THE CYCLICAL BLACK SHALES

WALTER G. PETERS*

Black shales of the Pennsylvanian System of west central Illinois were examined in a paleoecological study using micro-radiographic (X-ray) and photographic techniques. Over 80 different fossil varieties were tentatively identified, including a proposed new conodont species, Metalonchodina magnidentatus, Peters, a small Pennsylvanian Onychophore(?), and several freshwater Algae.

Study methods included gross and macrophotography, microscopic examination of thin shale chips, and photomicrographic inspection of X-rays of shale samples. The radio-photomicrographic technique supplemented and bypassed the usual practice of crushing and chemically disaggregating the shale to extract the microfossils. Structural details could be observed in fossil elements in X-ray negatives rotated on the stage of the polarizing microscope set at or near crossed nicols.

Cyclical deposition was indicated by the structural details of the shale as well as by the virtually mutually exclusive occurrence of foraminifera and conodonts in successively alternating bedding planes and black shale matrix. Rapid transport and burial was implied from the following observations: Orbiculoidea shells packed into lenses up to one inch thick; microlaminations apparently interrupted by small coal balls; and the distorted bedding, both at the bottom and the top of the shale member.

All of the reported observations strongly support the Biblical tidal interpretation of fossil deposition and burial.

Introduction

Several Pennsylvania black shales were studied and used as the basis of a thesis submitted in partial fulfillment of the requirements for a degree of Master of Science in Education to the Geology Department and Graduate School of Northern Illinois University, DeKalb, Illinois. The research was initiated during the Fall of 1968, and for purposes of the Thesis was completed during the Fall of 1969 and presented in 1970.[1] Since that time, all the X-Ray negatives (radiographs), samples, and notes have been rechecked and updated into a manuscript entitled, "Challenge of Black Shale Radiography."

The most significant result of the study was the establishment of the cyclical nature of black shale sedimentation. Other important observations were the sudden change from land to sea or marine-type fossils; the black-gray shale laminations indicating short-period (time duration) sediment changes; the occurrence of possible fresh-water algae at the bottom and the top of the shale member; the proposed presence of soft-bodied worm-like Onychophores in Pennsylvania rock layers; the two-fold use of the X-Ray negative (Radiograph) technique; and the proposal of a new "species" of conodont (small, still-puzzling toothed fossil elements).

Material and Methods

The shale studied in detail was hard, compact, sheety (fissile), highly carbonized and very dark gray to black in color. Most of the samples were obtained in Fulton County, in west-central Illinois. This shale *(Member 98* of Wanless)[2] directly overlies a widely mined coal seam, the Springfield or Harrisburg (No. 5) Coal (see Figure 1). It is thought to be Unit No. 8 of the St. David Cyclothem, correlated with the middle section of the Carbondale Group (Illinois nomenclature) and with the middle-late Desmoinesian Stage of the Middle Pennsylvanian System (Period).

On a nation-wide scale this shale is associated with the following deposits and geological "events": Washingtonville deposits of the Allegheny Group in the Appalachian region; Ouachita mountain fault blocks and volcanic deposits; Uncompaghra Arch deposits from northeast Utah to north-central New Mexico; and deposits of the "uplift" of the Front Range of the Rocky Mountains (formation of some of the Hogbacks facing the Rockies) in central and northeastern Colorado and southeastern Wyoming, including the uplift of the Laramie Mountains.

Three basic techniques were used: (1) gross and macrophotography of shale at sample sites and of shale samples; (2) examination of shale samples using stereoscopic and regular microscopes; and (3) microscopic examination and photography of images in X-Ray negatives (Radiographs). A fourth technique (X-Ray Diffraction) was used only once to determine the principal component of the distinctly granular gray lenses, that contrasted so sharply with the black shale matrix of the lowermost and topmost layers of our black shale, Member 98. Most of the photomicrographs were taken with a Carl Zeiss Automatic Photomicroscope in the University Geology Laboratory or through a Unitron Polarizing microscope Model MPS with a SLR camera.

With a good Stereo-microscope one can frequently see a three-dimensional panoramic view of the shale matrix and its imbedded microfossils.

*Walter G. Peters, M.S.Ed. in Geology, is the Earth Science Instructor at Spoon River College, Canton, Illinois 61520.

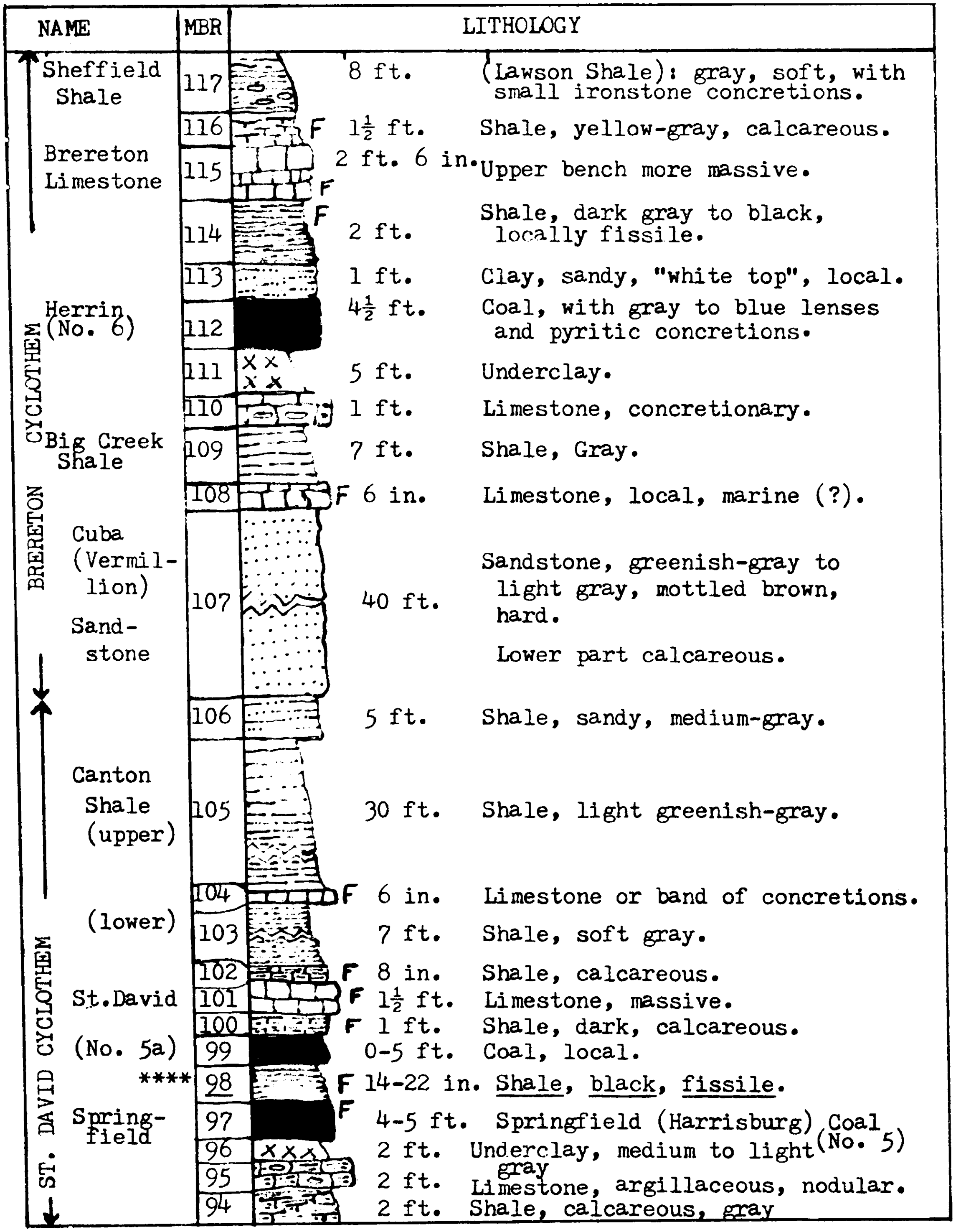


Figure 1. Generalized stratigraphic sequence of the St. David and Brerton Cyclothems in western Illinois. F: fossiliferous. Adapted from Wanless (1958, pp. 11, 12) and Kosanke, et. al. (1960, pp. 65, 66).

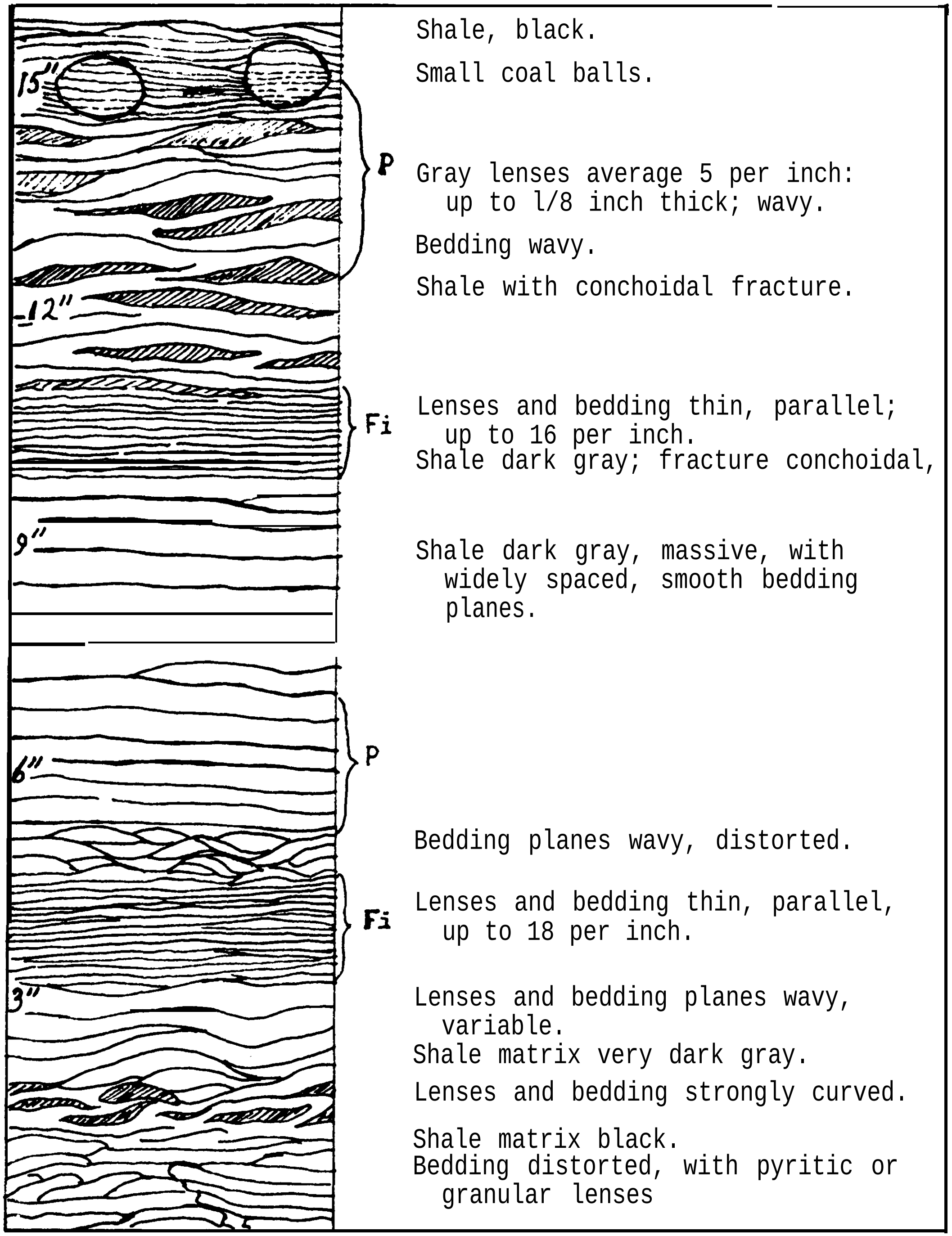


Figure 2. Composite section of the black shale overlying the Springfield (No. 5) Coal, Fulton County, Illinois. P: Platform conodonts; Fi: Very fine lenses and bedding planes.

If the radiograph can be cut and taped to a 3 x 4-inch section of plate glass, it can be rotated on the stage of a polarizing microscope without scratching the X-Ray negative (radiograph). With the polarizing microscope set at or near crossed nicols, the negative can then be rotated from a position of maximum interference (brightest field) toward "extinction" (darkest field). As this is done, cellular and structural details of specimens otherwise overlooked are evident.

Massive pieces of shale about 15 to 16½ inches thick (Figure 2) and having a total area of about eight square feet were obtained *in situ* from open pits of operating coal mines. The total volume of these pieces was about 12 cubic feet. These were then chiseled into thin chips (individual samples) 1/8-inch to 1-inch in thickness. Each chip was numbered and fossil elements were marked-off for more careful identification and tabulation.

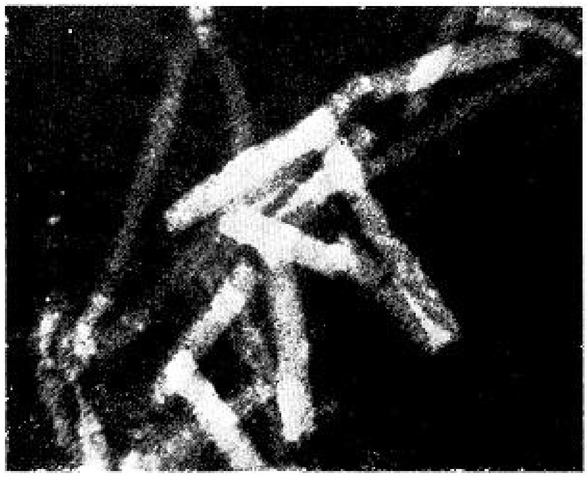


Figure 3. *Cladophora.* Sample 200A. 49 X magnification. Radioautograph.

Cyclical Deposition

Black shale, Member 98 of the St. David Cyclothem (Pennsylvanian System), exhibits a cyclical change in shale structure and fossil components. The bedding planes are most strongly distorted, the gray granular lenses are thickest and most prominent, and the black shale matrix is the darkest (blackest) at the lowermost and topmost levels (see Figure 2). The bedding planes are the straightest, the gray granular lenses and microlaminations are the thinnest, and the dark gray shale matrix layers are the thickest in the "massive" central section of the Member.

In two levels of the shale member, the 3-inch and the 10 to 11 inch levels, the lenses and bedding are thin, parallel, and up to 16 to 18 levels per inch. These microlaminations measure about 1/50 of an inch (0.5 mm) in thickness. The persistent alternation of the "black" and "gray" microlaminations strongly suggests alternating sources of sediment laden water.

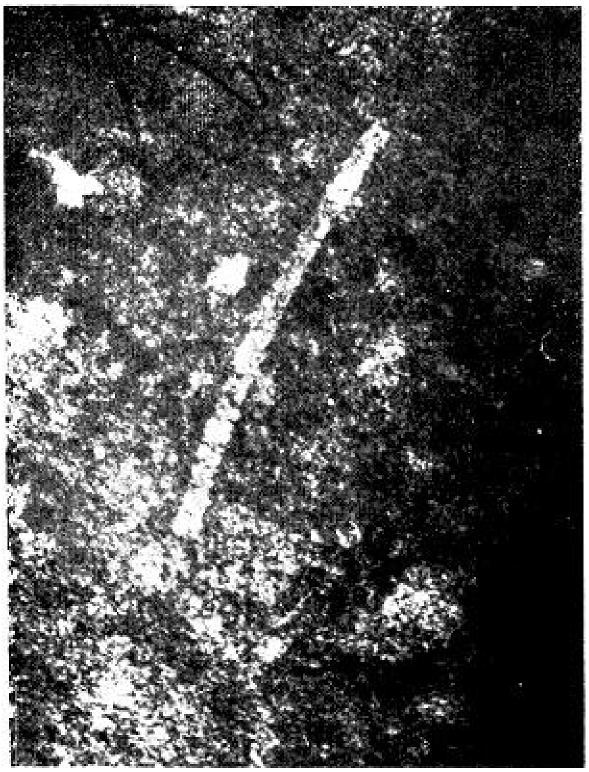
This is further emphasized by the nearly complete segregation of "protozoan" foraminifera and conodonts into different layers throughout the vertical depth of the shale. Foraminifera are very small shelled protozoans and many species are used as index fossils. The exact affinities of the conodonts is still being debated. They are minute, phosphatic fossils that in general either have "toothed" bars or "blades" attached to a spoon shaped platform. The conodonts were found nearly exclusively in the black shale matrix, while the foraminifera were found nearly exclusively in the gray granular lenses, which were mainly composed of Wilkeite, an intermediate Apatite with the chemical formula $Ca_5[(P, S, Si, C)O_4]_3 \cdot OH$.

The time duration of deposition of these alternative layers, especially the microlaminations, must have been short, perhaps only hours or even minutes. This conclusion results from consideration of (1) the lack of any evidence of erosion in any of the layers, (2) lack of gradation in degree of compaction, (3) inclusions continuing through several to many layers or laminations (as with coal balls to be discussed later).

Other fossil changes as the shale increases in depth above the coal suggest a rapid change from a land environment to a marine and probably back to a nearly emerged land environment. Put another way, this might reflect a tidal sea advance and retreat. What appear to be freshwater algae *(Cladophora, Draparnaldia,* and *Oscillatoria)* (see Figures 3, 4, and 5) and tissue of coal-forming trees are abundant in the lowest inch of the shale. These are mixed with marine(?) *Orbiculoidea* and *Lingula* (inarticulate brachiopod) shells.

One lens of *Orbiculoidea* shells measured nearly l-inch in thickness, with up to 18 shells exposed per square inch of horizontal surface (sample 105.5/8). This thickness of *Orbiculoidea* shells closely packed into such a lens strongly suggests rapid transport of the shells to the burial spot (allochthanous deposition) (see Figure 6). Rapid burial is also suggested by the fine state of preservation in which the shells are found, most of them still possessing the pearly gray "mother of pearl" aragonite mantle layer.

Marine vertebrate fossil elements were not found below the 1¼-inch level of Member 98. At this level one barbed denticle of a *Listracanthus* (Elasmobranchian) shark was recorded from sample 107.1¼. All other fossil elements of marine Vertebrates (sharks and fishes) were recorded from the 3-inch and higher levels of the shale. These elements included skin denticles, scales and teeth of three different groups of sharks and one group of fishes, the Paleonis-



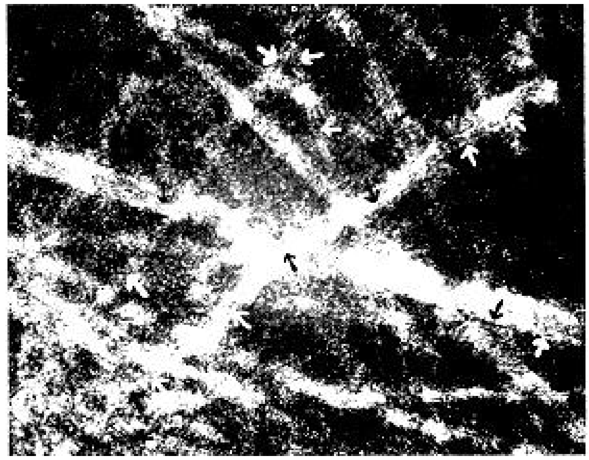


Figure 5. Possible *Oscillatoria*. Sample 107.1 $^{5}/_{8}$. (165 X) Radioautograph.

Figure 6. *Orbiculoidea*. (3.6 X) Shells tightly-packed. These number 18 to 22 per square inch of exposed surface.

abruptly in density per square inch of exposed sample surface and in radiographs at the 13 inch level and above. This level also roughly corresponds to the level of thicker gray granular lenses and increasingly distorted and wavy micro laminations and bedding planes. It also coincides with the level in which algal and fungal filaments reoccur. Finally at this level the soft-bodied fossil thought to be an Onychophore was excavated.

The controversial fossil, the Onychophore, a wormlike Arthropod, measures only 4.5 mm long, but seems to bear at least six pairs of retractile appendages. The end of each "appendage" bears six symmetrically positioned hooks or protuberances, which surround a central projection. The *head* appears to be a contraction of several segments, with a centrally located mouth surrounded by two pairs of laterally positioned appendages and an anterior appendage. Each of these "head"‘-appendages appears to be similar in structure to the body or abdominal appendages. Except for its small size, the specimen fits the description of the Pararthropod, *Onychophora* (see Figures 7 and 8).

This writer does not accept the suggestion that the fossil above may be a coprolite. The hypothetical organism, in excreting the "pseudofossil" above would have required of necessity, that its cloaca symmetrically arrange in paired positions digestive residue of nearly identical food-organisms. Secondly, no illustrations of fecal material yet observed by the writer have exhibited internal or external symmetry.

Figure 7. *Onychophora*. Sample 112-13.5. 16 X magnification.

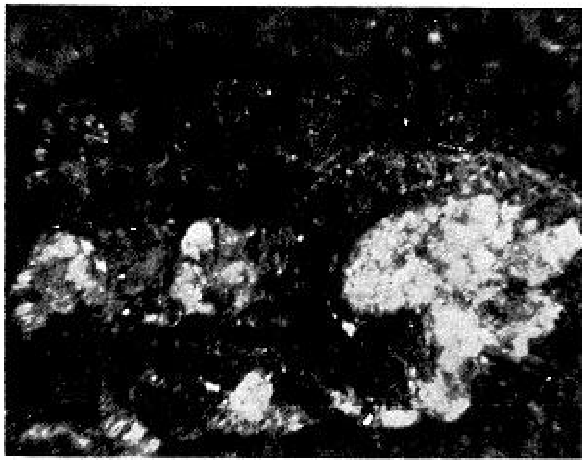


Figure 8. *Onychophora*. 27 X magnification.

A further indication of increased wave action was noted at the 15-inch level. Two small "coal balls" were recorded here (see Figure 9). One of the coal balls became dislodged exposing the inside walls of the cavity it once occupied. The bedding planes lining the cavity were essentially parallel, as they were around the coal ball remaining in the shale matrix. However, *all* bedding planes appeared to be distinctly interrupted by the coal balls. They did not diverge to form lenses around the coal balls as would be expected if the coal balls had originated as concretions.

The angles of the intervening and interrupted bedding planes strongly suggest that the coal balls were transported to their burial site. Their burial would therefore be allochthanous rather than autochthanous, refuting the widely taught concept that they, like the coal, are found where they were formed (or the trees grew). The rate of burial, furthermore, would be rapid rather than slow, probably within a period of minutes rather than of years, since no erosion of the coal balls was observed.

Radiographic Identification

Animal and plant fossil elements can at times be effectively identified in X-Ray negatives (radiographs). Several different kinds of conodents, foraminifera, brachiopods, ostracodes, algal filaments, (fungal hyphae ?), and tissue of coal-forming trees could be more or less readily identified in the radiographs. The conodont, *Hibbardella milleri*, Rexroad, was exactly identified by rotating it 220° and reexposing the shale sample. The second radiograph clearly showed the small anterior denticle specific for *H. milleri*, Rexroad (see Figure 10). Among other conodonts identified to the species, were *Streptognathodus* cf *eccentricus*, Ellison, and *Polygnathus* cf *cristata*, Hinde.

An identification which has evoked some interest and controversy is that of the two brachiopods, *Anoplia* and *Girtyella*. The brachiopods are still hidden within the shale matrix of Sangamon County sample 330A. Adjacent to the anterior and lateral edges of the *Girtyella* shell, the radiograph is distinctly darker than it is adjacent to the other brachiopod shells. Close examination reveals the presence of many Endothyroid foraminifera crowded around the brachiopod shell. The writer proposes that they were buried while crowding around the *Girtyella*, rather than settling in this crowded, clustered arrangement as a result of random drifting during deposition. The presence and locations of the Endothyroids are therefore submitted as further evidence of rapid, allochthanous burial (tidal burial).

Perhaps the most interesting plant remains observed in shale samples and radiographs are those of freshwater green and blue-green algae. Filaments apparently displaying distinctly cellular structure resembling *Draparnaldia*, *Cladophora*, and *Oscillatoria* (and possible fungal hyphae) occur in shale samples and radiographs from the lowermost and topmost levels of the Black Shale Member 98 (see Figures 3-5). Their absence in the intervening central massive sec-

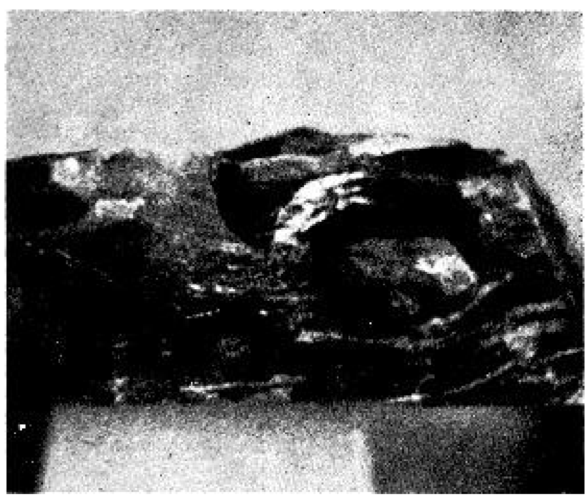


Figure 9. Coal balls in the 15-inch level of Member 98, series 140.

Figure 10. The conodont, *Hibbardella milleri* (Rexroad). Radioautograph. (46 X)

Figure 11. *Metalonchodina magnidentatus*, Peters. Sample 120.7. 62 X magnification.

tion of Member 98 suggests a temporary tide-like invasion or intrusion and retreat from the deposition area.

Member 98 was interpreted as a land-ward tidal intrusion of incoming ocean-water mixed with sea-ward moving freshwater causing the distorted bedding planes and microlaminations. As the sea-water level increased in height, it engulfed the deposition site; the tide-like waves becoming deeper and deeper until they deposited the massive central section, and then temporarily retreated from the deposition site causing the reversal of lamination structure. The result being that the laminations and bedding planes at the top of Member 98 were distorted and wavy, as were the bottom layers of the Shale Member. The incoming sea water would engulf the land-freshwater environment causing a mixture of fauna and flora; this mixture is what we apparently observed in the fossil distribution: land-sea mixture at the bottom and at the top of the Member.

Radiographic Population Counts

Shale samples from three other Illinois counties were obtained for comparison with samples from Fulton County, mainly for radiographic studies. In several of the radiographs, the numbers of conodont specimens recorded contrasted sharply with the numbers observed visually on the sample surfaces, as follows:

(a) Hamilton County sample 700C revealed 44 *Hibbardella* specimens in the X-Ray negative and *none* visually;

(b) Sangamon County sample 300C (the shale overlying the Herrin, No. 6, coal) revealed 60 *Hibbardella* specimens in the radiograph and *only* 5 visually;

(c) Gallatin County sample 200A revealed an extensive network of algal filaments and minute (radiolarian?) organisms in the X-Ray negative and none exposed at the surface. The algal filament in sample 200A is tentatively identified as that of *Cladophora,* a freshwater green alga (see Figure 3).

New Pennsylvanian Forms

Among animal and plant fossil elements perhaps new to the Pennsylvanian System are the Onychophore described above, freshwater green and blue-green algae, an unidentified egg or seed, and a new conodont species, *Metalonchodina magnidentatus,* Peters[3] (see Figure 11). The holotypes of the proposed new conodont species are at present in the Geology Department of Northern Illinois University. The unique feature distinguishing the proposed new species is its large first axial denticle (as opposed to the first distal—rear bar—denticle). This denticle measures 1.2 mm long, 0.1 mm longer than the main cusp, and gently diverges from the vertical axial plane of growth along an angular curvature equal to but opposite and away from the main cusp. The denticle and cusp curve gently away from each other. In other growth and structural characteristics the new proposed species corresponds to the limiting characteristics of the genus *Metalonchodina.*

Geological and Philosophical Implications

Geological and philosophical implications that can be drawn from the present study of Pennsylvanian black shales may be somewhat provocative. Among the geological implications the following may merit consideration:

1. Structural and fossil distribution similarities between the bases of Member 98 and the Francis Creek Shale suggest that both were conformably deposited directly over their respectively underlying coal seams.[4] Perhaps there was no "intervening" 6th or 7th rock (lithic) unit in the depositional history of Member 98 of Fulton County (the 8th unit of the "ideal coal cyclothem").

2. Radiography and photo-microradiography can be effectively used in a non-destructive approach to identification of fossils and for microfossil population counts, at least for black, carbonized shales.

3. Many new plant and animal fossil species and genera may be added to the fossil checklists of geological systems, series and stages as the nondestructive X-Ray (radiographic) technique is perfected.

4. Pre-Cambrian, Paleozoic, and more "recent" shales may contain fossil elements that may radically change the interpretation of the environment in which they were deposited. Refinement of the radiographic technique may require a restudy of such shales as the Proterozoic, the Scandanavian Pre-Cambrian, the British Columbian Cambrian Burgess Shale, the Green River Shales, and others.

5. Absence of certain fossils from the checklists of geological systems, stages, formations, or strata does not preclude their existence in some environment of the world (even nearby) during the time the rock layers in question were being deposited. The possible Onychophore, the algae, and *Metalonchodina magnidentatus* are not found in existing available Pennsylvanian checklists.

6. Member 98 exhibited a distinctly cyclical (perhaps tidal) deposition pattern. Many structural and fossil features seem to require a rapid, allochthanous interpretation of its depositional history.

From the geological observations it is obvious that the uniformitarian interpretation of long-time, slow, undisturbed sedimentation and mineralization cannot hold true for Member 98. Nearly all of the structural and fossil evidence seems to require rapid burial of sediment material transported to the burial site.

These details illustrate the kind of structural details one should expect if the earth had been subjected to a period of intense crustal disturbances and dislocations. They are what one should expect in rock layers laid down during a period of world-wide volcanism, crustal buckling, mid-ocean ridge and rift disturbances, and cloudburst type rain storms that can accompany crustal catastrophies (Furneaux, 1966, 155-165, etc.).[5]

The fossils and structure of the black shale Member 98 in Fulton County, Illinois in many aspects support rather than undermine a Biblical catastrophic interpretation of Paleozoic sedimentation. The writer hopes that more high school graduates and paleontologists will take up the challenge of photomicroradiography, help refine the X-Ray (radiographic) technique, and extend the range of strata (rock layers) of geological systems examined.

It is my belief that, when all formations are studied, it will be found that the entire range of plant and animal families, genera, and species existed simultaneously. The present *apparent* paleontological segregation is attributable to lack of complete identification of all fossils in the various sedimentary rock systems.

It is not proposed that each period such as the Cambrian, Silurian, and Devonian will exhibit all the species of plants and animals, but rather that present boundaries, defined essentially by index fossils, will have to be abandoned when overlap of these fossils from one period into the other is demonstrated. Thus, eventually, vertebrates will be found in the Paleozoic and flowering plant pollen in the Cambrian system.

Acknowledgment

Without the help of my wife, Dorothy, the study reported could never have been completed within the time allotted for the completion of the thesis.

References

[1]Peters, Walter G. 1970. Masters Thesis: A paleoecological study of Pennsylvanian black shales using photographic and radiographic techniques. Geology Department, Northern Illinois University, DeKalb, Illinois. 130 pp.

[2]Wanless, H. R. 1958. Pennsylvanian faunas of the Beardstown, Glasford, Havana, and Vermont quadrangles. Illinois State Geological Survey, Report of Investigation 305. pp. 9, 11, 12ff.

[3]Peters, Walter G. *Op. Cit.*, pp. 31,33, and pp. 118-120.

[4]*Ibid.*, pp. 24.

[5]Furneaux, R. 1966. Krakatao. Prentice Hall, Inc., Englewood Cliffs, N. J. pp. 155-65 ff.