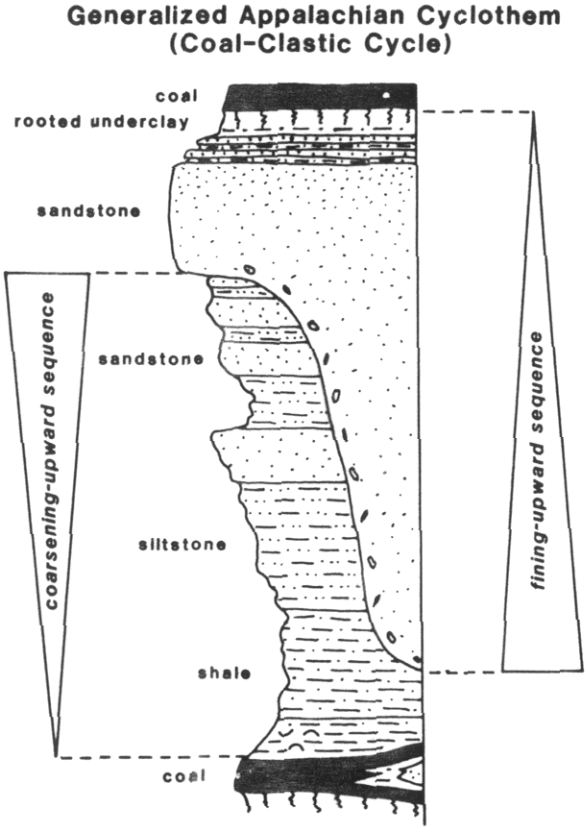


Figure 3. Generalized lithologic column of the Appalachian cyclothem.

The major coal beds were once thought to be very limited in distribution and entirely controlled by autocyclic and tectonic mechanisms (Ferm, 1979). However, (1) detailed mapping at a scale of 1:24.000, (2) extensive coal-resource investigations, (3) distribution of tonsteins in coal beds, as well as (4) surface- and deep-mining records indicate that the major coal beds were extensive (more than 200 km in extent). A compilation of paleontological studies showed that a11 the major coal beds were overlain by marine or brackish strata over part or all their distribution in Kentucky (Chesnut, 1981, 1991b). The extensive nature of these coal-bearing cyclothems supports either eustatic or widespread tectonic control over sedimentation rather than autocyclic mechanisms such as delta switching or river avulsion.

Chronologic analyses (see Chesnut, in press A), based on 10 different chronologic schemes developed during the last decade, provide the following cycle or trend durarions: the Breathitt coarsening-upward trend lasted an average of 20 Ma: the major-marine transgression cycle was about 2.5 Ma: and the coal-clastic cycle (Appalachian cyclothem) lasted about 0.42 Ma. The Breathitt coarsening-upward trend probably represents increasing intensity and proximity of the Alleghcnian (Hercynian) Orogeny. The 2.5 Ma periodicity of the major-marine transgression

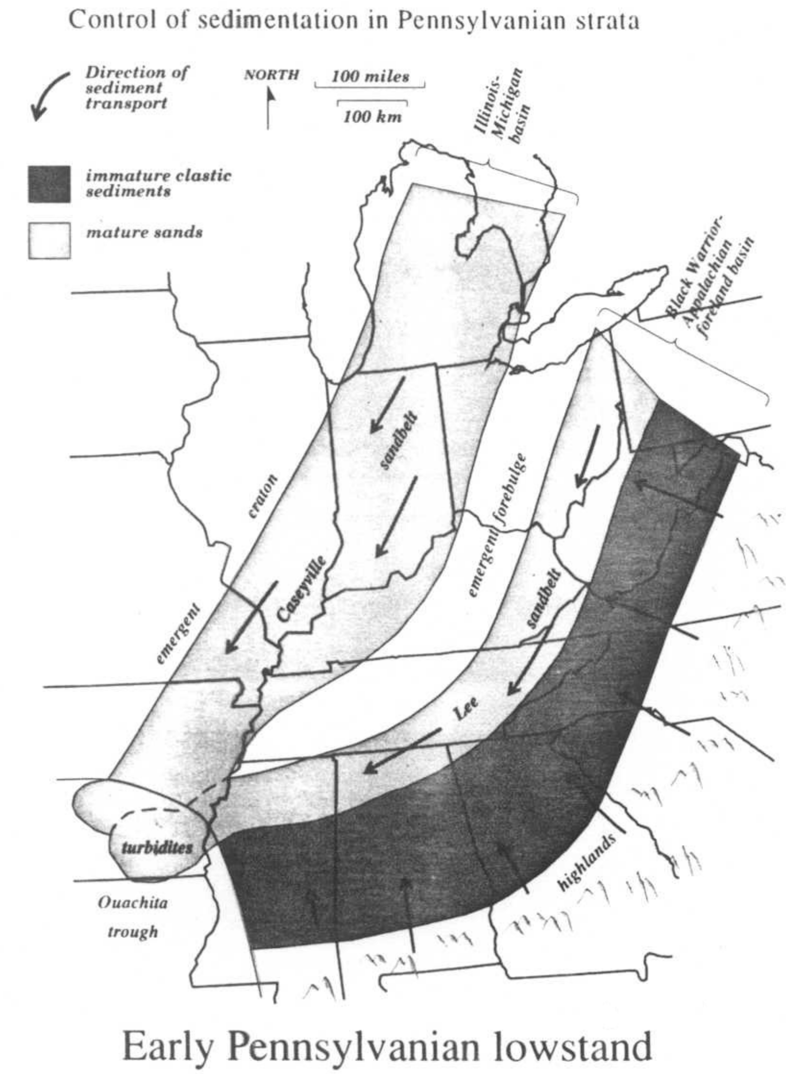
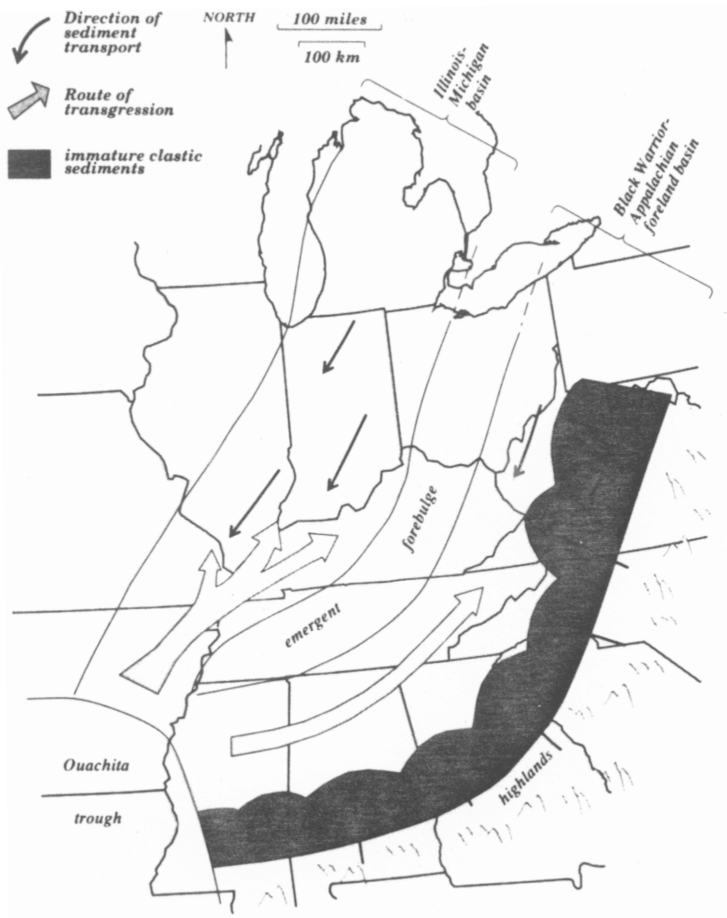


Figure 4. Paleogeography during an Early Pennsylvanian extreme lowstand. Arrows indicate direction of clastic transport.

cycle docs not match any known orbital or tectonic periodicity, and must be caused by unknown but recurring orbital or tectonic mechanisms. The 0.42 Ma periodicity of the coal-clastic cycle matches the second-order orbital eccentricity (Long Earth Periodicity) cycle (a Milankovitch cycle) that is known to modulate glaciation. This match supports a glacioeustatic control over deposition of the Appalachian cyclothem.

Autocyclic processes, although not the dominant control, do have some affect upon the coal-bearing rocks. Autocyclic processes such as delta-switching and avulsion are represented within individual cyclothems. Perhaps some of the minor coal beds were deposited by these processes.

The major coal beds of the Breathitt Formation, however, were deposited as lowstand peats, based upon vertical facies relationships (i.e., marine strata overlying coal beds) and the modern analog, the Indonesian cyclothem (see Chesnut and others, these proceedings). Peats were accumulated at the relative stasis of sea level change occurring at either high- or lowstand. Highstand peats were not preserved because of erosion during the subsequent drop in elevation.



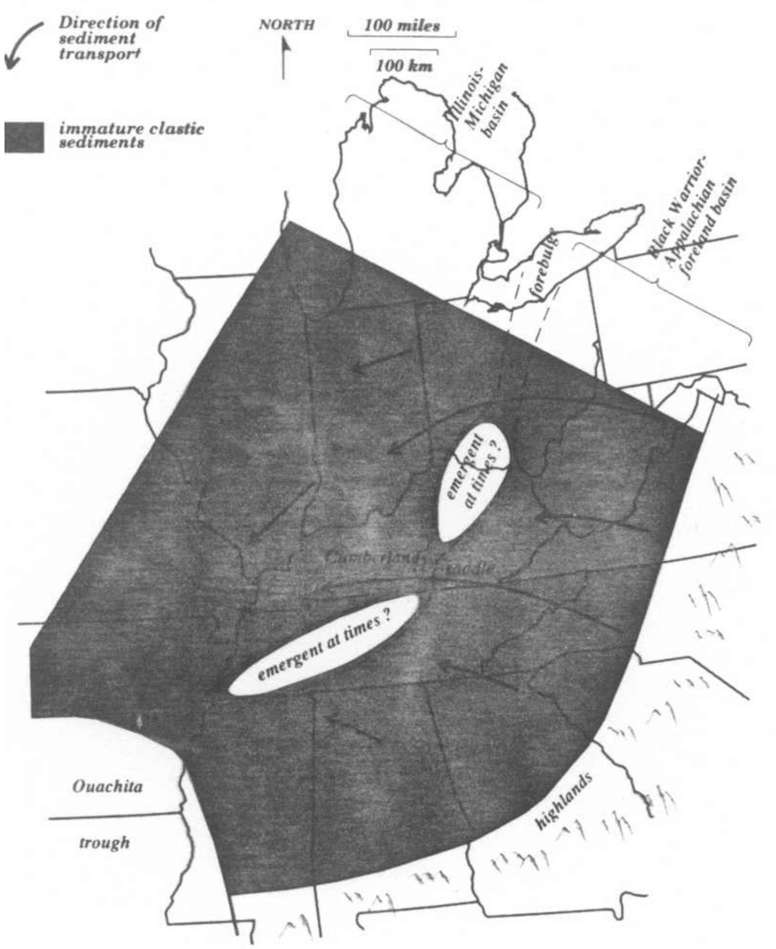
Early Pennsylvanian highstand

Figure 5. Paleogeography during an Early Pennsylvanian highstand. Large arrows indicate route of transgression.

LOWSTAND AND HIGHSTAND PALEOGEOGRAPHY

Little is known of the Pennsylvanian paleogeography of eastern North America at lowstand and highstand. Inferences can be made based on the distribution of strata within the basins (e.g., Nelson and others,. 1991a; Chesnut, in press B) and the distribution of biofacies within the marine strata (Chesnut, 1991b). Preliminary Pennsylvanian paleogeography maps based on these inferences are discussed here.

An Early Pennsylvanian (post mid-Carboniferous unconformity) extreme lowstand is shown in Figure 4. During the Early Pennsylvanian, strata progressively onlapped the newly formed Appalachian and Illinois Basins, but had not covered the forebulge between the two basins. Current indicators show that immature clastics (represented by the Breathitt Formation) derived from the Appalachian Mountains were transported to the west (Fig. 4). At lowstand, the Breathitt rivers flowed into a large trunk transport system (represented by the Lee Formation sandbelts) flowing to the southwest. The Lee sandbelts were situated between the forebulge and the Breathitt clastic wedges and may ultimately have dumped sediment in-



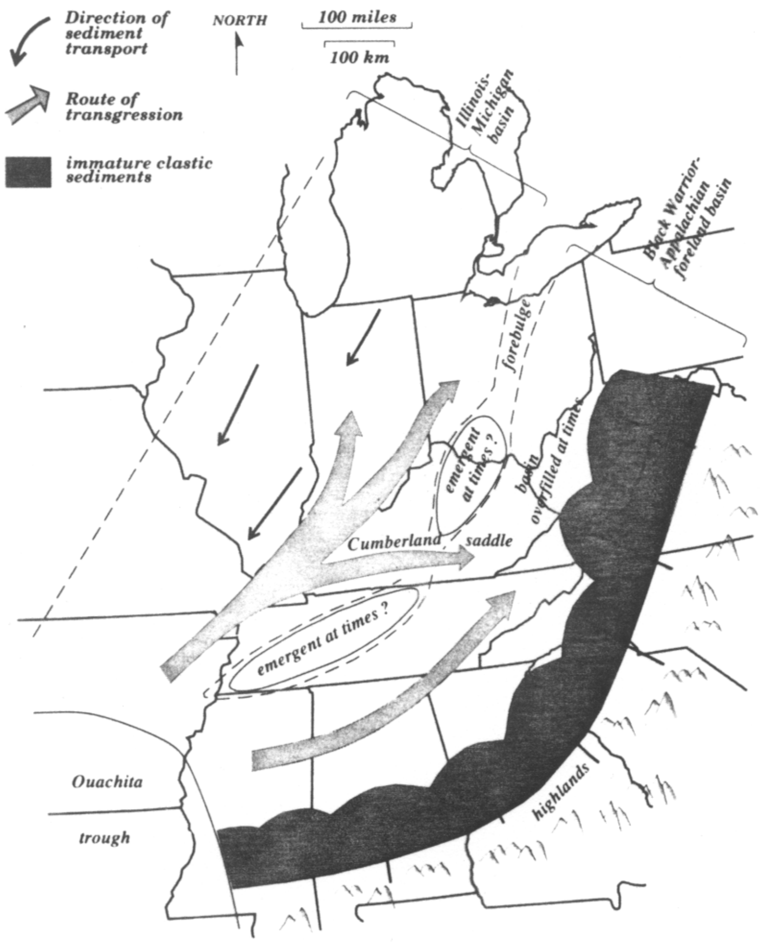
Middle Pennsylvanian lowstand

Figure 6. Paleogeography during a Middle Pennsylvanian extreme lowstand. Arrows indicate direction of clastic transport.

to the Ouachita Trough to the west via the Black Warrior-Southern Appalachian Basins. On the western side of the forebulge, the similar Caseyville sandstone belt carried sand to the northeastern part of the trough.

An Early Pennsylvanian highstand is shown in figure 5. Based on distribution of biofacies in the Eastern Kentucky Coal Field (Chesnut, 1991a & b) marine waters entered the Central Appalachian Basin from the south. Marine waters (represented by the Dark Ridge and Hensley members, Fig. 2) are inferred to have transgressed from the Ouachita trough (at extreme lowstand), through the Black Warrior-Southern Appalachian Basins, into the Central Appalachian Basin (Fig. 5). Marine waters also transgressed northeast across the Caseyville sandbelt: however, waters do not appear to have connected across the forcbulge separating the basins (Fig. 5).

During most of the Middle Pennsylvanian (Fig. 6) trunk transport systems like the Lee and Caseyville sandbelts did not form at lowstand. Rather, Breathitt rivers apparently carried clastics over the forebulge at saddles formed in the forebulge (Fig. 6). The ultimate destination of the clastics may have been the Ouachita Trough and areas west of the trough.



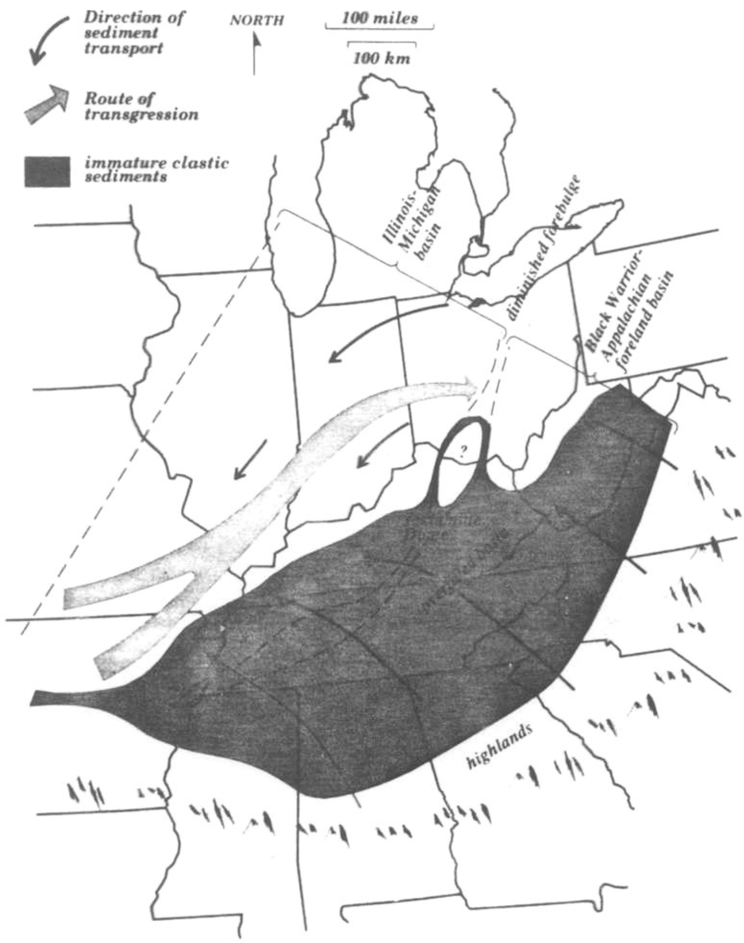
Middle Pennsylvanian highstand

Figure 7. Paleogeography during a Middle Pennsylvanian highstand. Large arrows indicate route of transgression

Preliminary biofacies distribution in marine strata in the central Appalachians indicates increasing marine conditions to the west and south during most of the Middle Pennsylvanian (Chesnut, 1991b). During rising sea level, marine waters apparently transgressed not only through the southern route to reach the Central Appalachian Basin, but also across saddles in the forebulge from the western basin (Fig. 7).

During the Late Pennsylvanian lowstands, transport direction of clastics was probably similar to that of the Middle Pennsylvanian (Fig. 6). However, the Ouachita Trough was destroyed by collisional tectonics during the late Middle and Late Pennsylvanian and could not have been the final destination of the Appalachian clastics. Clastic transport must have proceeded to the west.

Rising sea levels during the Late Pennsylvanian (Fig. 8) could not transgress from the Ouachita Trough through the Black Warrior-Southern Appalachian Basins because the trough was destroyed. and the southern route may havc been blocked by the collisional tectonism. Transgressions must have proceeded through the Illinois Basin and entered the southern part of the Northern Appalachian Basin across a much diminished forebulge north of theJessamine Dome (Fig. 8).



Late Pennsylvanian highstand

Figure 8. Paleogeography during a Late Pennsylvanian highstand. Large arrows indicate route of transgression

DISCUSSION

The distribution of coastal landmasses at highstand and lowstand determine where coastal, domed peats may have accumulated and where thick coal may be found. In addition, the distribution of landmasses and large bodies of water may have had a great influence on regional climate. The differences in the distribution of land and water at lowstand and highstand can generate very different regional climates. In order to model regional climates, paleogeography at both highstand and lowstand must be determined.

The preliminary inferences on Pennsylvanian paleogeography made here are not very detailed. Steps are being undertaken to refine or correct these interpretations using new data such as paleosol type, sulfur and ash-content of coals, paleobotanical data, and other information. These data are being compiled under the multi-institutional research initiative, Predictive Stratigraphic Analysis (C. Blaine Cecil and N. Terence Edgar, U. S. Geological Survey), in order to determine the role paleoclimate played in the Carboniferous rock record.

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