

1973

The Fauna and Paleoecology of the Charleston Quarry Shale

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Recommended Citation

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The Fauna and Paleoecology of the

Charleston Quarry Shale

(TITLE)

BY

JAMES KARL GILLIAM

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Zoology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1973

YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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The Fauna and Paleoecology of the
Charleston Quarry Shale

Presented by

James Karl Gilliam

a candidate for the degree of Master of Science in Zoology
and certify that it is acceptable to them.

Abstract

The fauna and paleoecology of a late-Pennsylvanian shale contained in the Livingston Limestone of eastern Illinois is here defined. The name, Charleston quarry shale, is informally used for this shale in the area of the Charleston Stone Company quarry, northeast of Charleston, Illinois (SEC. 32, T. 13N., R. 10E., Coles Co.).

The fauna consists mostly of bryozoans, brachiopods and crinoids distributed throughout three distinct zones in the Charleston quarry shale. This fauna inhabited an offshore quiet bottom area in a shallow, warm, marine epicontinental sea which covered the area in the late-Pennsylvanian geologic period. The depth of water above the Charleston quarry shale during its deposition was approximately 20 meters.

Introduction

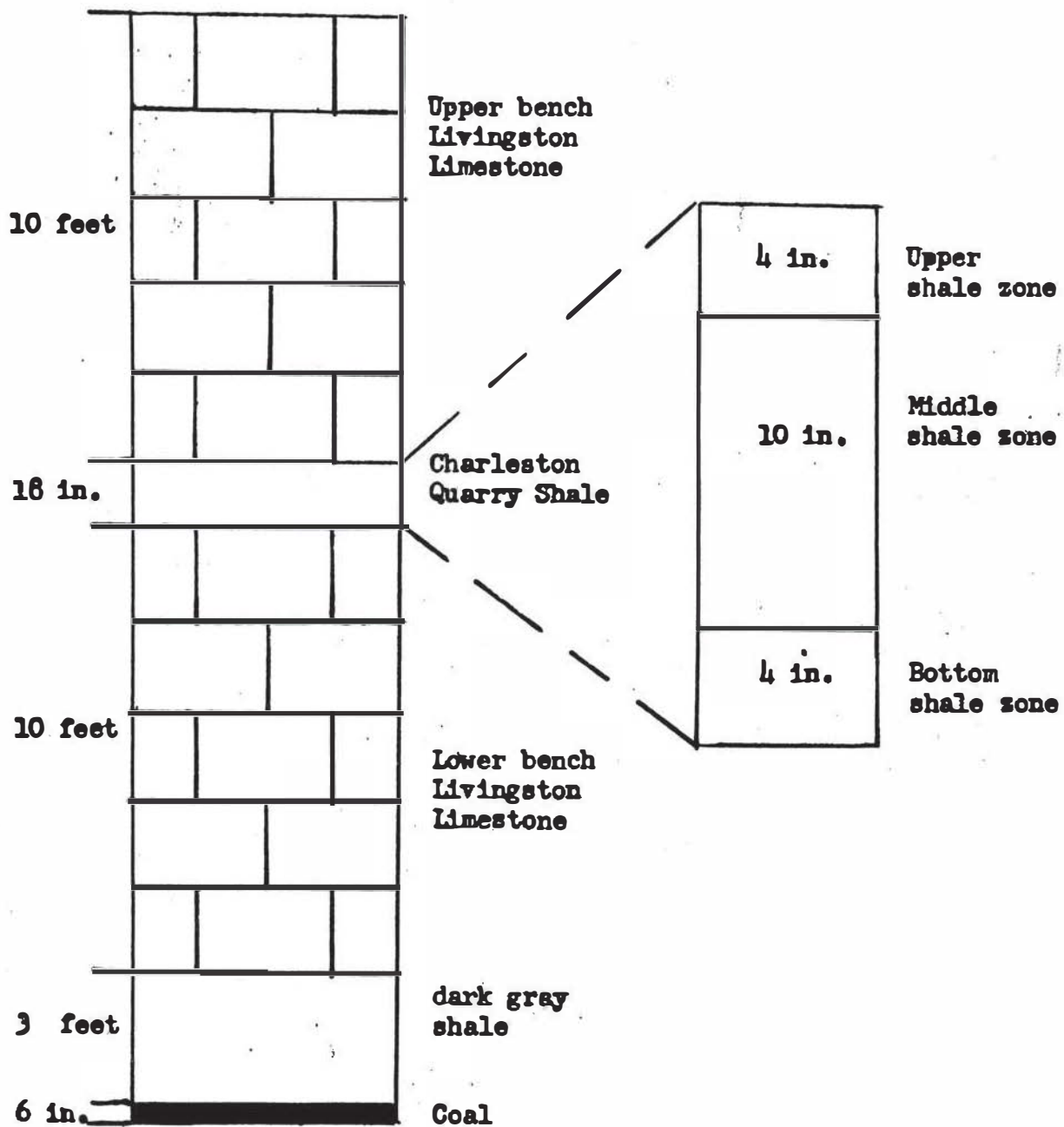
The purpose of this paper is to describe and discuss the significance of the fauna and paleoecology of a late-Pennsylvanian shale, hereafter informally referred to as the Charleston quarry shale, included in the Livingston Limestone of east-central Illinois.

The Charleston quarry shale, a marine deposit, has been exposed by mining in the quarries of the Charleston Stone Company along the Embarrass River, northeast of Charleston, Illinois (SEC. 32, T. 13N., R. 10E., Coles Co.). The thickness of the Charleston quarry shale at the study site, a newly opened pit in the quarry (¼SE., ¼SE., ¼SW., SEC. 32, T. 13N., R. 10E., Coles Co.), is 18 inches. It divides the Livingston Limestone, of which it is a part, into two distinct benches, each approximately 10 feet thick (Fig. 1). The shale is fined grained, predominantly gray in color and occurs in three distinct zones: a bottom shale zone (a heavy, dense shale in abrupt contact with the lower limestone bench), a middle shale zone (a soft, thinly-bedded, greenish-gray shale mottled with darker shale patches), and an upper shale zone (a limey shale gradually grading into the upper limestone bench).

Stratigraphy

The Livingston Limestone was named by Worthen (1875). The Livingston Limestone, with the included Charleston quarry

**Figure 1. Measured stratigraphic sequence from the Charleston
Stone Company quarry.**



shale, is currently classified as a member of the Bond Formation, McLeansboro Group, Pennsylvanian System of eastern Illinois (Kosanke et al. 1960).

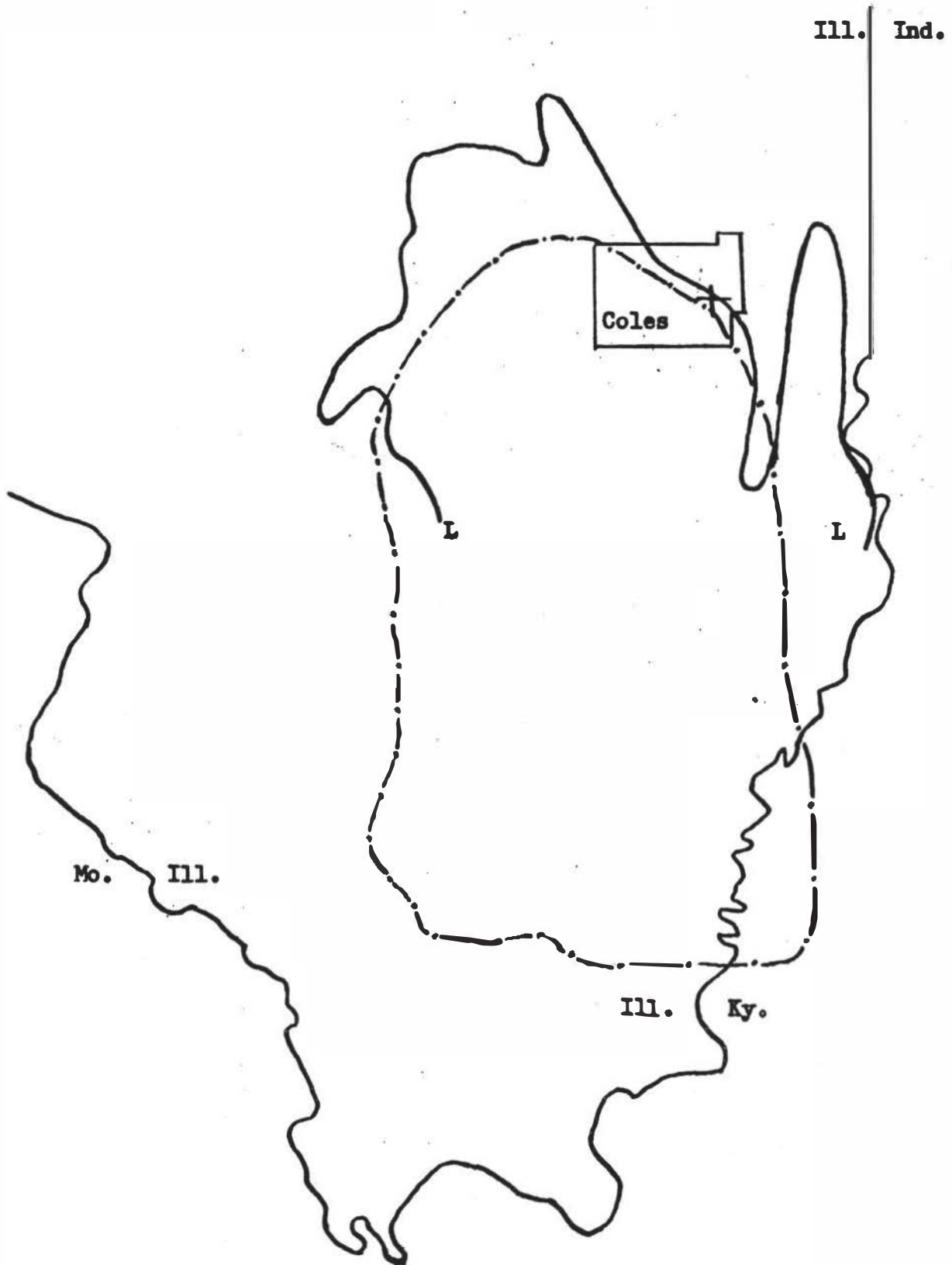
The most useful summary of the Pennsylvanian geology of the study area can be found in Clegg (1959). In that report, the limestone containing the Charleston quarry shale is referred to as the Millersville Limestone, but Kosanke et al. (1960) have classified the limestone east of the La Salle Anticline as the Livingston Limestone. A direct correlation between the Millersville and Livingston Limestones is noted by Clegg (1959) and Kosanke et al. (1960).

The Millersville-Livingston Limestone extends through the deep part of the Illinois Basin (Fig. 2). Clegg (1959) has described these limestones from Douglas, Coles and Cumberland Counties. DuBois (1951) identified them in Moultrie and Shelby Counties to the west of Coles County. Williams and Rolley (1955) found them in Jasper County to the south of Coles County. Clegg (1965) found the limestone limited to a strip 10 to 12 miles in width by post-Pennsylvanian erosion in Clark and Edgar Counties to the east of Coles County. Several authors have mentioned a shale bed separating the Livingston Limestone into two benches, but no definitive study of this shale, the Charleston quarry shale, has been published. At places in the Illinois Basin, the limestone reaches a total thickness of 50 feet or more. It is also present, although

Figure 2. Map of southern Illinois showing the outline of the deep part of the Illinois Basin and northernmost limits of the Millersville-Livingston Limestone in relation to Coles Co. (modified after Clegg 1959 and Weller 1942)

Legend

- .-.** Outline of the deep part of the Illinois Basin
- L—** Outline of the northernmost extent of the Millersville-Livingston Limestone
- +** Location of the study area



not quite so well developed, on the southern part of the Bellair-Champaign Uplift, the northernmost extent of the limestone and the location of the study area.

At the study area in the Charleston Stone Company quarry, the Livingston Limestone is unconformably overlain by Pleistocene deposits. All intervening deposits have been removed by post-Pennsylvanian erosion.

In the quarry, the Livingston Limestone benches were directly measured and are about 10 feet thick and are divided by the 18 inch thick Charleston quarry shale. The upper limestone bench was described by Mylius (1927) as more fossiliferous than the lower limestone bench at an outcrop to the south of the study area (SEC. 18, T. 12N., R. 10E., Coles Co.), however, Mylius fails to mention the fossil content of the shale. In general, the limestones of the study area agree with Mylius (1927) as to their fossil content. The upper bench is more fossiliferous than the lower bench. The Livingston Limestone is gray to buff, extremely dense, crystalline rock.

The Livingston Limestone is the upper boundary of the Bond Formation. It is separated by 200 feet of shales and thin coals from the lower boundary of the Bond Formation, the Shoal Creek Limestone (Clegg 1959).

Newton and Weller (1937) included the study area in the southern part of the La Salle cyclothem. They recognized

two marine limestones in the study area and designated them the upper and lower La Salle limestones. Kosanke et al. (1960) and Wanless (1956) equate the La Salle Limestone of northern Illinois to the Millersville and Livingston Limestones. This La Salle Limestone of Newton and Weller (1937) was apparently a mistake in reference and should have been called the Livingston Limestone. According to Newton and Weller (1937), when both the upper and lower benches of limestone are found together, neither one of the limestones is included in a series of strata which constitutes a complete cyclothem. However, the fact that these two benches of the Livingston Limestone primarily crop out together in only two counties, Coles and Clark, caused Newton and Weller (1937) to place both the upper and lower limestone benches, alone or together, in one cyclothem, the La Salle cyclothem.

Sampling

Numerous samples of the Charleston quarry shale were collected during the summer of 1973. The samples were taken from a newly opened pit in the quarry ($\frac{1}{4}$ SE., $\frac{1}{4}$ SE., $\frac{1}{4}$ SW., SEC. 32, T. 13N., R. 10E., Coles Co.) on the west side of the Embarrass River. These samples were compared to specimens and supplemented by a gastropod from the Paleobiology collection of Eastern Illinois University consisting of Charleston quarry shale obtained from an abandoned pit to the northeast of the study pit and on the east side of the Embarrass River.

All of these samples consisted of as complete as possible stratigraphic sequence of shale. The shale samples were removed from the quarry to Eastern Illinois University for study. The shale was prepared by taking it apart bedding plane by bedding plane and examining it for fossils.

Analysis of the individual samples indicated no specific orientation of the fossils due to water currents. Most fossils were articulated and showed no surface wear from transport. Different types and numbers of fossils were found in each of the three shale zones and are summarized in Table 1.

**Table 1. Faunal composition and specimen occurrence in the
Charleston quarry shale.**

P = present, 1-3 specimens

C = common, 4-8 specimens

A = abundant, 9 or more specimens

Species	bottom shale zone	middle shale zone	upper shale zone
A. Coral			
<u>Lophophyllidium proliferum</u>	P	P	P
B. Bryozoa			
<u>Fenestrellina mimica</u>	A	A	C
<u>Fenestrellina modesta</u>	A	A	C
<u>Polypora sp.</u>	P	C	-
<u>Penniretepora sp.</u>	P	P	P
<u>Rhombopora lepidodendroides</u>	A	P	P
C. Brachiopoda			
Class Inarticulata			
<u>Orbiculoidea missouriensis</u>	A	P	P
Class Articulata			
<u>Derbyia crassa</u>	-	P	-
<u>Chonetinella flemingi</u>	P	P	-
<u>Kozlowskia splendens</u>	A	A	A
<u>Reticulatia huecoensis</u>	-	C	-
<u>Hustedia mormoni</u>	C	C	C
<u>Composita argentea</u>	P	-	P
<u>Neospirifer dunbari</u>	A	C	A
<u>Punctospirifer kentuckyensis</u>	-	P	P
<u>Crurithyris planoconvexa</u>	P	C	P
D. Bivalvia			
<u>Acanthopectin carboniferus</u>	P	-	-
E. Gastropoda			
<u>Glabrocingulum grayvillense</u> P*	?	?	?
<u>Platycerus sp.</u>	-	C	-
F. Trilobita			
cf. <u>Ditomopyge</u>	-	P	P
G. Crinoids			
stemules and plate fragments	A	A	A

* one specimen of unknown zonation from the Paleobiology collection of Eastern Illinois University.

Paleoecology

Any attempt to reconstruct past environments is difficult. In only a few cases is the fossil evidence clear and indisputable. This section will present the basic paleoecological data and assumptions used in an environmental reconstruction of the Charleston quarry shale.

A. Coral

Lophophyllidium proliferum was a small, solitary rugose coral in the fauna. According to Hill (1956), these corals were apparently able to exist in numbers in conditions where large compound corals could not flourish, the sedimentary environment suggesting, perhaps, deeper seas with less light. Ziegler, Cocks and Bambach (1968) suggest that the "cornucopia" shape and weight concentration on the outer curve of the coral would have served to keep its soft parts raised above the sediment surface without being firmly anchored to the substrate by cementation. Furthermore, the body shape and outer curve weight concentration would have been able to right the coral, if disturbed, much like a weighted cork rights itself in water after being upset. The trophic mode of the coral has been designated by Walker (1972) as a high level suspension feeder. The "cornucopia" shape would have placed the calice or "oral" surface several centimeters above the bottom.

Specimens of the coral were not abundant, but all specimens were unfragmented and showed no surface wear from transport.

B. Bryozoans

The bryozoans of the fauna were of two morphological types: the fan shaped members of the family Fenestrellidae (Fenestrellina mimica, Fenestrellina modesta and Polypora sp.) and the branching or ramose forms (Penniretepora sp. and Rhombopora lepidodendroides). No encrusting forms were present in the Charleston quarry shale, although specimens of encrusting bryozoans were found in the upper Livingston Limestone bench.

Except for R. lepidodendroides which was abundant in the upper shale zone, the fan shaped colonies were more common than the branching forms. A reason for the fenestrellid abundance may have been its colony form. Fenestrellid colonies were flat and only one zooid thick. The upright frond usually arose from the supporting base as a fan or funnel. According to Ryland (1970) they presumably evolved in response to a need for the filtration area of the colony to be as large as possible in habitats not subject to appreciable water movement. Walker (1972) classified the trophic mode of the branching bryozoans as high level suspension feeders. The fenestrellids probably had a comparable feeding mode as their upright fronds extended a few centimeters above the substrate and their adaptation for the quiet waters during the Charleston quarry shale deposition gave them a selective advantage over the less common branching forms.

Preservation of these delicate bryozoan skeletons was

excellent. This preservation suggests a quiet water habitat with rapid burial and no transport of specimens after death.

C. Brachiopoda

Class Inarticulata

Orbiculoidea missouriensis, the only inarticulate of the fauna, had a small, shiny, thin, flattened, subcircular shell. This brachiopod had a pedicle used for attachment to a substrate. However, O. missouriensis was not found attached to any preserved material in the Charleston quarry shale. During life, it could have attached to a free-lying brachiopod, an unpreserved shell fragment or worm tube or it could have rested directly upon the bottom relying upon its small size and weight to prevent sinking into the soft sediment. The data seems to support the explanation of a free lying mode in which its pedicle could have remained unattached and functioned as a dragline to impede disturbances.

Class Articulata

The articulate brachiopods make up the majority of specimens of the fauna. With the exception of Composita argentea which had a large, heavy, biconvex shell and needed a firm substrate for attachment, all of the articulate brachiopods possessed a shell morphology that would have allowed them to live on a soft substrate, as well as in other areas.

Order Strophomenidina

Four species of strophomenids were present in the fauna:

Derbyia crassa, Chonetinella flemingi, Kozlowskia splendens and Reticulatia huecoensis.

D. crassa had a slightly biconvex shell unlike the concavo-convex shell of the other atrophomenids. According to Muir-Wood and Williams (1965), the shell was attached to a surface by cementation of the ventral umbo having lost a functional pedicle. In the Charleston quarry shale, this species was always found unattached to any surface. This observation can lead to two possible deductions of its paleoecology. It is possible the animal was cemented during life to a free-lying brachiopod, an unpreserved part of the assemblage, such as an alga, shell fragments or some other organism upon or above the sediment surface; or, more likely, it was free-lying upon the bottom, not utilizing its cementation, but relying upon its small size and weight and broad surface to prevent sinking.

C. flemingi had a concavo-convex shell morphology. Rudwick (1970) suggests that this shell shape was apparently an adaptation in these free-lying brachiopods for keeping the valve edges away from the substrate after atrophy of the pedicle. The shell could rest on the soft sediment on its convex pedicle or ventral valve, while the valve edges were kept growing upwards, away from the substrate. Rudwick (1970) conducted experiments with working models to show that if the shell was overturned by some bottom currents or the action of

a scavenger, a vigorous snapping reaction would have enabled it to somersault back into correct orientation. More importantly, if sedimentation threatened to clog or bury the valve edges, a snapping action would have caused the whole shell to rise off the substrate and move posteriorly out of the sediment (Rudwick 1970).

The other two strophomenida, Kozlowskia splendens and Reticulatia huecoensia, are members of the suborder Productidina. These types of brachiopoda were equipped with spines to spread out their weight and maintain them on the surface of a soft sediment (Rudwick 1970). Broken unattached spines were common fossils in the Charleston quarry shale. Spine scars were observed on all specimens of K. splendens and R. huecoensis and one spine was preserved still attached to a specimen of K. splendens, the most abundant brachiopod of the fauna (Table 1). As spat, these brachiopoda would cling to vegetation by a clasping pair of spines developed on the posterior ventral valve on either side of the pedicle (Rudwick 1970). After atrophy of the pedicle and development of the spines on the ventral valve, the brachiopods would drop to the surface of the sediment and be supported by their ventral spines.

Order Spiriferida

Five species of the order Spiriferida were present in the shale: Huatedia mormoni, Composita argentea, Crurithyris planoconvexa, Neospirifer dunbari and Punctospirifer kentuckyensis.

These five species can be divided into morphological types, not necessarily following phyletic divisions; H. mormoni, C. argentea and C. planoconvexa with a pedicle and N. dunbari and P. kentuckyensis free-lying without a functional pedicle.

C. argentea was found to be common in the limestone benches but rare in the shale. It intrudes into only the bottom and upper shale zones. C. argentea needed a firm substrate for attachment that was not offered in the middle shale zone. Its large size and weight would need bigger objects to attach to than would the smaller Hustedia mormoni or Orbiculoidea missouriensis that also had pedicles. C. argentea's biconvex shell shape could not readily rest directly on a soft bottom without sinking.

Hustedia mormoni and Crurithyris planoconvexa were present throughout the three shale zones. H. mormoni occurred in constant numbers throughout the shale, but C. planoconvexa was common only in the middle shale zone (Table 1). Their small size and weight would have allowed them to attach by pedicle to free-lying brachiopods, bits or fragments of shells or vegetation or to rest directly upon the bottom using their pedicles as "tethers" or "draglines" to combat unwanted movement.

Neospirifer dunbari and Punctospirifer kentuckyensis, both of the suborder Spiriferidina, were epifaunal free-lying brachiopods without functional pedicles. Pedicles, when present in this suborder, functioned only to tether the

brachiopods to an area, allowing currents to swing around the point of attachment (Rudwick 1970). These two species had a shell form which would allow for life on a soft bottom. The shells were considerable heavier than other brachiopods which made them more stable on the bottom and less likely to be disturbed by chance currents. The shell weight was concentrated in the posterior-ventral hinge area to return the shell, if disturbed, to a position with the ventral edge away from the substrate and the posterior margin slightly imbedded in the substrate (Rudwick 1970). Rudwick (1970) mentions that the large surface area to the sides of the main body of the shell in these two species, developed by extension of the hinge line laterally into a pair of wings, may have had a ski-like function to stabilize the shell on a soft substrate. N. dunbari was the second most abundant species of the fauna (Table 1).

Walker (1972) described the trophic mode of the brachiopods as low-level suspension feeders. Most of these brachiopods must have had their shell margins level with the bottom and filtered the water immediately adjacent to the bottom.

D. Bivalvia

The only bivalve in the fauna was Acanthopectin carboniferus, represented by only two specimens in the upper shale zone. This scallop occupied about the same

ecological niche as recent pectins if similar body form means similar function. A. carboniferus was probably a low level suspension feeder resting on the bottom and swimming when sedimentation or other factors threatened it.

E. Gastropoda

Two members of the order Archaeogastropoda were present in the fauna: Glabrocingulum grayvillense and Platyceras sp. G. grayvillense had a rhipidoglossa type radula suggesting a herbaceous diet (Knight et al. 1960) and was represented by only one specimen in the Paleobiology collection of Eastern Illinois University. The writer did not collect the specimen of G. grayvillense so its shale zone of origin is not known (Table 1). Platyceras sp. was definitely associated with the middle shale zone (Table 1). It was an ectocommensal upon crinoid calices (Knight et al. 1960).

F. Trilobita

The trilobite cf. Ditomopyge was represented by many entire pygidia. In only one instance was it also represented by disarticulated thoracic segments and cephalonic spines. This predominance of pygidia suggests some type of differential preservation. Lack of many cephalonic parts made positive identification impossible. Although little is known of trilobite paleoecology, this trilobite was probably some type of epifaunal detritus feeder.

G. Crinoidea

Only stemules and a few plate fragments of crinoids were present in the Charleston quarry shale. The crinoid stemules were extremely abundant in all three shale zones and followed a trend of decreasing diameter as one proceeded from the bottom shale zone to the upper shale zone. The stemules appeared to be of several morphological types. Crinoid identification without the whole organism is extremely difficult and was not attempted with the fragments. Crinoids were and still are ciliary mucus filter feeders utilizing the water a few centimeters above the bottom for a food source. The abundance of crinoid fragments would suggest a productive environment.

Discussion

Paleoecological reconstructions are confined to broad generalizations by the limitations of the fossil record. Preserved organisms are not always representative of a complete fauna because only a small portion of the animals with hard parts and none of the soft-bodied organisms were usually preserved. The environmental interpretation presented here seems most consistent with the data collected, but it is by no means the only interpretation possible.

During the Pennsylvanian period, the land that is now central Illinois underwent cyclic changes in sea level due to the constant sinking of the Illinois Basin (Koanake et al. 1960).

This sinking basin led to periods of land submergence under a shallow sea of marine waters. It was the transgression of these waters over the site of the present Charleston Stone Company quarry that allowed the Charleston quarry shale to be deposited.

Variations in cyclically deposited sedimentary rocks and their included faunas usually reflect differences in water depth. By knowing the water depth, one can usually predict the ecological stability of an ancient environment in relation to its onshore or offshore position in a sea. The depth of water over a habitat and its distance from shore are related to the abundance and diversity of the fauna found there. Marine organisms increase in abundance and diversity from tidal flat environments toward offshore, shallow subtidal environments. Ecological conditions are less variable and more stable in subtidal offshore environments than in the harsher nearshore environments (Walker and Laporte 1970). Stevens (1971) has devised a method of determining water depth by the number of brachiopod genera present in a fauna. His theory states that more brachiopod genera were found in the more stable deeper waters offshore than were found in the less stable shallower waters nearshore. Using the thin coal seam seen in the study pit beneath the Livingston Limestone as a starting point and the upper Livingston Limestone bench as the end point of a sedimentary sequence in the quarry (Fig.1),

one can estimate the changes in water depth. The thin coal seam represents the remains of a low-lying swamp. This coal was deposited on land before the transgression of an epicontinental sea. Above the coal is a three foot layer of dark gray shale which would represent the original shallow bottom of the sea. This first bottom was mud mixed with organic material from the nearby land. Water depth gradually increased and under a depth of between 5-15 meters, the lower Livingston Limestone bench was deposited. This depth is arrived at from Stevens' (1971) theory which related a water depth of 5-15 meters to 3-6 genera of brachiopods present. The actual number of brachiopods was four: Composita argentea, Neospirifer dunbari, Kozłowska splendens and a rhynchonellid. These specimens were collected by the Eastern Illinois University Paleozoology classes and this writer. After the deposition of the lower Livingston Limestone bench, the water depth suddenly deepened and the sediment changed. This sudden change in water depth can be deduced from the abrupt contact between the upper surface of the lower Livingston Limestone and the bottom shale zone on the Charleston quarry shale. This rapid change in depth was probably due to the further sinking of the Illinois Basin.

The water depth above the Charleston quarry shale was over 20 meters which, according to Stevens' (1970) theory, would have 10 genera of brachiopods present (Table 1). After

the deposition of the Charleston quarry shale, the water became shallower. This was a gradual process as seen by the gradual gradation of the upper shale zone upwards into the upper Livingston Limestone bench. This lessening of water depth was probably due to a recession of the epicontinental sea. Although Mylius (1927) has described 9 genera of brachiopods in the upper Livingston Limestone bench from an outcrop to the south of the study area (SEC. 18, T. 12N., R. 10E., Coles Co.), the writer and Eastern Illinois University's Paleozoology classes found only 5 genera: Composita argentea, Neospirifer dunbari, Kozlowskia splendens, Punctospirifer kentuckyensis and a rhynchonellid. This would mean a depth of 5-15 meters, the same depth of deposition as the lower Livingston Limestone bench, although the upper bench possessed a generally more abundant and diverse fauna than the lower bench, it had only one more brachiopod genus.

The upper Livingston Limestone bench is the end of the Pennsylvanian strata in the quarry as all intervening beds between the upper limestone bench and the Pleistocene deposits have been removed by post-Pennsylvanian erosion. Mylius (1927) has described sandstones, shales, slates and a thin limestone of Pennsylvanian age above the upper Livingston Limestone bench from the better preserved outcrop to the south of the study area. This would seem to indicate the continuation of the typical Pennsylvanian cycle of deposition after the formation

of the Livingston Limestone.

The position of the study area during the deposition of the Charleston quarry shale was offshore. This conclusion was reached by considering the water depth of 20 meters that in Stevens (1971) was the deepest, farthest offshore locality. Supporting evidence is given by the extent of the Livingston Limestone (Fig. 2) that extends far enough to the east and north to preclude a nearshore environment. The study area could have been a bay in the epicontinental sea of the Illinois Basin.

Some other factors must also be considered in a paleo-ecological study: light penetration, water temperature, salinity, bottom condition and food supply.

According to Welch (1952), light penetration through water is dependent upon light intensity, angle of incidence, dissolved materials and suspended materials. It is impossible to deduce all these factors for a sea that existed 280 million years ago. Welch (1952) does cite examples of light penetration to 213 meters in the Atlantic Ocean. If light conditions now were similar to light conditions in the Pennsylvanian era, then it is probable that some wavelengths of light reached the bottom for some period of each day.

Water temperature was assumed to be warm in shallow epicontinental seas of the Pennsylvanian period.

Water salinity was influenced by rainfall, water temper-

ature and mixing currents. There is no way to determine salinity in the study area beyond the presumed tolerance range of such a normal marine fauna found in the Charleston quarry shale. There were no brackish water genera such as Lingula present so salinity was assumed to be normal for marine seas of the Pennsylvanian period.

Many factors played a part in the determination of the bottom condition of the three shale zones of the Charleston quarry shale including water currents, suspended particles and sedimentation.

The Charleston quarry shale is composed of fine mud and clay particles which would have required ample time to settle out of a quiet suspension. Any appreciable water movement would have inhibited the shale formation. The exclusion of water currents from the bottom could have occurred in three ways. First, the bottom would have to be deep enough and far enough offshore to preclude any wave action. The water current necessary to carry the shale particles to the area of deposition was far enough above the bottom to insure that the bottom was relatively undisturbed. Second, the bottom was covered by a lush growth of vegetation that had reached a height which effectively inhibited bottom currents of a velocity necessary to disturb the shale deposition. Third, a combination of low velocity bottom currents and some vegetation excluded the high velocity bottom currents. In any of

these three hypotheses, the offshore location of the Charleston quarry shale depositional area is assumed because currents from the shore tend to carry small sediment particles, like the clay and mud of the shale, the farthest away from shore before depositing them. A quiet bottom is postulated for shale formation as well as to accommodate certain aspects of the fauna. First, the fragile bryozoan skeletons were not fragmented by transport nor was any surface wear observed on any other fossil. Second, the fossils were not oriented toward any particular direction that would indicate a current. Third, the fenestrellid bryozoans, in life, were presumably adapted to a quiet water habitat. All this, of course, does not mean that the water was completely free of sediment. Instead, the water was well supplied with suspended particles of detritus continually raining down from above. These fine particles would tend to stay in suspension for long periods. These suspended fine particles of clay and mud, as well as organic food materials, required the animals of the fauna to have highly evolved mechanisms for sorting and rejection to separate their food from inorganic particles.

The bryozoans had a highly advanced lophophore to sort out their food from the other detritus. The brachiopods used their shell margin which they only opened to a certain small aperture to exclude the bigger pieces of detritus and their lophophore to further sort out food from non-food material.

The rain of detritus from above was not the same in all three shale zones. The bottom shale zone had thick bedding planes (.75-1.25mm) indicating that sedimentation was heavy when it did occur but probably intermittent. The middle shale zone had thin bedding planes (.25-.50mm) indicating that sedimentation was probably constant. The upper shale zone is thinly bedded at its base (.30mm) but in the portion of the zone immediately below the upper Livingston Limestone bench, there are no bedding planes. The upper shale zone is very limey indicating reworking with the mixing of the shale and limestone. This mixing could have occurred during or after the deposition of the upper few centimeters of the upper shale zone.

The relative firmness of the bottom was different in each of the three shale zones. The bottom shale zone was thin and well compacted. It was probably a fairly solid bottom with the water squeezed out from between the fine sediment particles. As a firm substrate, it offered sufficient anchorage for Composita argentea and large crinoids. The middle shale zone was probably a semi-ooze bottom with water filling the spaces between the fine shale particles. This zone was several feet thick and was compacted to its present 10 inches by the weight of overlying rocks squeezing the trapped water from the shale. This was definitely a less firm substrate than the bottom shale zone and one on which C. argentea could not attach. The upper

shale zone has the least number of species. This was probably a slightly firmer bottom than the middle shale zone. It contained C. argentea but whether this brachiopod attached during deposition of the upper shale zone or after mixing with limestone had occurred is not known. The upper shale zone had the crinoids stems of the smallest diameter. Perhaps this transitional zone from shale to limestone offered the least stable environmental conditions of the three shale zones.

The food supply was abundant. The amount of organic food material suspended in the water must have been great to support all the filter feeders in the fauna. Only two groups were non-filter feeders, the herbaceous gastropod and the detritus feeding trilobite. Although the primary trophic mode was filter feeding, specializations in feeding habits reduced competition. Brachiopods and the bivalve filtered the water immediately adjacent to the bottom. Corals, bryozoans and crinoids filtered water at least a centimeter above the bottom.

For an overall view of the ancient environment of the fauna of the Charleston quarry shale, a community approach can be assumed. In such an approach, relationships between fauna and substrate can be reviewed.

The Charleston quarry shale can be designated a Kozlowskia-Neospirifer community. These two genera are the most abundant and characteristic of the fauna. They also exhibited specializations, such as the spines of Kozlowskia and the wide wings

of Neospirifer, that relate them to the soft bottom of the Charleston quarry shale.

This Kozlowskia-Neospirifer community inhabited all three shale zones with only minor fluctuations in composition (Table 1). The three main components of the community were the bryozoans, brachiopods and crinoids. The bryozoans all attached to the soft sediment with a supporting base that allowed them to stand upright. The fenestrellid bryozoans dominated the ramose or branching forms because the large, flat, fan-shaped fronds of the fenestrellids allowed them to achieve more surface area for filtration than the single branched stalk of the branching forms. This larger filtration area was important in the quiet waters above the Charleston quarry shale. The brachiopods were more diverse in body form but no less adapted to their environment than were the bryozoans. The sedentary Kozlowskia splendens and Reticulatia huecoensis were supplied with ventral spines which supported them at the surface of the bottom. Neospirifer dunbari and Punctospirifer kentuckyensis supported themselves with wide wings that served a ski-like function and kept them on top of the bottom. Chonetinella flemingi could literally swim out of a covering sediment and its concavo-convex morphology allowed it to settle at the bottom surface without sinking. The smaller brachiopods (Orbiculoidea missouriensis, Derbyia crassa, Hustedia mormoni and Crurithyris planoconvexa) had an unclear

mode of support but were well represented in the fauna.

Composita argentea showed a preference for a hard substrate for attachment that was not offered in the middle shale zone but was found in places in the upper and bottom shale zones. This assemblage of large flat brachiopods (K. splendens and N. dunbari) and small angular brachiopods (D. crassa and H. mormoni) is characteristic of quiet water near or below wave base (Anderson 1971). The crinoids were an ubiquitous group of the Paleozoic era. They had their largest stem diameters in the bottom shale zone and progressively smaller stem diameters in the middle and upper shale zones.

Minor components of the community were the bivalve, the gastropods and the trilobite. The bivalve, Acanthopectin carboniferus, was only represented by two specimens from the upper shale zone. It probably had an ecology similar to modern pectins. The gastropods, Glabrocingulum grayvillense and Platycerus sp., were respectively a herbavore and an ecto-commensal on crinoids. The trilobite, cf. Ditomopyge, was an epifaunal detritus feeder crawling over the bottom surface.

There was no evidence of infaunal species in the community of the Charleston quarry shale. No burrows or reworking of the sediments were found.

Summary

The Charleston quarry shale was formed of fine sediments in a quiet bottom habitat of 20 meters of water depth in an

offshore position of a warm epicontinental Pennsylvanian sea. Sedimentation varied from heavy and intermittent to light and steady during the deposition of the various shale zones. The relative firmness of the shale zones differed.

The fauna can be designated a Kozlowskia-Neospirifer community. The primary trophic mode was filter feeding on an abundant food supply. All of the fauna was epifaunal and was a characteristic marine assemblage.

Acknowledgements

The writer is deeply indebted to Dr. Frederick R. Schram of Eastern Illinois University and the Field Museum of Natural History for guidance and encouragement in the production of this paper. He would also like to thank Mrs. Joan Schram of the University of Illinois for help with the literature.

The writer is also grateful for help and critical review of this paper by Drs. B.T. Ridgeway, R.C. Funk and E.O. Moll, Department of Zoology, and Dr. J.P. Ford, Department of Geography and Geology, all of Eastern Illinois University.

Gratitude for help with checking fossil identification goes to Dr. Lois Kent and Mr. Rodney Norby of the Illinois State Geological Survey, Urbana, Illinois.

Special thanks is extended to my wife, Mrs. Kim Gilliam, for encouragement and tolerance in the production and typing of this paper.

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APPENDIX

Systematic Paleontology

- Phylum Coelenterata Frey and Leuckart, 1847
 - Class Anthozoa Ehrenberg, 1834
 - Subclass Zoantharia de Blainville, 1830
 - Order Rugosa Milne-Edwards and Haime, 1850
 - Suborder Streptelasonatina Wedekind, 1927
 - Superfamily Cyathaxoniicae Milne-Edwards and Haime, 1850
 - Family Lophophyllidiidae Moore and Jeffords, 1945

Lophophyllidium proliferum (McChesney)

- Phylum Bryozoa Ehrenberg, 1831
 - Subphylum Ectoprocta Nitsche, 1869
 - Class Gymnolaemata Allman, 1856
 - Order Cryptostomata Vine, 1883
 - Family Fenestrellidae King, 1850

Fenestrellina mimica (Ulrich)

Fenestrellina modesta (Ulrich)

Polypora sp. McCoy, 1844

- Family Acanthocladiidae Zittel, 1880

Penniretepora sp. D'Orbigny, 1849

- Family Rhabdomesidae

Rhombopora lepidodendroides Meek

- Phylum Brachiopoda Dumeril, 1806
 - Class Inarticulata Huxley, 1869
 - Order Acrotretida Kuhn, 1949
 - Superfamily Discinacea Gray, 1840
 - Family Discinidae Gray, 1840
 - Subfamily Orbiculoideinae Schuchert and Le Vene, 1929

Orbiculoidea missouriensis (Shumard)

- Class Articulata Huxley, 1869
 - Order Strophomenida Opik, 1934
 - Suborder Strophomenidina Opik, 1934
 - Superfamily Davidsoniacea King, 1850
 - Family Orthotetidae Waagen, 1884
 - Subfamily Derbyiinae Stehli, 1954

Derbyia crassa (Meek and Hayden)

Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetacea Bronn, 1862
Family Chonetidae Bronn, 1862
Subfamily Chonetinellinae Muir-Wood, 1962

Chonetinella flemingi (Norwood and Pratten)

Suborder Productidina Waagen, 1883
Superfamily Productacea Gray, 1840
Family Marginiferidae Stehli, 1954
Subfamily Marginiferinae Stehli, 1954

Kozlowskia splendens (Norwood and Pratten)

Family Dictyoclostidae Stehli, 1954
Subfamily Dictyoclostinae Stehli, 1954

Reticulatia huecoensis (King)

Order Spiriferida Waagen, 1883
Suborder Retziidina Boucot, Johnson and Staten, 1964
Superfamily Athyridacea M'Coy, 1844
Family Athyrididae M'Coy, 1844
Subfamily Athyridinae M'Coy, 1844

Composita argentea (Shepard)

Suborder Spiriferidina Waagen, 1883
Superfamily Spiriferacea King, 1846
Family Spiriferidae King, 1846

Neospirifer dunbari (Hall)

Superfamily Spiriferinidae Davidson, 1884
Family Spiriferinidae Davidson, 1884

Punctospirifer kentuckyensis (Shumard)

Superfamily Cyrtiacea Fredericks, 1919 (1924)
Family Ambocoeliidae George, 1931

Crurithyris planoconvexa (Shumard)

Phylum Mollusca Linne, 1758
Class Bivalvia Linne, 1758 (Bonanni, 1681)
Subclass Pteriomorpha Beurlen, 1944
Order Pterioda Newell, 1965
Suborder Pteriina Newell, 1965
Superfamily Pectinacea Rafinesque, 1815
Family Aviculopectinidae Meek and Hayden, 1864

Subfamily Aviculopectininae Meek and Hayden, 1864

Acanthopectin carboniferus (Stevens)

Class Gastropoda Curvier, 1797

Subclass Prosobranchia Milne-Edwards, 1848

Order Archaeogastropoda Thiele, 1925

Suborder Pleurotomariina Cox and Knight, 1960

Superfamily Pleurotomariacea Swainson, 1840

Family Eotomariidae Wenz, 1938

Subfamily Eotomariinae Wenz, 1938

Tribe Eotomariides Wenz, 1938

Glabrocingulum grayvillense (Norwood and Pratten)

Suborder Trochina Cox and Knight, 1960

Superfamily Platyceratacea Hall, 1859

Family Platyceratidae Hall, 1859

Platyceras sp. Conrad, 1840

Phylum Arthropoda Siebold and Stannius, 1845

Class Trilobita Walch, 1771

Order Ptychopariida Swinnerton, 1915

Suborder Illaenina Jaanusson, nov.

Superfamily Proetocea Salter, 1864

Family Phillipsiidae Oehlert, 1866

cf. Ditomopyge Newell, 1931

Phylum Echinodermata Klein, 1734

Subphylum Crinozoa Matsumoto, 1929

Class Crinoidea

stemules and plate fragments