Transgressions and Regressions of Early Allegheny (Pennsylvanian) Seas in Indiana

HAYDN H. MURRAY,[1] Indiana University

Introduction

The cyclical nature of Pennsylvanian sediments was recognized by many early workers including Udden (5) and Stout (4). Moore (2), Weller (12, 13), Wanless (6, 7), and Cline (1) described Pennsylvanian successions in central and east-central United States. Recently, Wanless and Patterson (9) have described cyclic sedimentation in the marine Pennsylvanian of southwestern United States.

Many correlations have been based on groups of repetitive beds sometimes called cyclothems. Wanless and Weller (11) defined a cyclothem as a series of beds deposited during a single sedimentary cycle of the type present in the Pennsylvanian period. In stratigraphic nomenclature a cyclothem ranks as a formation. Wanless (7) correlated many of the Pennsylvanian rocks on the basis of cyclothems. Pennsylvanian correlations are always difficult because the character of the sediments changes rapidly. For example, coals thicken and thin in relatively small areas, limestones vary in lithology and thickness and are often cut out by unconformities. Facies changes are common in the Pennsylvanian sedimentary rocks.

Regional Cyclothemic Patterns

Weller (12) described a cyclothem of ten members, occurring in western Illinois in the following order:

10. Gray shale with clay ironstone bands or nodules.
9. Marine fossiliferous limestone and calcareous shale.
8. Black, slaty shale, frequently with large black spheroidal limestone concretions containing marine fossils.
7. Marine limestone or shale.
6. Gray, non-calcareous shale without marine fossils and commonly with plant fossils.
5. Coal.
4. Underclay, non-laminated, with at least the upper part generally non-calcareous.
3. "Fresh-water" limestone, generally nodular, discontinuous, and unfossilferous.
2. Sandy shale.
1. Sandstone, in some instances conglomeratic and locally resting on erosional surfaces.

[1] Dr. H. H. Murray is now Director of Applied Research, Georgia Kaolin Company, Elizabeth, New Jersey.

The members 1 (sandstone), or 2 (sandy shale), 4 (underclay), 5 (coal), 8 (black shale), 9 (limestone) and 10 (gray shale) are the most persistent units and, therefore, the most commonly encountered in Indiana. Wanless (8) stated that studies in other parts of the United States have shown that the succession described by Weller is not characteristic of the Pennsylvanian throughout any large area. Individual members thin out or change in lithology so that over widely separated areas the sedimentary rocks will be cyclic in nature but the lithology may differ. In the southwestern portion of the United States the Pennsylvanian rocks are dominantly marine. In Arizona and New Mexico, Pennsylvanian rocks are almost wholly marine, in Kansas they are about 40 to 75 percent marine, in Illinois and Indiana 10 to 25 percent marine, and in West Virginia they may range from less than 1 percent to nearly 5 percent marine (8).

Wanless (8) listed four broad factors which influence the depositional pattern in a locality.

1. Relief and lithology (the proximity, extent, relief, and lithologic make-up of the nearby lands yielding detrital particles).
2. Depositional environment (whether the locality across which the strand line migrated was generally above or below sea level).
3. Rate of downwarping of the depositional basin.
4. Climate (the climate in the depositional basin, in the area of derivation of sedimentary particles and in the area through which these particles were transported).

The cause for the repetitive cycles present in the Pennsylvanian rocks has been explained in numerous ways. Stout (4) attributed the cycle to intermittent subsidence. Weller (12) believed the cycle resulted from diastrophism involving both uplift and subsidence. Wanless and Shepard (10) proposed that the depositional basins were subsiding intermittently in conjunction with eustatic shifts in sea level caused by alternate growth and waning of Gondwana glaciation.

Cyclothemic Patterns in Western Indiana

In work completed on the Pennsylvanian underclays and shales along the eastern edge of the Eastern Interior basin, some anomalies in the succession of marine and non-marine beds have been noted. These anomalies can best be explained by transgression and regression of the Pennsylvanian seas across the area along the eastern edge of this basin. On Figure 1 a typical marine transgression is exemplified by the members which include the "Minshall" coal (Rock Island Coal of Western Illinois (7)).

The arenaceous shale was considered by Weller to be non-marine, i.e., deposited in relatively fresh water. Some workers consider underclay to be the old soil on which the vegetation grew to form the coal. Coal is characteristic of a swamp or paludal environment. The marine invasion started with the deposition of the black fissile shale which is

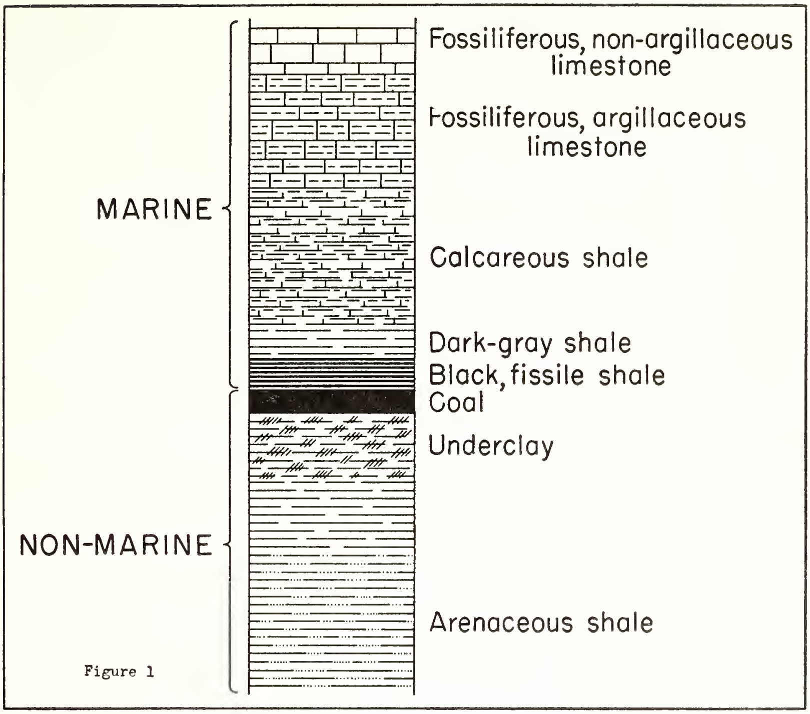

Figure 1. Cyclothem in Western Indiana which includes the Minshall coal.

characteristic of a restricted, brackish water environment. This black shale grades upward into a marine fossiliferous shale and limestone which represents marine conditions with open circulation. The fossiliferous limestone appears clastic in many places which presumably indicates that it was deposited above wave base. Such a non-marine through marine sequence is evident in the Linton formation (14) in the members underlying Coal IIIa and in the Petersburg formation including Coal IVa and Coal V.

If sea level were eustatically shifted a regressive phase of deposition should be evident in some of the Pennsylvanian rocks. This regressive phase should logically have a sequence of members which is partly reversed from those shown for the typical marine transgression. In a regressive sequence the marine portion would be below the coal and the non-marine portion above it. This sequence of beds might be generalized as shown on Figure 2.

The cyclic repetitions of members instead of being non-marine-coal-marine-non-marine-coal-marine would be non-marine-coal-marine-coal-non-marine-coal, etc. (Figure 3). The sequence would be marine between two coals and non-marine between the next two if the transgressions and regressions of the sea were cyclic.

Many of the numbered coals of Indiana have rider coals above them, which are generally relatively thin, and many of the rider coals are

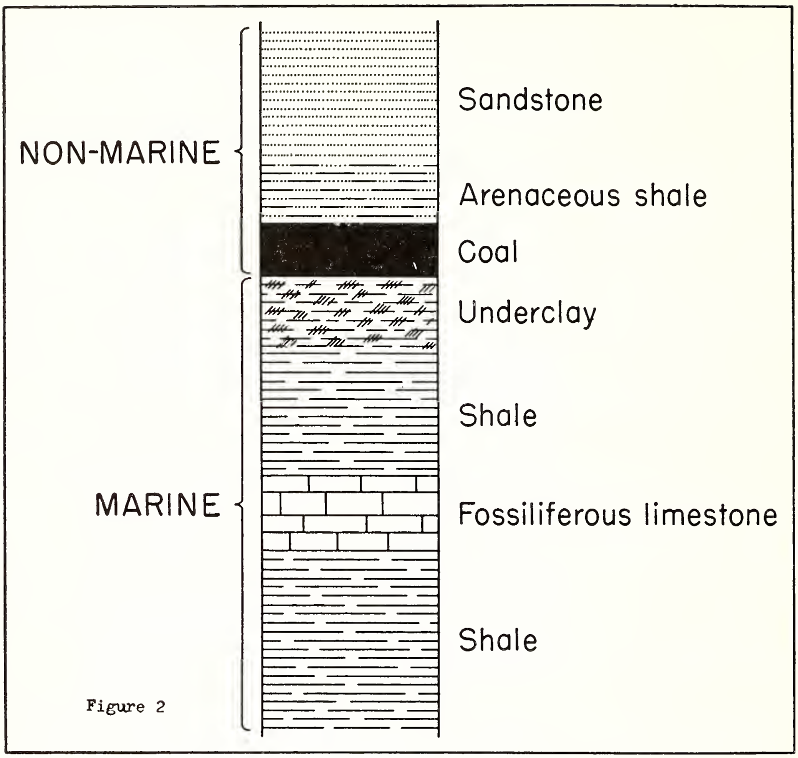

Figure 2. Generalized sequence showing reversal of normal cyclothem.

overlain by gray shale. Some of the rider coals without the normal black fissile shale overlying them may represent the regressive phase of deposition. Other rider coals have black fissile shale and marine limestone above them and represent the marine transgressive phase of the cyclothem. An example of a sequence in Indiana which includes both the transgressive and regressive phases is in the Staunton, Linton, and Petersburg formations (all Alleghenian in age) (Figure 4).

Wilson pointed out (15) that marine limestones are found below the underclay in some cyclothems. The Universal limestone underlies Coal VII and a thin limestone underlies a rider coal to V, both coals of the Dugger formation in Indiana. The presence of these underclay limestones, as Wilson has called them, can best be explained in many instances by regressive phases of deposition. Further analyses of underclay formation, mineralogy and geochemistry of shales, and spores in coals will have to be made to substantiate fully the idea of transgressive and regressive deposition. A study of the underclays and shales is in progress in the author's laboratory. This study has revealed that the illite content of the shales in the marine sequence is generally higher

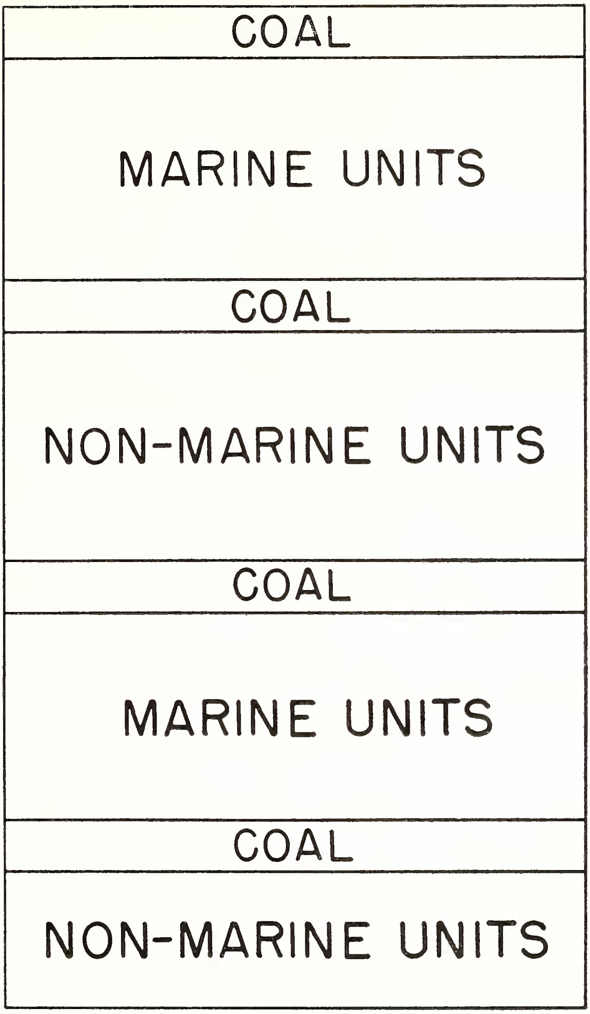

Figure 3

Figure 3. Idealized sequence indicating alternate transgressions and regrssions.

than it is in the non-marine sequence. Murray (3) and others have pointed out that illite is the dominant clay mineral in most marine shales.

In conclusion, it must be emphasized that this transgressive and regressive sequence of deposition is postulated only in a limited area along the eastern edge of the Eastern Interior basin, but other geologists should look for similar evidence in areas where Pennsylvanian sedimentation occurred on the unstable intracratonic shelf areas.

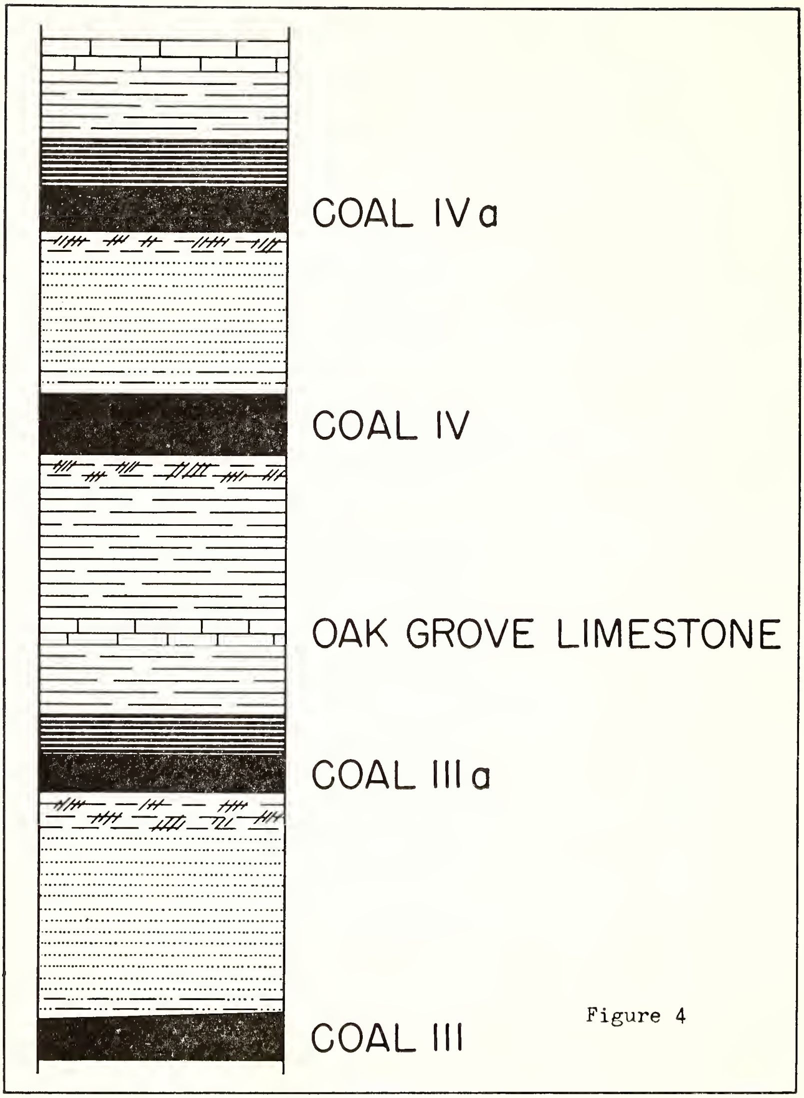

Figure 4. Cyclothems in western Indiana best explained by alternate

Summary

Recent lithologic investigations in the lower part of the Allegheny series in western Indiana indicate that the sediments were deposited in transgressive and regressive seas that resulted in an ascending sequence of nonmarine beds—coal (developed in front of the transgressive sea)—marine beds—coal (developed behind the regressive sea)—nonmarine beds, etc. This sequence suggests that deposition occurred under conditions of marine transgressions and regressions along the eastern fringe of the Eastern Interior basin in early Alleghany time.

Transgressive-regressive conditions prevailed in restricted areas of subdued relief that were intermittently occupied by shallow, epicontinental seas. Such conditions, briefly maintaining in early Allegheny time in western Indiana, developed the following generalized stratigraphic sequence: (1) Arenaceous shale and/or sandstone, (2) underclay developed on non-marine material, (3) coal, (4) black fissile shale, (5) fossiliferous shale, (6) fossiliferous limestone, (7) argillaceous shale, (8) thin nodular limestone, (9) underclay developed on marine material, (10) coal, and (11) arenaceous shale and/or sandstone, lithologically similar to (1).

Literature Cited

1. CLINE, L. M. 1941: Traverse of upper Des Moines and lower Missouri series from Jackson county, Missouri to Appanoose county, Iowa. Amer. Assoc. Petrol. Geologists, Bull. 25: 23-72.
2. MOORE, R. C. 1936: Stratigraphic classification of the Pennsylvanian rocks of Kansas. Kansas Univ. Bull. 22: 256.
3. MURRAY, H. H. 1954: Genesis of clay minerals in some Pennsylvanian shales of Indiana and Illinois. Proc. 2d Natl. Clay Conf. Natl. Research Council: 47-67.
4. STOUT, W. 1931: Pennsylvanian cycles in Ohio. Illinois State Geol. Survey Bull. 60: 195-216.
5. UDDEN, J. A. 1912: Geology and mineral resources of the Peoria quadrangle, Illinois. U. S. Geol. Survey Bull. 506: 103.
6. WANLESS, H. R. 1931: Pennsylvanian cycles in western Illinois. Illinois State Geol. Survey Bull. 60: 179-93.
7. ————. 1939: Pennsylvanian correlations in the Eastern Interior and Appalachian coal fields. Geol. Soc. America. Spec. Paper 17: 130.
8. ————. 1950: Late Paleozoic cycles of sedimentation in the United States. Inter. Geol. Cong. Report of the 18th Session, Britain 1948, Part IV: 17-28.
9. ———— and J. PATTERSON. 1951: Cyclic sedimentation in the marine Pennsylvanian of the southwestern United States. Extrait du Compte Rendu, Troisieme Congres de Strat. et de Geol. du Carbonifere-Heerlen: 655-664.
10. ———— and F. P. SHEPARD. 1936. Sea level and climatic changes related to Lake Paleozoic cycles. Bull. Geol. Soc. America. **47**: 1177-1206.
11. ———— and J. M. WELLER. 1932. Correlation and extent of Pennsylvanian cyclothems. Bull. Geol. Soc. America **43**: 1003-16.
12. WELLER, J. M. 1930: Cyclical sedimentation of the Pennsylvanian period and its significance. Jour. Geology. **38**: 97-135.
13. ————. 1931: The conception of cyclical sedimentation during the Pennsylvanian period. Illinois State Geol. Survey Bull. 60: 163-77.
14. WIER, C. E. 1952: Geology and mineral deposits of the Jasonville quadrangle, Indiana. Ind. Dept. Cons. Geol. Survey Bull. 6: 34.
15. WILSON, G. M. 1951: Underclay limestones. Bull. Geol. Soc. America. **62**: 1490.
transgressions and regressions.