Depositional Systems and Marine Benthic Communities in the Floyd Shale, Upper Mississippian, Northwest Georgia

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ABSTRACT

Fossil marine communities have been classified by many workers in onshore to offshore transitional sequences on marine shelves. This representation does not accommodate differences in community structure and composition parallel to the paleo-shoreline. Works of Craig (1955) and Ferguson (1962), used by Bretsky (1969) to generalize community structure in the Mississippian, may not be typical because each studied only one exposure, providing a view of a transgressive sequence at one point. Lack of work on a larger scale in Mississippian rocks resulted in a gap in Bretsky's (1969) chart in the "offshore" communities.

Five marine benthic communities identified from the Upper Mississippian Floyd Shale in northwest Georgia have been correlated with depositional systems and were used to interpret the depositional history of the Floyd Shale. Communities include (1) *Lingula*, (2) Bivalvia–Spiriferida–Productidina, (3) Fenestellidae, (4) *Pentremites*-Spiriferida–Fenestellidae, and (5) *Michelinia*–Rugosa. Community 1 occurs in siltstone and silty shale and is probably directly controlled by factors related to delta progradation, especially the distribution of delta front, prodelta, and interdistributary embayment facies. Communities 2 and 3 occur in shale and calcareous shale interpreted as semi- to well-protected bay facies developed along strike from principal delta lobes. Community 4 occurs in calcareous shale and calcilutite representing open bay

or shelf deposits, which locally became well developed shoreward during destructional phases of delta lobes. Community 5 occurs in calcilutite to calcarenite units interpreted as carbonate banks.

INTRODUCTION

Communities of marine benthic invertebrates observed in the fossil record have received considerable attention during the last several years. Emphasis has been placed on description of communities and their variations in time and space, and integration of paleoecologic data previously derived from observations of communal taxa. The objective has been a meaningful reconstruction of many aspects of community dynamics.

Study of community paleoecology implies evaluation of both biotic relationships and physical factors controlling biotic distribution. In the Holocene marine environment, thorough evaluation of these factors by marine ecologists is time consuming and costly. Attempts by paleontologists and geologists to analyze communities of organisms are probably superficial in comparison with true ecosystem analysis because of incomplete data. Studies of invertebrate communities in the Paleozoic are commonly beset by deficiencies such as nonpreservation of much of the marine flora and soft-bodied fauna, or difficulties in recovery of many planktic organisms. Trophic levels represented in the preserved biota may not be obvious, and food-chain relationships commonly afford only speculation. In addition, evidence of physical environmental factors may be lacking. Precise magnitudes and short temporal variations of such physical parameters as temperature, salinity, and sedimentation rate are not detectable by present analytic techniques.

Most evaluations of the physical environment in community studies have been restricted to simple description of lithologies, but with little correlation of sediment patterns over large outcrop areas. A further refinement is the recognition of gross stratigraphic patterns, such as transgressive and regressive marine sequences accompanied by faunal changes and identified on the basis of changes in lithology. The association of groups of organisms with recent sedimentary environments has been recognized at least since the time of Parker's studies (1956, 1959) along the Gulf Coast, but specific environments correlated with fossil communities have not been emphasized until recently with the works of West (1972, Pennsylvanian of Oklahoma) and Bowen et al. (1974, Devonian of New York).

Various aspects of sedimentary environments and depositional systems are excellently documented in Holocene examples. Furthermore, many of these features have been recognized in rocks ranging in age from Precambrian to Pleistocene. Numerous studies of Upper Paleozoic rocks (e.g., Brown, 1969; Galloway and Brown, 1972; Brown et al., 1973) provide excellent guidelines and data for comparison and identification of such phenomena in other areas. Depositional systems of terrigenous clastic sediments provide a variety of physical environments, which vary greatly in ability to support a preservable invertebrate community. The Floyd Shale is an approximately 400-m sequence of Upper Mississippian terrigenous clastic and carbonate rocks that crop out in the Valley and Ridge area of northwestern Georgia and southeastern Tennessee, and in the Appalachian Plateau of northern Alabama. In Georgia, the Floyd Shale ranges in age from middle Meramecan through middle Chesteran and is the shoreward, clastic facies of the Tuscumbia Limestone and Monteagle Formation that crop out to the northwest on the Appalachian Plateau (Fig. 1). Lithologies in the terrigenous facies of the Floyd Shale range from quartz sandstone to clay shale. In the carbonate facies, lithologies range from calcereous shale and calcilutite to coarsely crystalline and skeletal calcarenite.

DEPOSITIONAL ENVIRONMENT

The greater thickness of the Floyd Shale and Hartselle Sandstone in the southern and eastern part of the outcrop belt (Cressler, 1970; McLemore, 1972) suggests that the sediment source was probably a land area to the east and south of the marine basin. Sediments were transported fluvially to the marine environment where deposition resulted in the irregular progradation of the shoreline. This, according to Fisher et al. (1969, p. 14), is the basic definition of a delta.

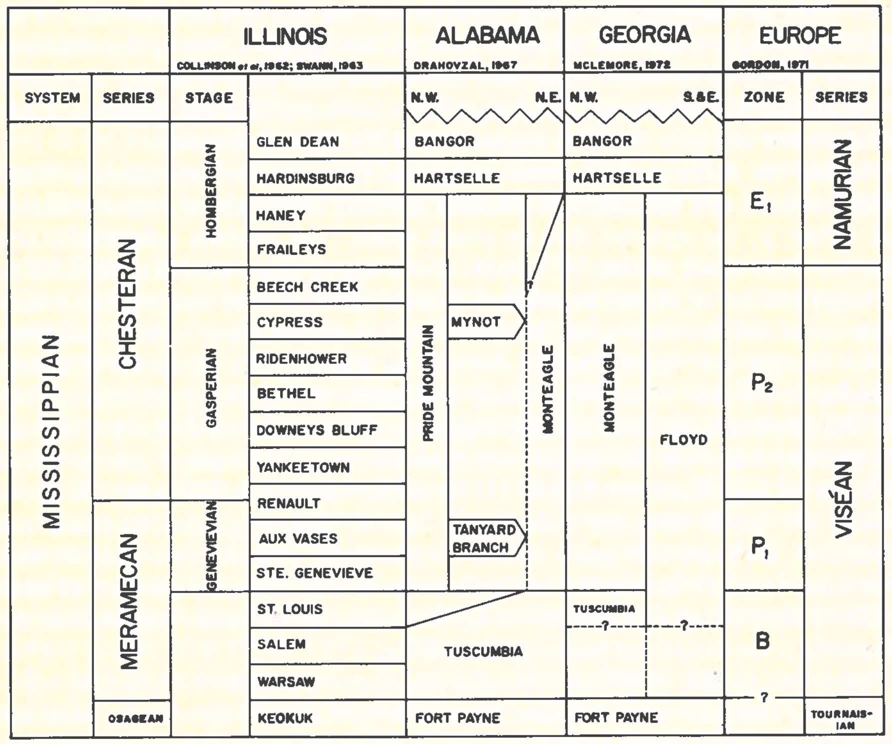


Figure 1
Regional correlation of the Floyd Shale in Georgia with rocks in Alabama and Illinois in the American and European time-stratigraphic framework.

The large volume of terrigenous clastic sediment that constitutes the Floyd Shale suggests that deltas responsible for Floyd deposition were of the "high-constructive" type, which develop under conditions of high sediment input relative to marine energy. Two basic types of high-constructive deltas (Fisher et al., 1969) are (1) high-constructive elongate, with sediment load high in mud, and sand facies prograding over relatively thick mud sequences, and (2) high-constructive lobate, which develop under similar conditions, but with relatively less mud load, and with sand facies prograding over thin mud sequences.

The basic component facies of a high-constructive delta during the constructional phase is summarized from Fisher et al. (1969, p. 15–19) as follows. At the base of the delta sequence and at the distal end of the facies tract is the prodelta facies, composed of clay and silt that settle from suspension. Overlying and geographically landward of the prodelta is the delta front, composed primarily of sand deposited by rivers flowing into the marine basin. The proximal or landward part of the delta front consists of a series of distributary channels, distributary mouth bars, and distal bars. The distal or seaward part of the delta front consists of marine reworked sheet sands that have been "spilled out" from the distributaries onto the proximal prodelta. With progradation, the vertical delta sequence coarsens upward in grain size from the clay and silt of the prodelta into the fine and medium sand of the delta front. Landward from the delta front, and overlying it in the vertical sequence, is the commonly extensive delta plain facies. The delta plain is mostly subaerially exposed and includes several component facies, including mud and organic-rich subaerial levees, marshes, and lakes and sand-filled distributary channels.

During the destruction of abandoned deltas the rate of sedimentation is drastically reduced, and the dominant processes affecting sediments are marine. Fisher et al. (1969, p. 19) reported that on abandonment "the prodelta area reverts to a normal shelf facies, marked by a much slower rate of deposition, and inhabited by a larger number of marine organisms." Delta-front sands that accumulated in shallow areas become extensively reworked by waves and other marine processes.

In Georgia, the Floyd Shale is overlain by the Hartselle Sandstone (Hartselle Sandstone Member of the Floyd Shale of Cressler, 1970). The gradational contact of the Floyd and Hartselle strongly suggests a genetic relationship between the two formations based on the model described above. In the western part of Floyd County at Judy Mountain, Cressler (1970, p. 48) reported the Hartselle to be about 300 f (91 m) of massively bedded very fine- to medium-grained sandstone and quartzite, siltstone, and quartz-pebble conglomerate, with siltstone common near the base. Cressler's description of the Hartselle, in addition to the presence of small channel sand bodies and thin "sheet sands" farther to the north, suggests that the Hartselle is the delta-front facies of Floyd deltas.

Ferm and Ehrlich (1967, p. 13) considered the Floyd Shale in Alabama to represent delta-front and prodelta facies. McLemore (1972, p. 73) agreed with Ferm and Ehrlich, but stated that in Georgia

> the great thickness and lack of shallow water sedimentary structures (ripple marks, mud cracks, etc.) seem to indicate that the Floyd was deposited rather rapidly in deeper waters. The carbonaceous material and paucity of fossils appear to indicate that the general depositional environment was unfavorable to benthonic life and probably reducing.

McLemore's analysis seems to confirm Ferm and Ehrlich's interpretation. However, the absence of shallow-water sedimentary structures in most Floyd outcrops does not necessarily preclude deposition in shallow water. Bioturbation during periods of low sedimentation may disrupt ripple marks in the delta front and small cross beds that may form in the proximal prodelta facies (Fisher et al., 1969, p. 18). Ripple marks were observed at one locality, but mud cracks should not be expected in the delta front or prodelta because these facies are not subjected to subaerial exposure.

Abundant carbonaceous debris and low faunal abundance and diversity are characteristic of prodelta mudstones, as has been well documented from Pennsylvanian rocks of north-central Texas (Galloway and Brown, 1972; Brown et al., 1973). At many localities the Floyd is dark gray to black shale and siltstone that are unfossiliferous or contain only a few broken fragments of echinoderms and articulate brachiopods or locally abundant linguloid brachiopods. Reducing conditions commonly associated with prodelta facies are indicated in the Floyd by locally common siderite and pyrite nodules and limonite boxwork probably derived from the weathering of iron sulfides. An important aspect of several of the siderite–pyrite nodules is the abundance of goniatitic ammonoids and terrestrial plant fragments in excellent states of preservation. This association is similar to that in the Fayetteville Shale of Arkansas (Zangerl, 1971) in which siderite nodules apparently nucleated about decaying organic debris. Most fossils in nodules from the Floyd were highly motile or easily transported types; very few benthic fossils were observed.

The Floyd Shale is locally fossiliferous (124 of 392 localities studied), with many of the most diverse faunas occurring in the included carbonate rocks. Nevertheless, fossiliferous occurrences in the clastic facies commonly contain distinctive faunas that appear to correlate to a large degree with sedimentary environment. It is unlikely, based on the models mentioned above, that these zones are directly related to deltaic progradation. Rather, they may represent interdeltaic, lagoonal, shelf, or carbonate bank deposits similar to those in the Pennsylvanian of north-central Texas (Brown, 1969; Galloway and Brown, 1972; Brown et al., 1973). Toward the north and west, particularly in Catoosa County, Georgia, great thicknesses of the equivalent Tuscumbia and Monteagle limestones may represent shelf and bank carbonate rocks deposited in areas away from terrigenous influx. The local abundance of tabulate and rugose corals in this area suggests that water depth possibly did not exceed 50 m (Wells, 1957, p. 774).

The lack of extensive sandstone units in the Floyd Shale in Georgia makes interpretation of the genesis and depositional environment of the formation difficult, particularly if the study is restricted to the shale unit. Cressler's description of the overlying Hartselle Sandstone (1970, p. 48) suggested that the Floyd and Hartselle constitute a coarsening upward sequence. This strongly indicates that the Floyd, in part, represents a prodelta facies and that, at least in part, the Hartselle represents a delta-front facies. Rocks in or above the Hartselle that may be construed as delta plain or distributary facies probably once existed to the southeast along a facies tract typical of delta systems, but have not been recognized in Georgia, because of removal by erosion.

The general depositional history of the Floyd Shale and associated contemporaneous facies in Georgia may be summarized as follows (Fig. 2): delta progradation began initially during the Meramec, contemporaneous with deposition of the Tuscumbia Limestone on a shelf area to the northwest. During the late Meramec and early Chester, deltas, temporarily abandoned, were destroyed by marine processes and were replaced by offshore environments of the transgressive Monteagle Formation. Progradation in the area began again during the early Chester and continued through the middle Chester when Floyd deltas apparently reached their maximum geographic extent. Following abandonment, destructional phases occurred near the end of the middle Chester and continued into the late Chester, during which time delta-front Hartselle sands were reworked and the Bangor Limestone transgressed the foundering delta system.

Marine organisms living in this regime were greatly affected by changes in depositional environment. Areas of active sedimentation such as the delta-front and prodelta facies were unsuitable for many benthic organisms. During delta progradation, however, embayment and offshore shelf environments supported large and diverse faunas. Marine transgressions during delta destruction resulted in colonization of new areas by benthic organisms.

BENTHIC COMMUNITIES IN THE FLOYD SHALE

Fossil assemblages studied in the Floyd Shale comprise five major types identified on the basis of presence and relative abundance of component taxa. Many species and genera occur in more than one assemblage type, but their relative abundance and co-occurrence with other taxa facilitate identification of the five types. Overlapping distributions of genera and species in the assemblages of the Floyd Shale present a complex arrangement of biofacies. These biofacies have been combined primarily on the basis of assemblage characteristics into five types, which probably represent the preserved remains of marine benthic invertebrate communities. Diversity in the communities was evaluated at the generic level, and the lowest taxonomic level used to define these communities was the genus. Characterization of communities at the generic and higher taxonomic levels facilitates widespread geographic recognition; thus all five Floyd Shale communities may be regarded as "parallel communities" in the sense of Thorson (1957). The five communities are (1) *Lingula,* (2) Bivalvia-Spiriferida-Productidina, (3) Fenestellidae, (4) *Pentremites*-Spiriferida-Fenestellidae, and (5) *Michelinia*-Rugosa.

The inarticulate brachiopod, *Lingula,* in moderate to great abundance characterizes faunas of community 1. Associated rock types range from sandy siltstone to silty shale, which are commonly bioturbated and contain fragments of terrestial

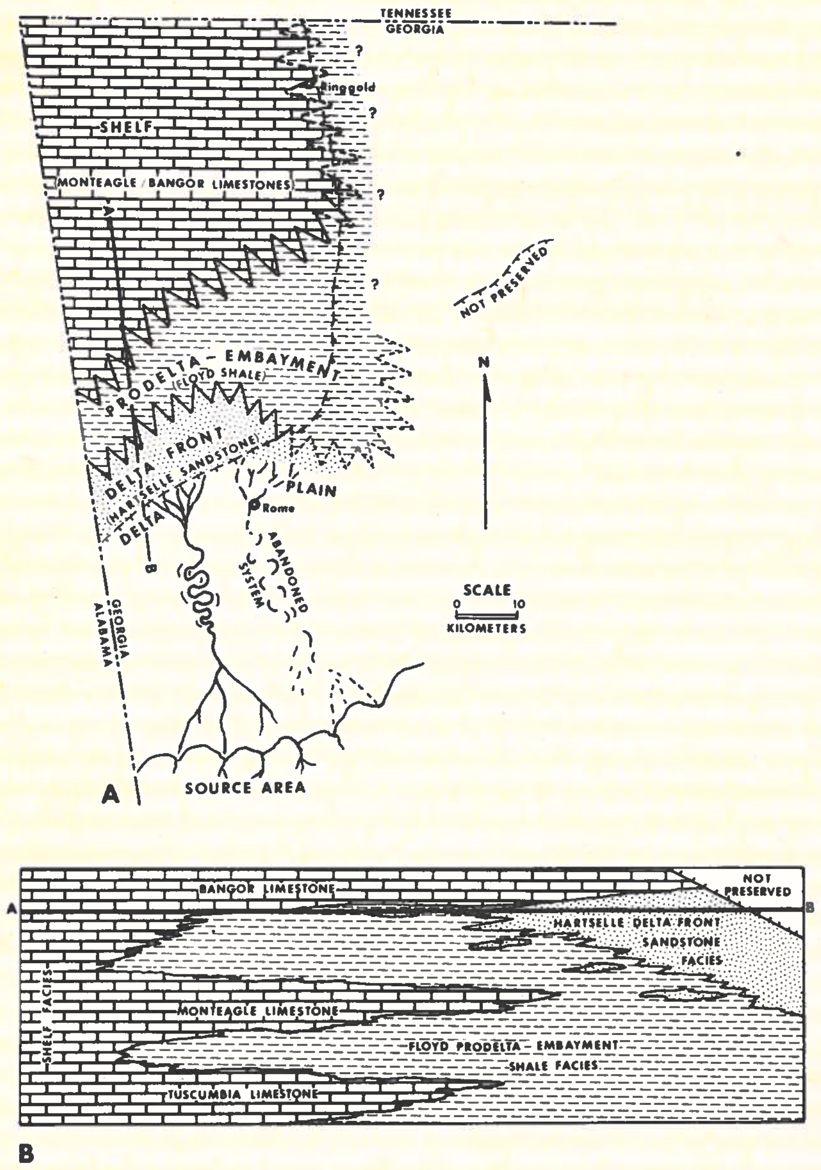


Figure 2
(A) Interpretation of middle Chesteran depositional environments in northwest Georgia showing the relationship of the Hartselle Sandstone and Floyd Shale during transgression of the Bangor Sea. (B) Diagrammatic (no scale) section of upper Mississippian rocks in Georgia. Line AB corresponds to position of facies shown in A. [Modified after Cressler (1970) and McLemore (1972).]

plants. This clastic-rich environment was probably developed as part of the prodelta mud or distal delta-front facies of Floyd deltas. Fluctuating salinity would have precluded stenohaline organisms because of the proximity to river outlets. Furthermore, the relatively high rate of sedimentation from settling clay and silt, although providing a source of food, would have resulted in burial of many sessile or nonburrowing animals. *Lingula* was well adapted to life in such an environment and may have lived in association with large numbers of worm-like organisms that inhabit similar Holocene environments. Orientation of most *Lingula* shells parallel to bedding suggests that currents or small turbidity flows from the delta front resulted in scouring.

The most common organisms in community 2 (Bivalvia-Spiriferida-Productidina) are the productid brachiopod *Inflatia* and several genera of bivalve mollusks, especially the nuculoid, *Phestia*, and the pterioid, *Aviculopecten*. Associated rock types range from silty shale to argillaceous limestone, with the more detrital-rich strata commonly containing fragments of terrestrial plants. This community is probably generally comparable to West's (1972) *Glabrocingulum* and transitional communities and is fairly common in the southeastern part of the outcrop area of the Floyd Shale. This community probably developed where abandoned delta lobes had foundered, and restriction of the embayments may have resulted from longshore transport of paralic sediments. Influx of freshwater into the embayment probably retarded colonization by more stenohaline organisms (e.g., corals, echinoderms, bryozoans), which are rare or absent at most localities. Also, a soft muddy substrate may have been unsuitable for larval attachment of many organisms, although shell debris may have commonly filled this requirement. Low sedimentation rate contributed to the growth of many sessile organisms. Although muds were reworked near the surface by burrowing bivalves, there is little indication of postmortem disturbance; few brachiopods are disarticulated, and many productid brachiopods are in inferred life position (Rudwick, 1970).

Community 3 (Fenestellidae) is dominated by fenestellid bryozoans and occurs in rocks ranging from slightly calcareous shale to siltstone. The community is named for the great abundance of fronds of the "*Fenestella*" type, most of which probably belonged to either *Fenestella* or *Archimedes*. This is the least common Floyd Shale community (six localities), and probably represents a sporadically developed environment on or marginal to the shelf, such as an embayment, distal prodelta, or mud bank facies. The assemblage in community 3 suggests that it was characterized by rapid colonization and growth of the fenestellids, which ultimately presented an effective nutrient filter that hampered the survival of lower-lying, suspension-feeding brachiopods. Accumulation of fronds on the bottom would have provided a good substrate for attachment of many larvae, but probably rendered the substrate unlivable for shallow-burrowing infauna.

Community 4 (*Pentremites*-Spiriferida-Fenestellidae) is the most generically diverse community in the Floyd Shale and includes a great variety of stenohaline organisms (e.g., echinoderms, corals, bryozoans), suggesting that it represents an environment with open marine circulation. The most common genera in this community are the blastoid, *Pentremites*, and the spiriferoid brachiopods, *Cleiothyridinia*, *Composita*, *Spirifer*, and *Reticulariina*, which also occur in community 5, but with the exception of *Composita* and *Spirifer*, are not nearly as common in other communities. This community may be broadly similar to West's *Cleiothyridina* community, but differs largely in having fewer mollusks and more echinoderms and corals. Abundant articulated remains of pelmatozoan echinoderms, articulate brachiopods, and rare bivalves suggest little water agitation in this environment; it was probably largely developed below wave base.

Community 4 is the most widespread community in the Floyd Shale (48 localities) and characteristically occurs in rocks ranging from calcareous shale to calcilutite, which are commonly deeply weathered in outcrop, leaving a reddish-brown clay saprolite containing silicified fossils. The environment represented in community 4 was probably a vast carbonate- and mud-shelf facies over which Floyd delta lobes prograded and upon which carbonate banks developed from time to time. Circulation was probably excellent and sedimentation relatively slow, with an abundant food source in the plankton. At several localities, the faunas appear to be more nearly intermediate between community 4 and faunas of communities 2, 3, or 5, a circumstance that suggests local proximities of those associated environments to the open shelf.

Community 5 (*Michelinia*-Rugosa) commonly contains many of the faunal elements found in community 4, but diversity is more variable and generally lower. Where the rugose corals of community 4 are predominantly hapsiphyllids, those in community 5 characteristically include many dissepimented forms in addition to the hapsiphyllids. The tabulate, *Michelinia*, is relatively common in community 4 assemblages, but is more abundant in community 5. Other important communal organisms include blastoids (especially *Pentremites*), crinoids, and occasionally a wide variety of articulate brachiopods, including nearly all forms found in community 4. The most common associated rocks range from calcilutite to skeletal and oolitic calcarenite with weathering characteristics much like rocks containing community 4. Community 5 occurs in small carbonate buildups that are characteristic of carbonate-bank facies and commonly develop in clear, turbulent water. The wide range in diversity among faunas from various localities containing community 5 may represent differences in bathymetry relative to wave base, with the shallowest, most frequently agitated faunas characterized almost solely by tabulate and colonial rugose corals.

Because of the small thickness and areal extent of most Floyd Shale outcrops, transitions and changes from one community to another in one exposure are rare. A notable example, however, is the abrupt change from community 5 to 4 exposed in the quarry at Drag City near Ringgold, Georgia. In that quarry, about 25 m of dark gray, massively bedded oolitic and skeletal calcarenite containing abundant *Lithodrumus* sp., *Pentremites* sp., and unidentified inadunate crinoids is abruptly overlain by about 1 m of silty calcilutite to calcareous siltstone that contains numerous fragments of an arborescent lycophyte (aff. *Archaeosigillaria*). Above the plant-bearing beds, the rock grades upward into calcareous shale and calcilutite that contain abundant articulate brachiopods (*Composita, Cleiothyridina, Inflatia, Spirifer*), fenestellid bryozoans, hapsiphyllid corals, and a crinoid fauna dominated by

Agassizocrinus. The upper assemblage is characteristic of community 4 and developed in the area following the smothering of the community 5 fauna by the influx of the plant-bearing clastic sediment. Lack of Floyd exposures farther east in Catoosa and Whitfield counties precludes the possibility of identifying the paleoshore and possible source of the plants.

COMMUNITY DISTRIBUTION

Detailed analysis of community distribution within the Floyd Shale is particularly complicated by several factors: (1) complex geologic structure, (2) deep weathering, (3) time-transgressive lithic units (stratigraphic distribution) and (4) lack of detailed knowledge of the autecology of the organisms. The present geographic distribution of localities representing the five Floyd Shale communities is more simply presented (Fig. 3) and shows (1) the majority of localities containing communities 1 and 2 are in the south and east parts of the outcrop belt; (2) the widespread distribution of community 4, characterizing a broad, generalized environment; (3) the small distribution of community 3, suggesting a more restricted, sporadically developed environment; and (4) restricted occurrence of community 5 along the western part of the outcrop belt. Distribution of communities appears to be closely related to rock types that characterize particular sedimentary environments. This undoubtedly reflects the distribution of physical and biotic controls on the occurrence of communal organisms.

Distribution of many major taxa (Fig. 4) correlates with the bulk average inferred sediment type (Fig. 5). Communities 1 and 3 are characterized by low diversity, dominance by a single taxon (the genus *Lingula,* the family Fenestellidae) and trophic level (Fig. 5), and most commonly occur in rocks composed of a high percentage of terrigenous sediment. The association of more infaunal organisms with environments characterized by rapid sedimentation (e.g., the prodelta) or by probable changes in salinity (embayment) at least partly reflects some success in coping with unstable environmental factors. Grazing or deposit-feeding organisms in great abundance may suggest high levels of primary production or significant amounts of incoming nutrient-laden detritus. Several levels of epifaunal suspension feeders (e.g., community 4) are suggestive of stable environmental conditions and effective water circulation, but not necessarily of agitation.

Understanding of stratigraphic distribution of communities in the Floyd Shale has by necessity been based on biostratigraphic criteria where these are present in fossil assemblages. The three major transgressive phases associated with the Floyd Shale (Tuscumbia, Monteagle, and Bangor) are characterized by establishment of communities 4 and 5. Morphologic grades in *Pentremites* (i.e., progressive broadening and reduced convexity to increased concavity of ambulacra) and the occurrence of several species of crinoids and articulate brachiopods facilitate age identification of communities 4 and 5. Age determinations of community 2 are aided by the occurrence of some of the same brachiopod species found in community 4 and by the additional occurrence of ammonoid cephalopods (*Lyrogoniatites, Cravenoceras*) at many localities. Determination of the stratigraphic position of localities containing

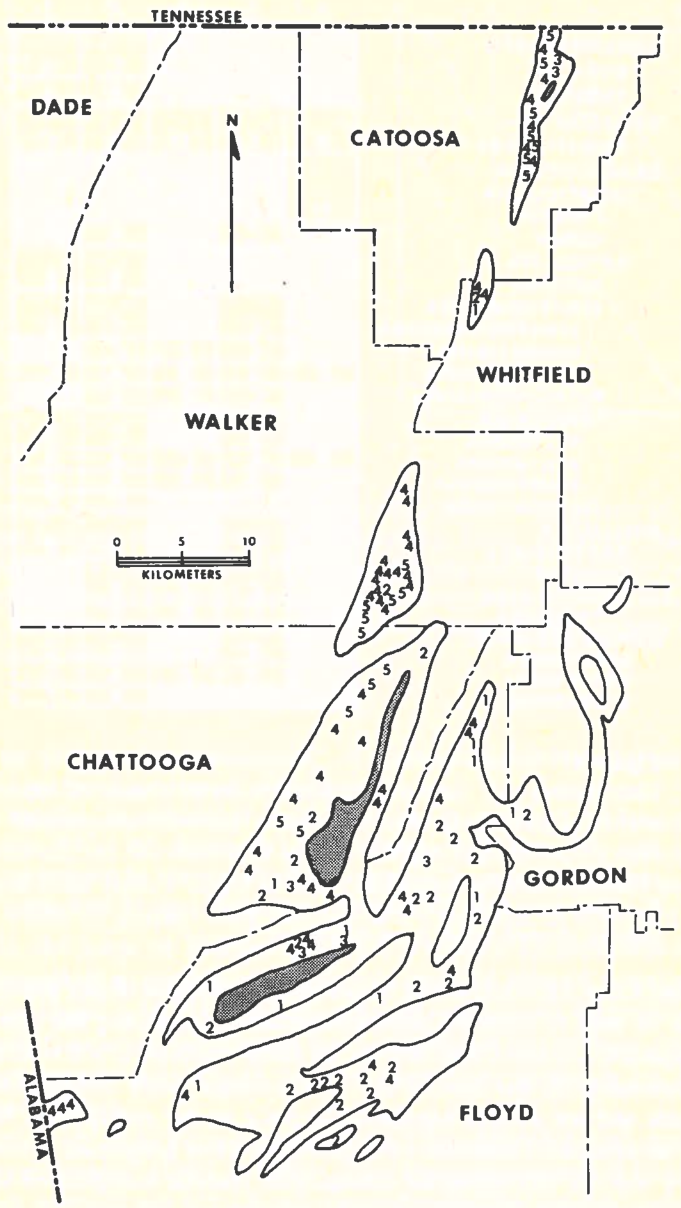
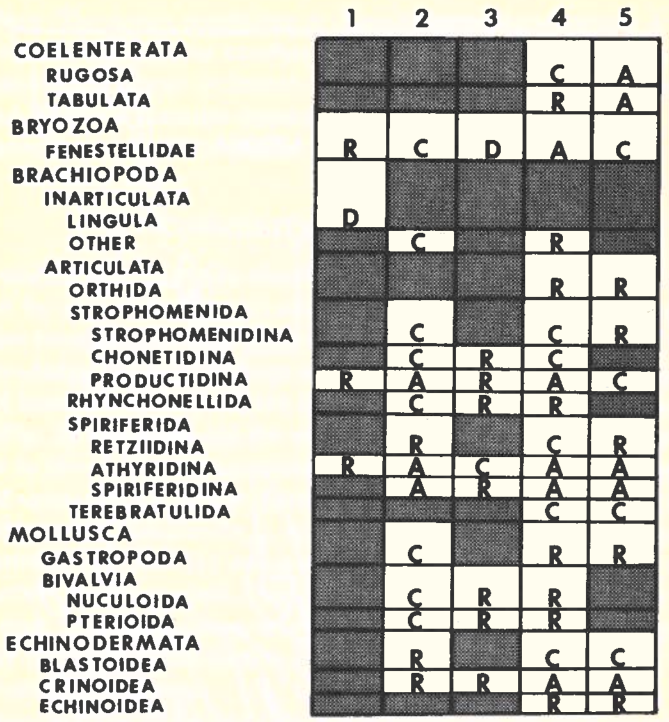


Figure 3
Distribution of localities containing benthic invertebrate communities in the Floyd Shale of Georgia. Numbers represent communities: 1, *Lingula*; 2, Bivalvia–Spiriferida–Productidina; 3, Fenestellidae; 4, *Pentremites*–Spiriferida–Fenestellidae; 5, *Michelinia*–Rugosa. Stippled areas indicate younger Paleozoic rocks.



	1	2	3	4	5
COELENTERATA					
RUGOSA	▨	▨	▨	C	A
TABULATA	▨	▨	▨	R	A
BRYOZOA					
FENESTELLIDAE	R	C	D	A	C
BRACHIOPODA					
INARTICULATA					
LINGULA	D	▨	▨	▨	▨
OTHER	▨	C	▨	R	▨
ARTICULATA					
ORTHIDA	▨	▨	▨	R	R
STROPHOMENIDA					
STROPHOMENIDINA	▨	C	▨	C	R
CHONETIDINA	▨	C	R	C	▨
PRODUCTIDINA	R	A	R	A	C
RHYNCHONELLIDA	▨	C	R	R	▨
SPIRIFERIDA					
RETZIIDINA	▨	R	▨	C	R
ATHYRIDINA	R	A	C	A	A
SPIRIFERIDINA	▨	A	R	A	A
TEREBRATULIDA	▨	▨	▨	C	C
MOLLUSCA					
GASTROPODA	▨	C	▨	R	R
BIVALVIA					
NUCULOIDA	▨	C	R	R	▨
PTERIOIDA	▨	C	R	R	▨
ECHINODERMATA					
BLASTOIDEA	▨	R	▨	C	C
CRINOIDEA	▨	R	R	A	A
ECHINOIDEA	▨	▨	▨	R	R

Figure 4
Distribution of important benthic invertebrate groups among Floyd Shale Communities: D, dominant, greater than 50 percent of specimens; A, abundant, 10 to 30 percent of specimens; C, common, 2 to 10 percent of specimens; R, rare, less than 2 percent (commonly one or two specimens); shaded areas, nonoccurrence.

communities 1 and 3 is complicated by the rarity or absence of any genus or species that could be used to correlate them with localities containing the other communities. Diagnostic articulate brachiopods are fairly common at a few localities containing community 3, but community 1 assemblages rarely contain fossils other than *Lingula* and are all but impossible to place in the stratigraphic framework. Thus, the occurrence of different communities in close geographic proximity is at least partly due to differences in stratigraphic position complicated by folding, faulting, and extreme weathering.

ENVIRONMENTAL INTERPRETATIONS

Generalized evolutionary and environmental patterns affecting Paleozoic communities of marine benthic invertebrates have been outlined and charted by Bretsky (1968, 1969). His arrangement depicted three major divisions of a generalized onshore to offshore transitional sequence on the marine shelf. Each division is characterized by at least one "association" of communities identified from Paleozoic rocks either by Bretsky or by other workers.

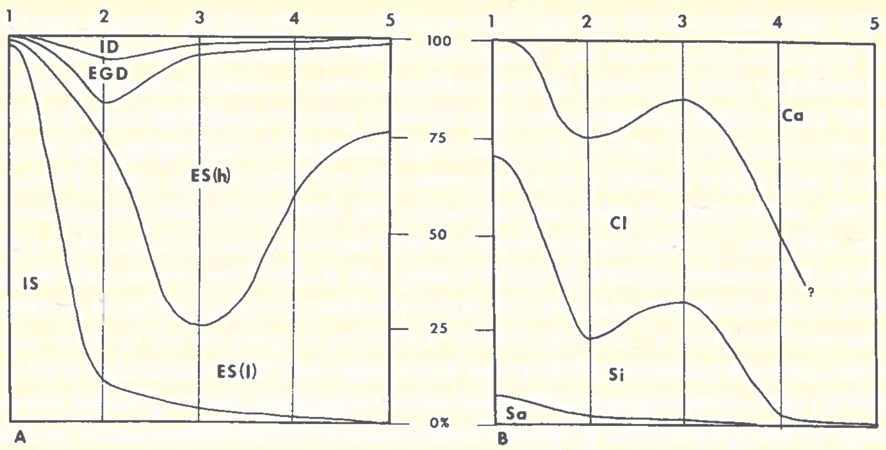


Figure 5
Gross average percentages of individuals in (A) trophic categories: IS, infaunal suspension-feeding; ID, infaunal deposit-feeding; EGD, epifaunal grazing and deposit-feeding; ES(h), epifaunal suspension-feeding (high-level); ES(1) epifaunal suspension-feeding (Low-level); and (B) inferred sediment type: Sa, sand; Si, silt; Cl, clay; Ca, carbonate. Data based on inferred trophic relationships and field description of lithotypes.

For the Mississippian, Bretsky relied on the work of Craig (1955) and Ferguson (1962), who studied the Visean of Britain. Craig examined approximately 0.6 m of a calcareous shale from a single locality, and collected and analyzed about 5,000 fossils of which 40 percent were macrofossils. From this he identified two communities in the sense of Petersen (1913); (1) *Lingula squamiformis–Nuculopsis gibbosa–Sanguinolites costellatus* community from an inferred nearshore, rough-water environment, and (2) *Posidonia corrugata*–arenaceous foraminifer–*Waylandella cuneola* (ostracode) community from a slightly farther offshore environment. Bretsky has appropriately placed both of these communities in his Linguloid-Molluscan association.

Ferguson's study included one outcrop of a 2.8-m-thick shale unit representing a "marine transgression" (1962, p. 1090). Four topozones identified (from the base of the unit upward) are (1) *Lingula squamiformis–Streblopteria oranta,* (2) *L. squamiformis–Crurithyris urei*, (3) *Schizophoria resupinata–Eomarginifera longispina,* and (4) *E. longispina*–corals–bryozoans. Bretsky combined topozones 1 and 2 into the *Lingula–Nuculopsis* community of the Linguloid–Molluscan association, and 3 and 4 into the *Schizophoria–Eomarginifera* community of the Productid–Chonetid association.

Inherent problems exist from the use of these studies to summarize benthic community structure in Mississippian strata. Not the least of these problems is that each study was done on one exposure, which reduces the facility of interpretation of geographic distribution and variation within the communities. Second, the small thickness of rock studied by Craig and Ferguson may represent a time interval too brief and physical conditions too transitional to permit the establishment of stable communities. Craig's study included only the "nearshore" communities, but Ferguson's unit grades upward into a limestone with a "*Lithostrotion* reef" (1962, p. 1106). Nevertheless, there is no community that Bretsky felt should be placed in the "offshore" community associations, which leaves a gap between the top of the Atrypid–Bryozoan association of the Lower and Middle Paleozoic and the Fusulinid–Paleotextulariid association of the Upper Paleozoic (Pennsylvanian and Permian).

Recent work by West (1972) on the Pennsylvanian of Oklahoma and by Watkins (1973) on the Mississippian and Pennsylvanian of California have augmented knowledge of stratigraphic and geographic distribution of Carboniferous faunal associations and communities. West's (1972) identification of depositional environments containing his communities greatly enhances the environmental significance of community distribution. Watkins (1973) carefully analyzed the petrology of rocks containing his associations and communities, but did not postulate specific depositional environments.

Floyd Shale communities can be assigned to the generalized categories proposed by Bretsky. Community 1 would correspond to the Linguloid–Molluscan association, filling the nearshore environment. Community 2, although it contains a diverse molluscan fauna, could be placed in the Productid–Chonetid association if its inferred environmental position is disregarded. Community 4 corresponds to the offshore open shelf environment, filling the gap in Bretsky's chart. Communities 3 and 5 developed in specialized environments that probably lacked broad geographic continuity and need not be considered in the simplified onshore sequence.

An attempt has been made by Anderson (1971) to place more emphasis on tectonic factors related to depositional environment. His models included:

> (1) . . . low slope epeiric seas (in the order of one foot per mile) where waves impinge on the substrate and are dissipated some distance offshore producing a low energy subtidal zone onshore. (2) . . . epeiric seas where the zone of maximum wave and current agitation is at or near the shoreline. Such condition is associated with shores which are building out or prograding or with shores of higher slope (in the order of five to ten feet per mile). Progradation tends to fill low-energy onshore zones and steeper slopes do not leave room for them to develop as separate recognizable entities onshore from the zone of wave dissipation (p. 296).

Anderson correlated the number of recognizable communities with the type of model, there being more communities with the more stable model 1. In short, he emphasized water depth and kinetics relative to wave energy as a function of depth, maintaining the concept of onshore to offshore transitions. The addition of wave energy and depth as variables may still be insufficient to describe community distributions, even in a general overview.

The nonuniform influx of sediment into a marine basin effectively creates barriers between previously existing areas of similar environment and produces areas of variable geographic and temporal span with a wide range of physical environments. Parker's (1956) correlation of macrofauna and sedimentary environments in the Holocene Mississippi River delta area is an excellent example, which shows that no straight line can be drawn from the "onshore" to "offshore" areas that will include all environments. Thus, the juxtaposition of communities in a "normal" onshore to offshore sequence may be precluded, and any very small area studied may result in the sampling of nontypical assemblages. The "missing communities" in Ferguson's work might be explained in terms of depositional environment and lateral distribution of controlling facies, and may be expected to occur either farther offshore or in a lateral position, depending on local conditions of sedimentation.

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