MARINE ZONES OF THE UPPER CARBONIFEROUS OF EASTERN KENTUCKY
Donald R. Chesnut
Kentucky Geological Survey

This is a preliminary report on occurrences of marine zones in the Pennsylvanian of eastern Kentucky. The recognition and interpretation of marine zones within the coal-bearing sequence are important for basic understanding of the depositional history of Pennsylvanian rocks. Marine zones have proved to be of great importance for stratigraphic analyses in the Pennsylvanian of eastern Kentucky. As key beds, the marine zones provide a stratigraphic framework and aid in the identification and correlation of coal beds across the coal field. The relationship between coal quality and depositional history is important in coal exploration, as higher sulfur content of coal is sometimes associated with marine rocks overlying the coal (Horne and Ferm, 1976; Hester and Leung, 1978). Acid mine drainage in surface coal mining operations is associated with the higher sulfur content of overburden rocks of marine or brackish origin (Despard, 1974; Caruccio and others, 1976; Hester and Leung, 1978). In a similar manner the occurrence of carbonate rocks can help in the neutralization of acid water, creating a beneficial environmental effect. The fossil fauna can be used to determine these depositional environments (e.g., marine, brackish, freshwater). Deposition of Pennsylvanian strata, particularly the Breathitt Formation, has been characterized as upper and lower delta plain by Ferm and others (1971), but little attention has been given to the marine contribution to the depositional record. A perusal of geologic quadrangle maps for eastern Kentucky shows that marine rocks are at least locally associated with almost every named coal. Most of these marine zones are thin and discontinuous, and are difficult to identify. Some, like the Magoffin, Kendrick, and Stoney Fork Members of the Breathitt Formation, are quite extensive. Forty-nine stratigraphically distinct zones that contain invertebrate fossil forms, animal bioturbation, limestone concretions, or calcareous lithologies have been identified in the lithologic descriptions of the geologic quadrangle maps of eastern Kentucky. All of these features are thought to be associated with marine conditions. Freshwater limestones have not been identified in the Breathitt Formation in eastern Kentucky, though better paleontological studies may show that some freshwater fauna have been misidentified as marine.

Many marine zones have been long recognized in the Pennsylvanian of eastern Kentucky. Morse (1931) reported seven: the Dwale Shales, Elkins Fork Shales, Kendrick Shales (Jillson, 1919), Magoffin Beds, Saltlick Beds, Lost Creek Limestone, and the Flint Ridge Flint. Later, McFarlan (1943) added four more that had appeared in other geological investigations: the Campbells Creek Limestone (White, 1885), Vanport Limestone (Phalen, 1912), "Lower Cambridge" Limestone (Brush Creek) (Phalen, 1912), and the Ames Limestone (Phalen, 1912). McFarlan and some other earlier workers generally considered the marine contribution to the Pennsylvanian sedimentary record to be very minor (5 percent when computed from Morse's total section, 1931, p. 296). After studying a limited part of the Pennsylvanian section in the Cumberland Overthrust Sheet in southeastern Kentucky, Eagar (1970, 1973) suggested that marine contribution might be much greater, perhaps as much as 25 percent of the total section. The area in which Eagar worked may have received more marine sediment than the rest of eastern Kentucky due to its proximity to the axis of the Appalachian geosyncline, where rapid subsidence took place (Rice and others, 1979, p. F19). The average percentage of rocks of marine origin for the Pennsylvanian section of eastern Kentucky is most likely between these two figures. In any case, only three of the above named marine zones are well enough known to be formally named; most of the others are known only informally by the name of the geologist who first recognized them, or are referred to only as "the marine zone" above a particular coal bed (Rice, personal commun.).

Three studies involve the fauna of the Lower Pennsylvanian of the Cumberland Overthrust Sheet (Scott and Summerson, 1943; Eagar, 1970, 1973). Since 1958, several invertebrate studies have been made of the Kendrick Shale in Kentucky. These include studies on ammonoids (Furnish and Knapp, 1966), crinoids...
The term "marine beds," as used in this index actually refers to marine and brackish beds.
and Knapp, 1966). and holothurian sclerites (Sommer-
son and Campbell, 1958). Cavoroc and Ferm (1968)in-
vestigated the sponge spiculite of the Kilgore Flint (Flint
Ridge Flint of Morse, 1931). Since 1975, 12 reports have
investigated marine zones in some detail. These studies
involve the Magoffin Member (Dennis, 1975; Ketani.
1980: and Ketani, this volume), an unnamed zone above
the Hazard No. 5 coal (Cumbee, in preparation), the
Stoney Fork Member (Lost Creek Limestone) (Garrison,
1977; Ping, 1978), the Flint Ridge Flint (Wetmore,
1978), the Brush Creek and Ames limestones (Walter,
1979). and the Kendrick Shale Member (Rice, 1980;

Present data (Fig. 22) indicate that the marine con-
tribution to the sedimentary record is greater than pre-
viously thought. Most of the marine beds identified in
this study have not been recognized as such in the litho-
logic descriptions of geologic quadrangles. A prelimi-
nary examination of available literature suggests that
the extent of marine-dominated depositional environ-
ments can be determined in a general way in the coal-
bearing rocks of eastern Kentucky by plotting their oc-
currences on base maps (Chesnut, in preparation].
Closer attention in the future to the lithologies from core
holes and careful investigation in the field might further
extend our knowledge of the occurrence and distribu-
tion of marine zones, too often overlooked in eastern
Kentucky.

The typical marine zone (Fig. 23) is usually recognized
as being a coarsening-upward, bayfill sequence that
may be from a few feet to as much as 120 feet thick.
They commonly overlie coal beds and are typically clay
shale at the base and siltstone, sandy siltstone, or silt-
stone with thin beds of sandstone at the top. Sediment
representing the maximum extent of transgression is
usually directly overlying the coal bed or within a few
feet over the coal bed. Brackish to marine fossils are
commonly found at the base of the bayfill deposits.
Pennsylvanian transgressions probably came from the
southwest and south prior to and in Magoffin time, and
from the west and north after Magoffin time (Rice and
others, 1979, p. F19). The Magoffin and the Kendrick
Shale were deposited in seas that covered most of east-
ern Kentucky. Many marine sediments, however, were
deposited in small marine embayments separated later-
ally by distributary and other terrestrial clastic sedi-
ments; these units are commonly difficult to trace lat-
erally. Rice andothers (1979, p. F19) suggest that some
discontinuous marine sequences were probably depos-
ited in tidal channels or small bays perhaps tens of kilo-
meters from large open bays (such as those represented
by the Magoffin). limestone beds associated with
marine zones tend to be thin and discontinuous. They
commonly occur at the base of the bayfill sequence.

The transgressive sequence above a coal, which is
sparsely to abundantly fossiliferous, is usually overlain
by a barren to sparsely fossiliferous progradational-re-
gressive sequence of upward-coarsening sediments
representing a variety of local deltaic environments
(e.g., bayfill). Some investigations (Eagar, 1970; Bless,
1970; Williams, 1960) suggested that bays formed by
widespread transgressions tend to become progressively less marine with time and the enclosed
fauna tend to reflect these changes. Many bayfill
sequences do not contain macrofossils; some,
however, may contain only trace fossils. In the absence
of macrofossils, the use of microfossils to identify
depositional environments should be attempted in
future work.

**LARGE CALCAREOUS CONCRETIONS**

Large limestone concretions are frequently found in
the Pennsylvanian section above the Lee Formation in
eastern Kentucky. These concretions can be observed
at Stops 2, 3, 4, 5, 8, 9, and 10 of this field trip, though
they are best exposed at Stops 3, 5, 8, and 9. The cal-
careous concretions, sometimes up to 15 feet long and
6 feet high, are thought to have been formed by very
early diagenetic concentration of calcite from the water
column or the calcareous sediment. Laminations from
the host rock can be seen to go through the concre-
tions, though the laminations are more compacted in
the host rock. Although the concretions often occur
along definite horizons within a coarsening upward se-
quence, many can be found throughout the sequence.
There is a tendency for concretions to become more
spherical-shaped as the grain size of the rock increases.
Some concretions tend to be lens-shaped in shales, and
almost spherical-shaped in sandstones. The lens shape
could be controlled by the amount of compaction of
the sediment; shales compact more than sandstones, there-
fore concretions in shales are lens shaped. More likely,
however, is that migration of calcium ions was isometric
in sandstones (i.e., equal in all directions), but in shales
most of the migration was from a lateral direction con-
trolled by the orientation of clay minerals (bedding). Mi-
gration would be slower in a direction normal to bed-
ding. The concretions almost invariably show calcite-
filled cracks due to de-watering and shrinkage. The con-
cretions are fossiliferous when they occur in fossil-
iferous strata. Calcite is often in great enough propor-
tion to classify the rock a limestone, although varying
amounts of calcite and siderite are found. The mineral-
ological content of the concretions is variable, but the
clastic content always matches the host rock. These
calcareous concretions were formed by early diagenetic
concentration of calcite. Their presence is used to identify marine to brackish water conditions.

**NOTES ON SOME COMMON TAXA**

While there are commonly a large number of species represented in the population of abundantly fossiliferous marine zones, most of the Pennsylvanian section contains only rare examples of a few taxa. Figure 24 shows the environmental range of common taxa from the freshwater environment to marine environments. The following are notes on some common non-open marine and brackish taxa which are sometimes found in large numbers.

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**Naiadites-Anthraconaia**

The pelecypod *Naiadites* has been used as an indicator for freshwater sediments by some (Rogers, 1965; Henry and Gordon, 1979, p. 101). Eagar (1973), however, said that some of these are probably a naiaditiform *Anthraconaia* (probably *A. ohioense* for the southeastern Kentucky forms). He suggested that the southeastern Kentucky *Anthraconaia* faunas lived in brackish waters, whereas the European forms lived in fresh water. Both viewpoints admit that they existed in waters of less-than-marine salinity. The pelecypod, when flattened, looks like and is frequently misidentified as *Lingula* (Figure 2 of Plate 17). Each valve of *Lingula* has
The inarticulate brachiopod, *Lingula* (Figure 1 of Plate 17), is often used in upper Carboniferous work as an indicator of brackish conditions, but according to Rudwick (1965, p. 211-212) in the "Treatise on Invertebrate Paleontology''

... The lingulids can survive occasional brief periods of immersion in brackish or fresh water (e.g., a tropical storm while exposed at low tide), but they do so by closing their shells tightly and by retreating into their burrows, i.e., by temporarily suspending all normal metabolic activities. No other
Figure 1. *Lingula carbonaria*, pyritized, from the Pennsylvanian of western Kentucky. X1.4

Figure 2. *Anthracocnaia (Naiadites)* sp. from a population of large forms in McCreary County, Kentucky. Pyritized in canneloid shales, overlying the River Gem (Lily) coal. X2, lightly coated with ammonium chloride.

Figure 3. *Wilkingia terminale*, sideritized cast, in heavily burrowed sandstone, near the Fire Clay coal in Knott County, Kentucky X1.3, lightly coated with chloride.
brachiopods possess even this limited tolerance of non marine conditions...The presence of fossil lingulids unaccompanied by other brachiopods is not a reliable indicator of brackish conditions of deposition. Such assemblages may indicate conditions that were normally marine but liable to occasional brief periods of brackish water. But lingulids are ecologically abnormal in several other aspects and other explanations are therefore possible...the inarticulate Lingula... (is) well adapted to living in water that is generally turbid.

**Wilkingia terminale**

Frequently, burrowed sandstones and siltstones are the only indication of marine or near-marine conditions. The burrowing pelecypod, Wilkingia terminale (Figure 3 of Plate 17) is usually the only body fossil found in these sandstones. Both pelecypod and burrows are often replaced by siderite.

**CONCLUSIONS**

Further study of the fauna and distribution of marine zones is needed in eastern Kentucky. The Kentucky Geological Survey is conducting a coal resource study of eastern Kentucky. In the course of this work, many new exposures of marine zones have been found and collected, adding to our knowledge of both the paleontology of the Pennsylvanian and its depositional framework. Studies have shown that the quality of coal can be related to environments of deposition. Currents (this volume), among others (Hester and Leung, 1978; Williams and Keith, 1963), shows in his work on coal quality that the sulfur content of coal beds may be related to the distribution of marine strata in the roof rocks of the coal beds. Comprehensive studies of coal quality and its relationship to the enclosing rocks will be possible as our knowledge of the marine zones grows.

Additional information about marine zones will assist in a better understanding of the depositional models for the Pennsylvanian. The resolution of such controversies as the back barrier-lower delta plain-upper delta plain model versus the cyclothemic model or other models may hinge on our knowledge of marine transgressions. The lateral extent and number of marine zones should decrease as progradation from lower delta plain to upper delta plain occurs. There is no apparent decrease in marine transgressions in the Breathitt Formation of eastern Kentucky to suggest a shift from lower delta plain to upper delta plain.

Further work is necessary to determine the areal distribution of these marine zones (this study examined only surface data). Closer examination of the fossil distribution and the environments they indicate may help in determining proximity to shore (Stevens, 1971; Cavaroc and Ferm, 1968) and thus a better understanding of the lateral extent of the marine zones.

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