MARINE ZONES OF THE UPPER CARBONIFEROUS OF EASTERN KENTUCKY

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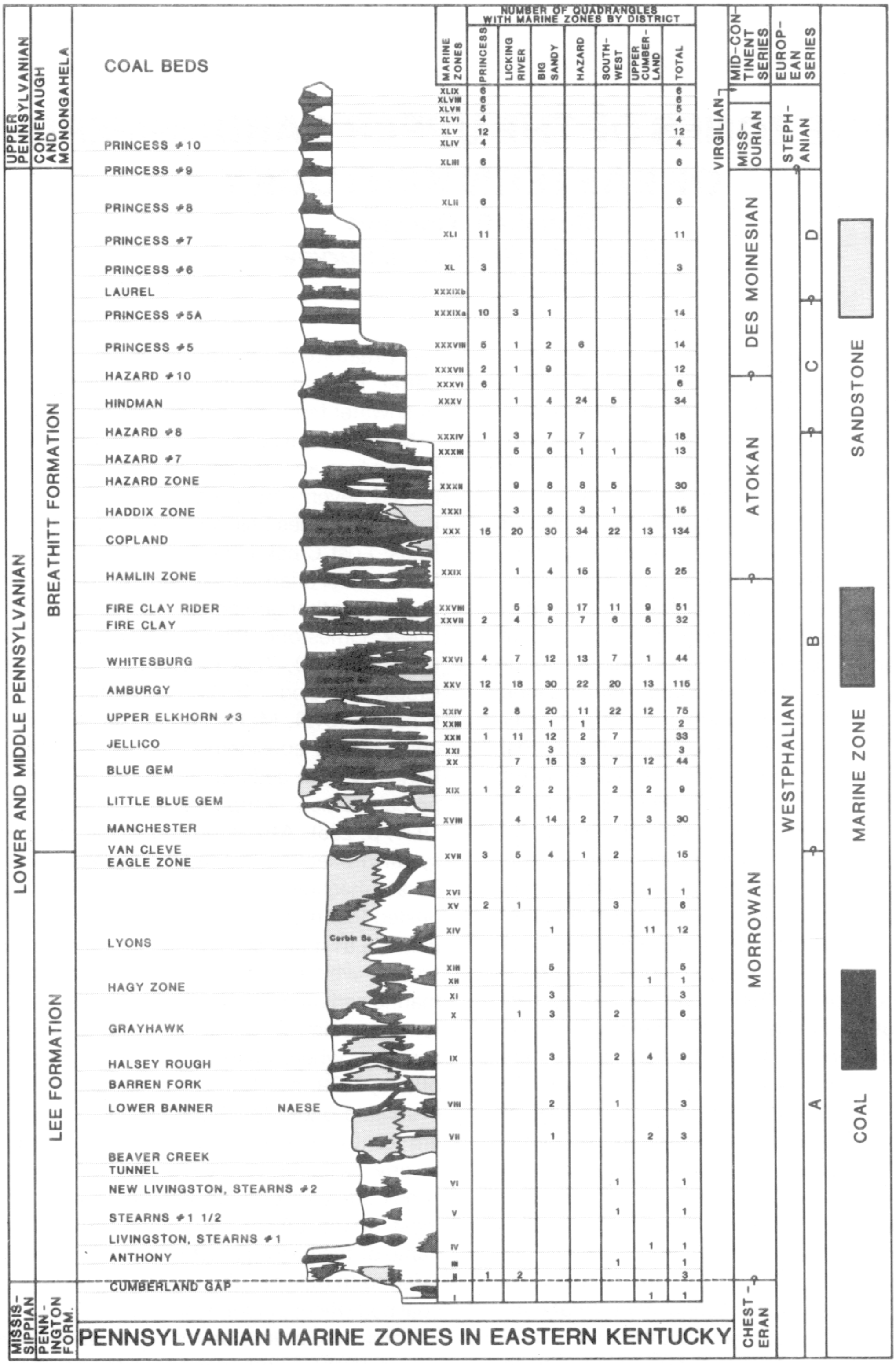
This is a preliminary report on ocurrences of marine zones in the Pennsylvanian of eastern Kentucky. The recognition and interpretation of marine zones within the coal-bearing sequence are important for basic understanding of the depositional history of Pennsylvanian rocks. Marine zones have proved to 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



Marine zones	Princess	Licking River	Big Sandy	Hazard	Southwest	Upper Cumberland	Total
	Number of quadrangles with marine zones by district						
XLIX	6						6
XLVIII	6						6
XLVII	5						5
XLVI	4						4
XLV	12						12
XLIV	4						4
XLIII	6						6
XLII	6						6
XLI	11						11
XL	3						3
XXXIXb							
XXXIXa	10	3	1				14
XXXVIII	5	1	2	6			14
XXXVII	2	1	9				12
XXXVI	6						6
XXXV		1	4	24	5		34
XXXIV	1	3	7	7			18
XXXIII		5	6	1	1		13
XXXII		9	8	8	5		30
XXXI		3	8	3	1		15
XXX	15	20	30	34	22	13	134
XXIX		1	4	15		5	25
XXVIII		5	9	17	11	9	51
XXVII	2	4	5	7	6	8	32
XXVI	4	7	12	13	7	1	44
XXV	12	18	30	22	20	13	115
XXIV	2	8	20	11	22	12	75
XXIII			1	1			2
XXII	1	11	12	2	7		33
XXI			3				3
XX		7	15	3	7	12	44
XIX	1	2	2		2	2	9
XVIII		4	14	2	7	3	30
XVII	3	5	4	1	2		15
XVI						1	1
XV	2	1			3		6
XIV			1			11	12
XIII			5				5
XII						1	1
XI			3				3
X		1	3		2		6
IX			3		2	4	9
VIII			2		1		3
VII			1			2	3
VI					1		1
V					1		1
IV						1	1
III					1		1
II	1	2					3
I						1	1

Figure 22. Pennsylvanian marine zones in eastern Kentucky. *See* facing page for explanation of marine zones.

XLIX
Marine beds above the Ames Limestone
XLVIII
Ames Limestone Member of the Conemaugh and Monongahela Formation
XLVII
Marine beds immediately below Ames Limestone
XLVI
Marine beds above Brush Creek Limestone
XLV
Brush Creek Limestone Member of the Conemaugh and Monongahela Formation
XLIV
Marine beds between Brush Creek Limestone and Princess No. 10 coal
XLIII
Marine beds above and within the Princess No. 9 coal zone
XLII
Marine beds above the Princess No. 8 coal
XLI
Marine beds above the Princess No. 7 coal
XL
Marine beds above the Princess No. 6 coal
XXXIXb
Lime Kiln (Johnston, 1962)
XXXIXa
Vanport Limestone of Kentucky (Phalen, 1912)
XXXVIII
Flint Ridge Flint of Morse 119311
XXXVII
Marine beds above the Broas coal zone
XXXVI
"Main Black Ore"
XXXV
Stoney Fork Member
XXXIV
Marine beds above and within the Hazard No 8 coal zone
XXXIII
Marine beds above and within the Hazard No 7 coal zone
XXXII
Marine beds above and within the Hazard coal zone
XXXI
Marine beds above and within the Haddix coal zone
XXX
Magoffin Member
XXIX
Marine beds above and within the Hamlin coal zone
XXVIII
Marine beds above the Fire Clay rider coal
XXVII
Marine bedsaboveandwithin the Fire Clay zone
XXVI
Marine beds above and within the Whitesburg coal zone
XXV
Kendrick Shale Member
XXIV
Elkins Fork Shale and Dwale Shale of Morse (1931)
XXIII
Marine beds within the Upper Elkhorn No. 3 coal zone
XXII
Marine beds above the Jellico coal
XXI
Marine beds above the Upper Elkhorn No. 1 coal
XX
Campbells Creek Limestone of White (1885)
XIX
Marine beds above the Little Blue Gem coal
XVIII
Cannelton Limestone of White (1885)
XVII
Marine beds above the Van Cleve coal
XVI
Marine beds below the Hance coal
XV
Marine beds within the Corbin Sandstone
XIV
Marine beds above the Lyons coal
XIII
Eagle Limestone of White (1891)
XII
Marine beds below the Mason coal
XI
Marine beds above the Hagy coal bed
X
Marine beds above the Grayhawk coal
IX
Marine beds above the Halsey Rough coal
VIII
Marine beds above the Naese sandstone
VII
Marine beds above the Bee Rock Sandstone
VI
Marine beds above the Stearns No. 2 coal
V
Marine beds between Hazel Patch Sandstone and Livingston Conglomerate
IV
Marine beds in the Middlesboro Member
III
Marine beds associated with the Livingston Conglomerate
II
Marine beds associated with or above the Olive Hill Clay bed
I
Marine beds below the Cumberland Gap coal

The term "marine beds," as used in this index actually refers to marine and brackish beds.

Figure 22. Continued. Explanation of marine zones. The term "marine beds" as used in this index actually refers marine and brackish beds.

and Knapp, 1966). and holothurian sclerites (Summerson and Campbell, 1958). Cavoroc and Ferm (1968) investigated 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; Brand, 1981a, 1981b).

Present data (Fig. *22)* indicate that the marine contribution to the sedimentary record is greater than previously thought. Most of the marine beds identified in this study have not been recognized as such in the lithologic descriptions of geologic quadrangles. A preliminary examination of available literature suggests that the extent of marine-dominated depositional environments can be determined in a general way in the coal-bearing rocks of eastern Kentucky by plotting their occurrences 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 distribution 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 siltstone 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 eastern Kentucky. Many marine sediments, however, were deposited in small marine embayments separated laterally by distributary and other terrestrial clastic sediments; these units are commonly difficult to trace laterally. Rice andothers (1979, p. F19) suggest that some discontinuous marine sequences were probably deposited in tidal channels or small bays perhaps tens of kilometers 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-regressive 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 Irequently 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 calcareous 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 concretions, though the laminations are more compacted in the host rock. Although the concretions often occur along definite horizons within a coarsening upward sequence, many can he 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, therefore 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 controlled by the orientation of clay minerals (bedding). Migration would be slower in a direction normal to bedding. The concretions almost invariably show calcite-filled cracks due to de-watering and shrinkage. The concretions are fossiliferous when they occur in fossiliferous strata. Calcite is often in great enough proportion to classify the rock a limestone, although varying amounts of calcite and siderite are found. The mineralogical content of the concretions is variable, but the clastic content always matches the host rock. These calcareous concretions were formed by early diagenetic

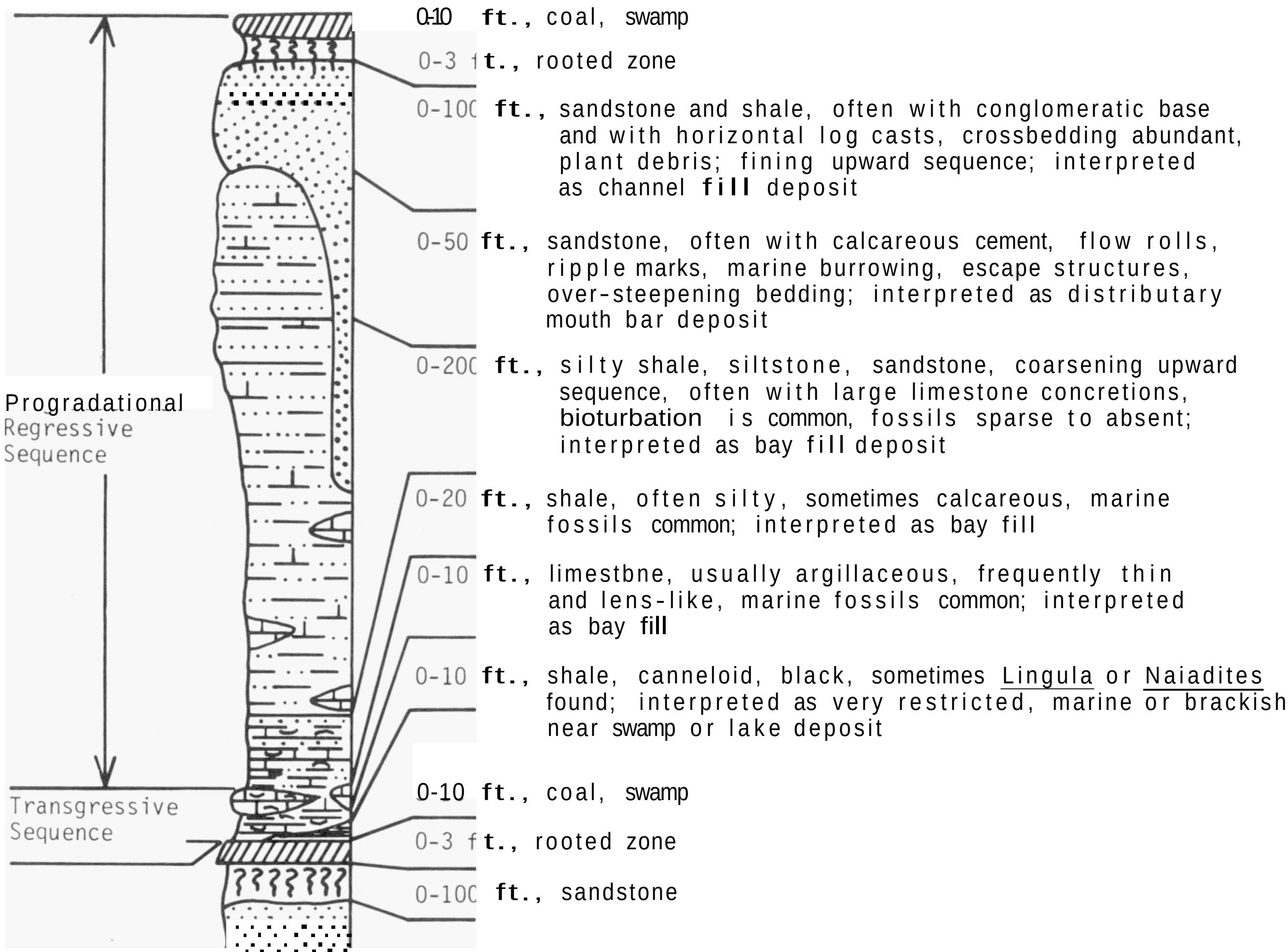


Figure 23. Generalized stratigraphic column of a marine zone

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.

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

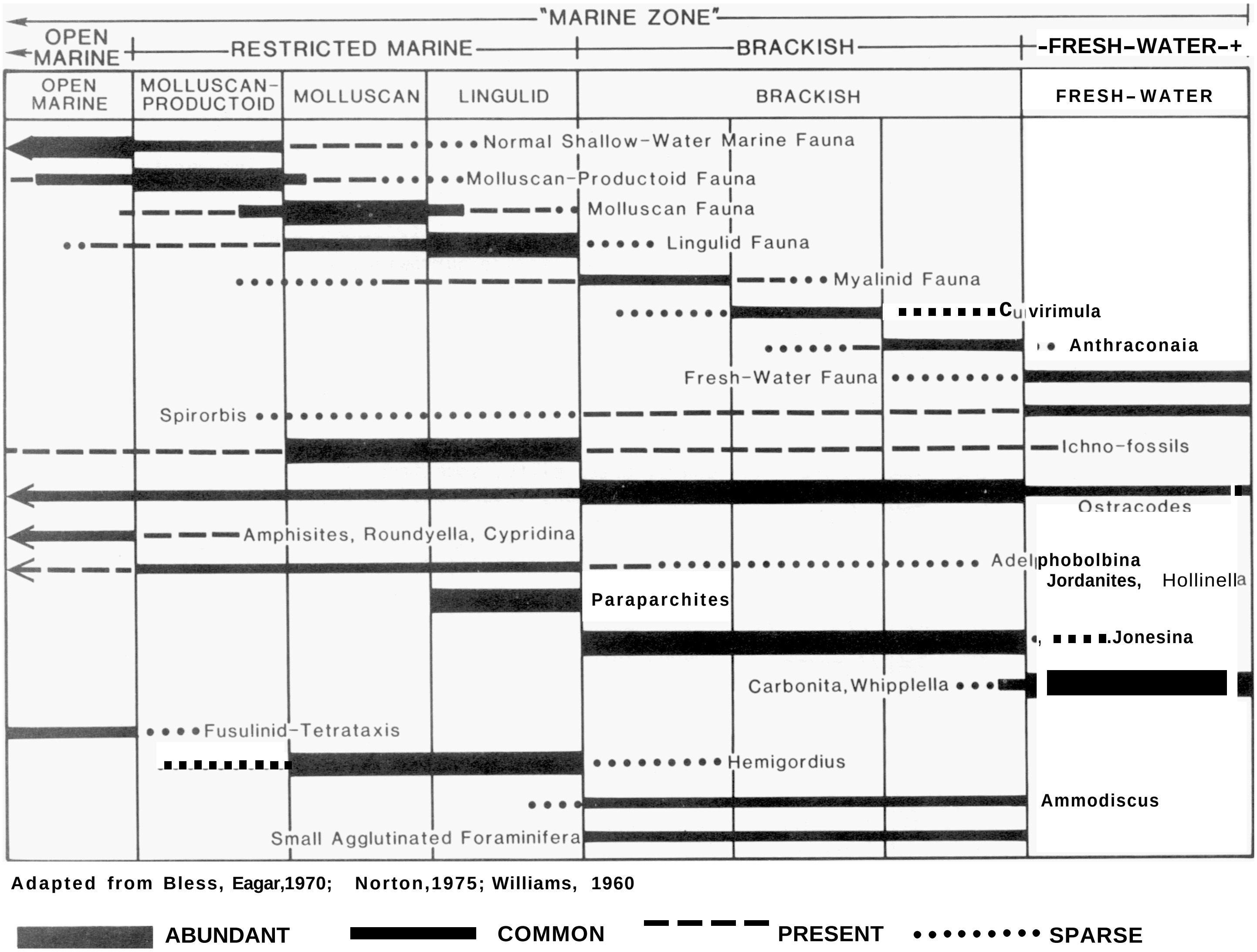


Figure 24. Preliminary environmental range chart of common taxa.

lateral symmetry, and is smooth, while a valve *Anthraconaia* is not symmetrical and has rougher concentric growth ridges. These pelecypods are frequently found in large numbers pyritized in brittle, black, fissile shale, often in association with *Calamites* stems. Perhaps the *Anthraconaia* grew on stems or floating algae overlying environments having anaerobic reducing conditions. They were preserved and pyritized when they settled to the sediment surface. Some forms of the pelecypod *Dunbarella,* which lived in more saline conditions, are found in similar black shales and may also have lived in a similar manner.

Lingula

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

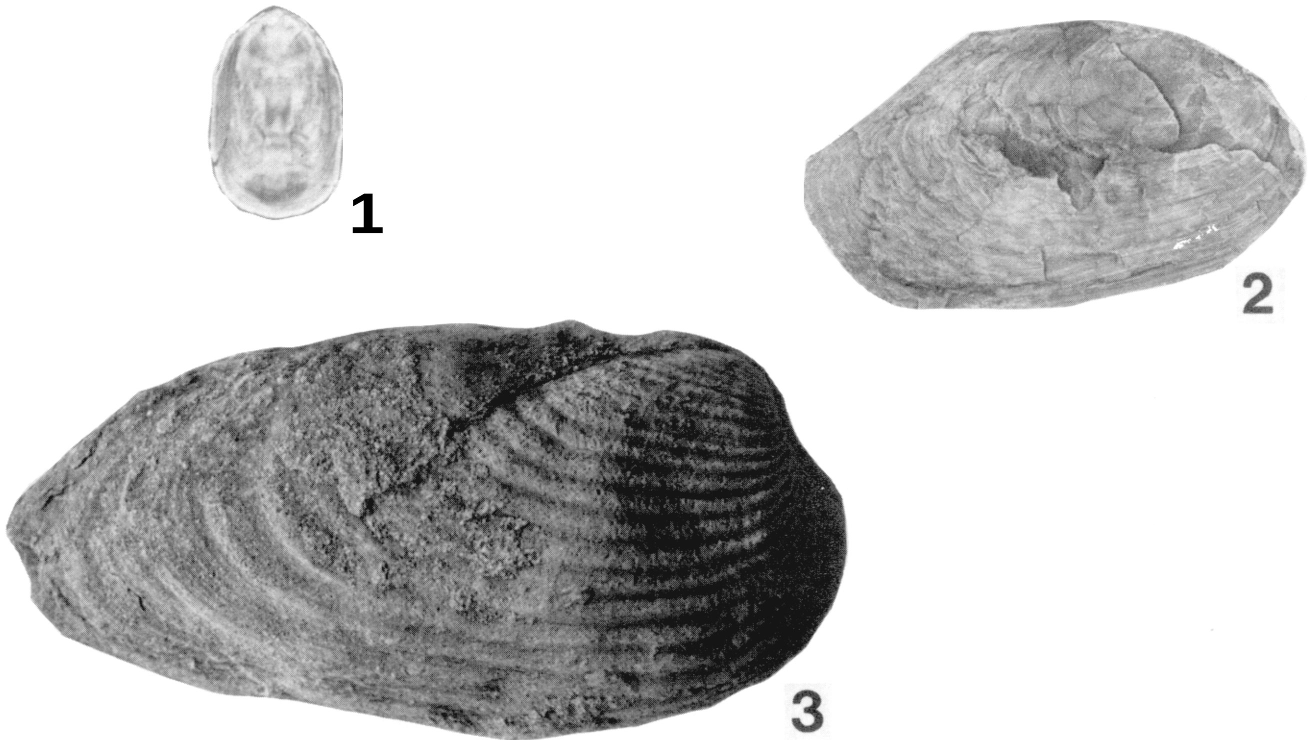


Plate 17. Upper Carboniferous fossils of Kentucky

Figure 1. *Lingula carbonaria,* pyritized, from the Pennsylvanian of western Kentucky. X1.4

Figure 2. *Anthraconaia (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 unacomm-panied by other brachiopods is not a reliable indicator of brack-ish 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 aspecfs 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 re-placed 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 paleon-tology of the Pennsylvanian and its depositional frame-work. Studies have shown that the quality of coal can be related to environments of deposition. Currens (this volume), among others (Hester and Leung, 1978; Wil-liams and Keith, 1963), shows in his work on coal qual-ity 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 tor 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 rnay 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 dis-tribution of these marine zones (this study examined only surface data). Closer examination of the fossil distribution and the environments they indicate rnay help in determining proximity to shore (Stevens, 1971; Cavaroc and Ferm, 1968) and thus a better understand-ing of the lateral extent of the marine zones.

REFERENCES CITED

Bless, M. D. M., 1970, Environments of some upper Carboniferous coal-basins (Asturias, Spain; Lim-burg, Netherlands): Compte Rendu, 6me Congress International Stratigraphie et Geologie Carbonifere, Sheffield 1967, 11, p. 503-516.

Brand, Uwe, 1981a, Mineralogy and chemistry of the Lower Pennsylvanian Kendrick fauna, eastern Ken-tucky, part 1. Trace elements: Chemical Geology, v. 32, p. 1-16.

Brand, Uwe. 1981b. Mineralogy and chemistry of the Lower Pennsvlvanian Kendrick Fauna, eastern Ken-tucky, part 2. Stable isotopes: Chemical Geology, v. 32, p. 17-28.

Caruccio, F. T., Ferm. J. C., and Horne, J. C.. 1976, Paleoenvironments of coal and its relation to drain-age quality: U. S. Environmental Protection Agency, Final Report, 90 p.

Cavarco, V. V., and Ferm, J. C., 1968, Siliceous spiculites as shoreline indicators in deltaic se-quences: Geological Society of America Bulletin, v. 79, p. 263-272.

Cumbee, Gilbert, In preparation, Depositional environ-ments of the interval between the Hazard coal and the Hazard No. 7 coal in the Breathitt Formation (M. Pennsylvanian) in a part of eastern Kentucky: Rich-mond, Eastern Kentucky University, M.S. Thesis.

Dennis. A. M., 1975, Bay-fill paleoecology in the Carbo-niferous of eastern Kentucky: Columbia, University of South Carolina. M.S. Thesis.

Despard, T. L., 1974, Avoid problem spoils through overburden analysis: U. S. Department of Agricul-ture Forest Service General Technical Report NE-10, 4 p.

Eagar. R. M. C., 1970, Preliminary notes on some near Pennsylvanian marine and non-marine faunas in the eastern U. S. A.: Compte Rendu, 6me Congress In-ternational Stratigraphie et Geologie Carbonifere, Sheffield, 1967, v. 11, p. 679-694.

Eagar, R. M. C., 1973, Variation in shape of shell in rela-tion to paleoecological station in some non-marine Bivalvia of the coal measures of south-east Kentucky and of Britain: Compte Rendu, 7e. Congress Interna-tional Stratigraphie et Geologie Carbonifere, Krefeld. 1971, v. 2, p. 387-416.

Ferm, J. C., Horne, J. C., Swinchatt, J. P., and Whaley. P. W., 1971, Carboniferous depositional environments in northeastern Kentucky: Guidebook and roadlog. Annual Spring Field Conference, Geological Society of Kentucky: Kentucky Geological Survey. ser. 10, 30p.

Furnish, W. M., and Knapp, W. D., 1966, Lower Pennsylvanian fauna from eastern Kentucky; pt. 1, Ammonoids: Journal of Paleontology, v. 40, no. 2, p. 296-308.

Garrison, R. K., 1977, Paleoenvironmental analysis of the Lost Creek Limestone and associated facies: Marine and non-marine: Cincinnati, Ohio, University of Cincinnati, M.S. Thesis, 338p.

Henry. T. W., and Gordon, MacKenzie. Jr., 1979, Late Devonian through Early Permian (?) invertebrate faunas in proposed Pennsylvanian System stratotype area, *in* Englund, K. J., Arndt. H. H., and Henry, T. W., 1979, Proposed Pennsylvanian System stratotype, Virginia and West Virginia: Field Trip No. 1. Ninth International Congress of Carboniferous Stratigraphy and Geology, The American Geological Institute, p. 97-103.

Hester, N. C., and Leung. S., 1978, Prediction of sulfur in coal-bearing rocks; its bearing on reclamation: Institute for Mining and Minerals Research, University of Kentucky, Lexington, Kentucky.

Horne. J. C., and Ferm. J. C., 1976, Carboniferous depositional environments in the Pocahontas Basin; eastern Kentucky and southern West Virginia: Field Guidebook, Department of Geology. University of South Carolina, Columbia, South Carolina, 129 p.

Jillson. W. R., 1919, The Kendrick Shale – a new calcareous fossil horizon in the coal measures of eastern Kentucky, *in* Mineral and Forest Resources of Kentucky: Department of Geology and Forestry, ser. 5, v. 1, no. 2. p. 96-104.

Ketani. R. V., 1980, Petrology of the Magoffin Beds of Morse (1931) along Daniel Boone Parkway in Kentucky: Richmond, Eastern Kentucky University. M.S. Thesis.

McFarlan, A. C., 1943, The geology of Kentucky: Kentucky Geological Survey, 531 p.

Morse, W. C., 1931, The Pennsylvanian invertebrate fauna of Kentucky, *in* Jillson, W. R., The paleontology of Kentucky: Kentucky Geological Survey. p. 295-349.

Phalen, W. C., 1912, Description of the Kenova 30-minute quadrangle, Kentucky-West Virginia-Ohio: U. S. Geological Survey Geological Atlas of the United States, Folio 184.

Ping, Russell, 1978, Stratigraphy and structural relationships of the Stoney Fork Member of the Breathitt Formation in southeastern Kentucky: Lexington, University of Kentucky, M.S. Thesis.

Rice, C. L., 1980, The Kendrick Shale Member of the Breathitt Formation, *in* Changes in stratigraphic nomenclature, United States Geological Survey, 1979: U. S. Geological Survey Bulletin 1502-A. p. A117-A122.

Rice, C. L., Edward, G., Dever. G. R., Jr., and Kehn. T. M., 1979, The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States – Kentucky, *in* The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States: U. S. Geological Survey Professional Paper, 1110-A-L, p. F1-F32.

Rogers, M. J., 1965, A revision of the species of nonmarine Bivalvia from the upper Carboniferous of eastern North America: Journal of Paleontology, v. 39, p. 663-686.

Rudwick, M. I. S., 1965, Ecology and paleoecology. *in* Moore, Raymond, ed.. Brachiopoda, part H. Treatise on invertebrate paleontology: Geological Society of America, p. H199-H214.

Scott, H. W., and Summerson. C. H., 1943, Nonmarine Ostracoda from the Lower Pennsylvanian in the southern Appalachians, and their bearing on inter-continental correlation: American Journal of Science, v. 241, no. 11, p. 653-675.

Stevens, C. H., 1971, Distribution and diversity of Pennsylvanian marine faunas relative to water depth and distance from shore: Lethaia, v. 4, p. 403-412.

Strimple, H. L., and Knapp. W. D., 1966, Lower Pennsylvanian fauna from eastern Kentucky: Pt. 2, crinoids: Journal of Paleontology, v. 40, no. 2, p. 309-314.

Summerson, C. H., and Campbell, L. J., 1958, Holothurian sclerites from the Kendrick Shale of eastern Kentucky: Journal of Paleontology, v. 32, no. 5, p. 961-969.

Walter, J. R., 1979, Interpretation of paleogeography and depositional environments for the Ames and Brush Creek Marine Horizons, Conemaugh Formation (Pennsylvanian) in northeastern Kentucky: Richmond, Eastern Kentucky University, M.S. Thesis.

Wetmore, C. C.. 1978, Petrographic analysisof the Flint Ridge Flint of the Upper Member of the Breathitt Formation (Pennsylvanian) in Breathitt and Magoffin Counties in east-central Kentucky: Richmond, Eastern Kentucky University. M.S. Thesis

White, I. C., 1885, Nomenclature of Appalachian coal beds: The Virginias, v. 6, p. 7-16.

Williams, E. G., 1960, Marine and fresh water fossiliferous beds in the Pottsville and Allegheny Groups of western Pennsylvanian: Journal of Paleontology, v. 34, no. 5, p. 908-922.

Williams, E. G., and Keith, M. L., 1963, Relationships between sulfur in coals and the occurrence of marine roof beds: Economic Geology. v. 58, p.