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The fauna of the Clayton Formation (Paleocene, Danian) of southern Illinois: a case of K/P survivorship and Danian recovery

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Abstract

Identification of 8640 specimens of bryozoan, mollusk, decapod, and vertebrate fossils from the Paleocene Clayton Formation in southern Illinois has resulted in recognition of 44 species-level taxa of which 40 have been identified to genus or species. The fauna is less diverse than other Clayton Formation faunas which may be a result of its having formed in an area of reduced salinity at the head of the Mississippi Embayment. One bryozoan, seven mollusk, and one shark species comprise 93% of the individuals. Thirty-nine of the taxa identified have been known previously from occurrences in Cretaceous rocks of the Atlantic and Gulf Coastal Plains and the Upper Midwest documenting a high percentage of survivors in this fauna. The area, although connected to the Gulf of Mexico, may have served as a refugium.

Key words: Paleocene, Danian, Clayton Formation, Bryozoa, Mollusca, Decapoda, Vertebrata, survivorship

Introduction

The fate of organisms as a result of the extinction event at the end of the Cretaceous Period has been the subject of a vast amount of literature. The documentation of survivorship and recovery of organisms following that extinction event has received less attention. Therefore, the description of highly fossiliferous Paleocene assemblages that document survivorship and recovery of organisms following the Cretaceous extinction is extremely important. It is the purpose of this note to evaluate the composition of the fauna of the Danian Clayton Formation in Illinois and to discuss the response of the organisms to the extinction event.

The Clayton Formation in southernmost Illinois consists of up to 6 m of bioturbated, dark green, glauconitic, micaceous, fine to medium sand alternating with dark gray clay. In surface exposures, the only body fossils of macroinvertebrates are poorly preserved molds barely identifiable as *Turritella* Lamarck, 1799, *Ostrea* Linnaeus, 1758, and *Venericardia* Lamarck, 1801.

The fossils from the Clayton Formation are dominantly phosphatic, including phosphatized shells and skeletons or phosphatic molds, and most of the mollusks (except for interior molds) are encrusted by bryozoans. The faunal composition, preservation style, and the abundant glauconite suggest low rates of sedimentation and active circulation of sea water (Lucas and Prevot *in* Allison and Briggs, 1991).

Before the present collection was made and studied, virtually nothing was known about the nature of the Danian fauna living at the head of the Mississippi Embayment. Collecting from spoil piles of the Clayton Formation has yielded marine mollusks, bryozoans, crustaceans, and vertebrates (Masters and Fluegeman, 1997; Mitchell and Cuffey, 1997). Continued, more extensive collecting by us and others produced a total collection of 8,640 fossils arrayed in approximately 44 taxa, of which 40 can be assigned to genus- or species-level taxa (Cope, 1999; Cope *et al*., 1999) (Table 1). The Clayton spoil, dug up while excavating sumps in the base of the clay pit, was below the water table and contained fairly well preserved body fossils. Since our last collecting trip the pit has been reclaimed.

The lower diversity of this fauna compared to the Clayton fauna in the Eastern Gulf Coast and the dominance of a few benthic and one nectonic species suggests brackish to near normal marine conditions at the head of the Mississippi Embayment during the Danian. One of us (RMF) attributes the lower diversity and high dominance to the possibility that this is a founder population in which ecological climax had not been reached or that there is a strong preservational bias favoring a few taxa. Thirty-six of the species recognized in the Clayton Formation in Illinois have been found previously in Paleocene or Cretaceous occurrences in the eastern Gulf Coast region, one species is known also from the Atlantic Coast, one also from the Western Interior Seaway and Pacific Northwest, and 16 co-occur in the western Gulf Coast, suggesting counterclockwise paleocurrent flow in the Mississippi Embayment from the southeast to the head of the embayment and toward the southwest.

Table 1. Relative abundance and reported ages and geographic occurrences of Clayton macrofauna.
Ages and occurrences from Applegate (1970), Canu and Bassler *in* Wade (1926), Case (1967), Case (1991), Hantzschel (1975), Holman (2002), Gardner (1935), Manning and Felder (1991), Moore (1969), Rathbun *in* Wade (1926), Rathbun (1935), Shimer and Shrock (1944), Stephenson (1914), Stephenson (1941), Toulmin (1977), Wade (1926).
EGC = Eastern Gulf Coast, WGC = Western Gulf Coast, ACP = Atlantic Coastal Plain, WIS = Western Interior Seaway.

Taxon	Number	Percent of total fauna	Cretaceous genus	Cretaceous species	Region reported
Turritella alabamiensis	3370	39.00	Yes	No	EGC, WGC
Conopeum damicornis	2641	30.57	Yes	No	EGC, WGC
Pitar? *ripleyanus*	728	8.43	No	No	EGC
Ostrea pulaskensis	503	5.82	Yes	No	EGC, WGC
Lamna cuspidata	206	2.38	Yes	Yes	EGC, ACP
Natica reversa	198	2.29	Yes	No	EGC, WGC
Venericardia smithii	168	1.94	Yes	No	EGC, WGC
Venericardia sp.	158	1.83	Yes	?	EGC
Strepsidura contorea	133	1.54	Yes	No	EGC
Turritella aldrichi	95	1.10	Yes	No	EGC
Venericardia mediaplata	95	1.10	Yes	No	EGC
Ranella showalteri	71	0.82	Yes	No	EGC
Unidentified fish teeth	46	0.53	?	?	?
Teredo mississippiensis	35	0.41	Yes	No	EGC
cf. *Tornatellaea cretacea appressa*	21	0.24	Yes	Yes	WGC
Cylichna cf. *C. secalina*	18	0.21	Yes	Yes	WGC
cf. *Latirus biplicatus*	17	0.20	Yes	No	EGC
Meandropolydora sp.	17	0.20	Yes	Yes	Europe
Clavipholas cf. *C. pectorosa*	13	0.15	Yes	Yes	WGC
cf. *Eulima clara*	13	0.15	Yes	Yes	EGC, WGC
Ischyodus williamsae	13	0.15	Yes	Yes	ACP
Shark vertebrae	11	0.13	Yes	?	EGC
Ostrea crenulimarginata	6	0.07	Yes	Yes	EGC, WGC
Jupiteria smirna	6	0.07	No	No	EGC, WGC
Chelonia sp.	6	0.07	Yes	?	EGC
Venericardia wilcoxensis	5	0.06	Yes	No	EGC, WGC
Teredolites sp.	5	0.06	Yes	?	EGC
Propensor hewletti	5	0.06	Yes	Yes	EGC
Bullata? cf. *B. semen*	4	0.05	Yes	Yes	EGC
Callianassa cf. *C. mortoni*	4	0.05	Yes	Yes	EGC
Linuparus canadensis	4	0.05	Yes	Yes	EGC, WGC, WIS
Glycymeris idonea	3	0.03	Yes	No	EGC
Ptychodus sp.	3	0.03	Yes	?	EGC
Banaogmis cf. *B. crieleyi*	3	0.03	Yes	Yes	EGC
Unidentified fish plates	3	0.03	Yes	?	EGC
Holoparia tennesseensis	2	0.02	Yes	Yes	EGC
Calyptraea sp.	2	0.02	Yes	No	EGC
Paguristes johnsoni	2	0.02	?	No	EGC
Crocodilian teeth	2	0.02	Yes	?	EGC
Orthosurcula? sp.	1	0.01	No	No	EGC, WGC
Spironema? cf. *S. perryi*	1	0.01	Yes	Yes	WGC
Epitonium? cf. *E. bexarense*	1	0.01	Yes	Yes	WGC
cf. *Porchyrhizodus caninus*	1	0.01	Yes	Yes	EGC
cf. *Trionyx* sp.	1	0.01	Yes	Yes	EGC
Totals	8640	100.00			

Location of Study and Repository

All fossils identified in this study came from spoil piles of the Clayton Formation in the Golden Cat Company's clay pit near Olmsted, Pulaski Co., Illinois (in the SW 1/4, Sec. 23, T. 15 S., R. 1 E.), U.S.A (Fig. 1). The specimens are housed in the collections of the Illinois State Geological Survey, Accession Number 90P.

Fig. 1. Map of the Paleocene outcrop pattern in the region of the Gulf Coastal Plain, southeastern United States, showingthe location, in southern Illinois, of the site from which fossils were collected.

Method of Collection

Over several years, a number of people visited the clay pit with one or more of us on numerous occasions. Early on, we collected from spoil piles in the pit next to the sumps excavated in the Clayton Formaton. Later, the pit manager, Jerry McKee, arranged to have the Clayton spoil hauled up onto the surface above the pit. The lithology of the Clayton is distinctively different from the underlying Owl Creek Formation or the overlying Porters Creek Formations so we are certain that all of the fossils studied are from the Clayton Formation. We collected every fossil or suspicious-looking nodule visible.

Because all fossils were collected, the 8640 specimens are a good census and provide a fair representation of the Clayton fossil assemblage at this locality. This is supported by the fact that the relative abundances of common taxa in Cope's thesis collection (made prior to 1998) and in a collection made by six people on May 14, 1998, are very similar. The clay pit has been closed and reclaimed so the Clayton is no longer accessible at this locality.

Clayton Formation

The Clayton Formation (Paleocene, Danian) lies immediately above the K/P boundary (Fig. 2) and is overlain by the Porters Creek Formation, which was being mined to manufacture Kitty Litter. Here, at the head of the Mississippi Embayment, the Clayton unconformably overlies the Upper Cretaceous (Maastrichtian) Owl Creek Formation or, locally, where the Owl Creek Formation is absent, the Maastrichtian McNairy Formation. Reed *et al.* (1977) used potassium-argon to date the glauconite. The sample from the Owl Creek Formation yielded an age of 65.7 ± 1.4 Ma, and the oldest sample from the Clayton Formation was dated at 60.6 ± 1.3 Ma. Cores taken at the clay pit by the Illinois State Geological Survey show that at this locality the Clayton Formation overlies the Owl Creek Formation. At three natural exposures 2.4 to 3.6 km northeast of the clay pit, the Clayton Formation directly overlies the McNairy Formation. At the clay pit, the Clayton consists of 5 to 6 meters of bioturbated, dark green, glauconitic, micaceous, fine to medium sand alternating with layers of dark gray clay (see Cope, 1999, for details). The Clayton is much better known in the eastern Gulf Coast region, where it is up to 46 m thick and consists of grayish yellow sandy limestone, sand, and light gray calcareous siltstone overlain by sandy fossiliferous limestone, which is overlain by white, massive fossiliferous limestone (Toulmin, 1977, p. 93).

System	Series	Stage	Formation	Thickness	Lithology
Tertiary or Paleogene	Paleocene	Danian	Porters Creek Formation	6m	Massive, compact, unbedded or weakly bedded dark gray clay. Parts are slightly micaceous, silty or glauconitic.
			Clayton Formation	5m	Bioturbated, dark green, glauconitic, micaceous, fine to medium sand alternating with thin layers of dark gray clay.
Cretaceous	Gulfian	Maastrichtian	Owl Creek Formation	2.6m	Fine-grained, light gray sand; micaceous and glauconitic. Some dark gray clay laminations in upper part; lower 0.5m dark brownish clay with light gray sand laminations.
			McNairy Formation	6m to base of core	Dark brownish gray to black clay with a few laminations of dark gray sand. Clay can be organic-rich and have lignitic leaf fragments.

Fig. 2. Coastal Plain sediments at the Golden Cat clay pit. Thickness and lithologies from John Masters' description of the core from Illinois State Geological Survey, Golden Cat #1.

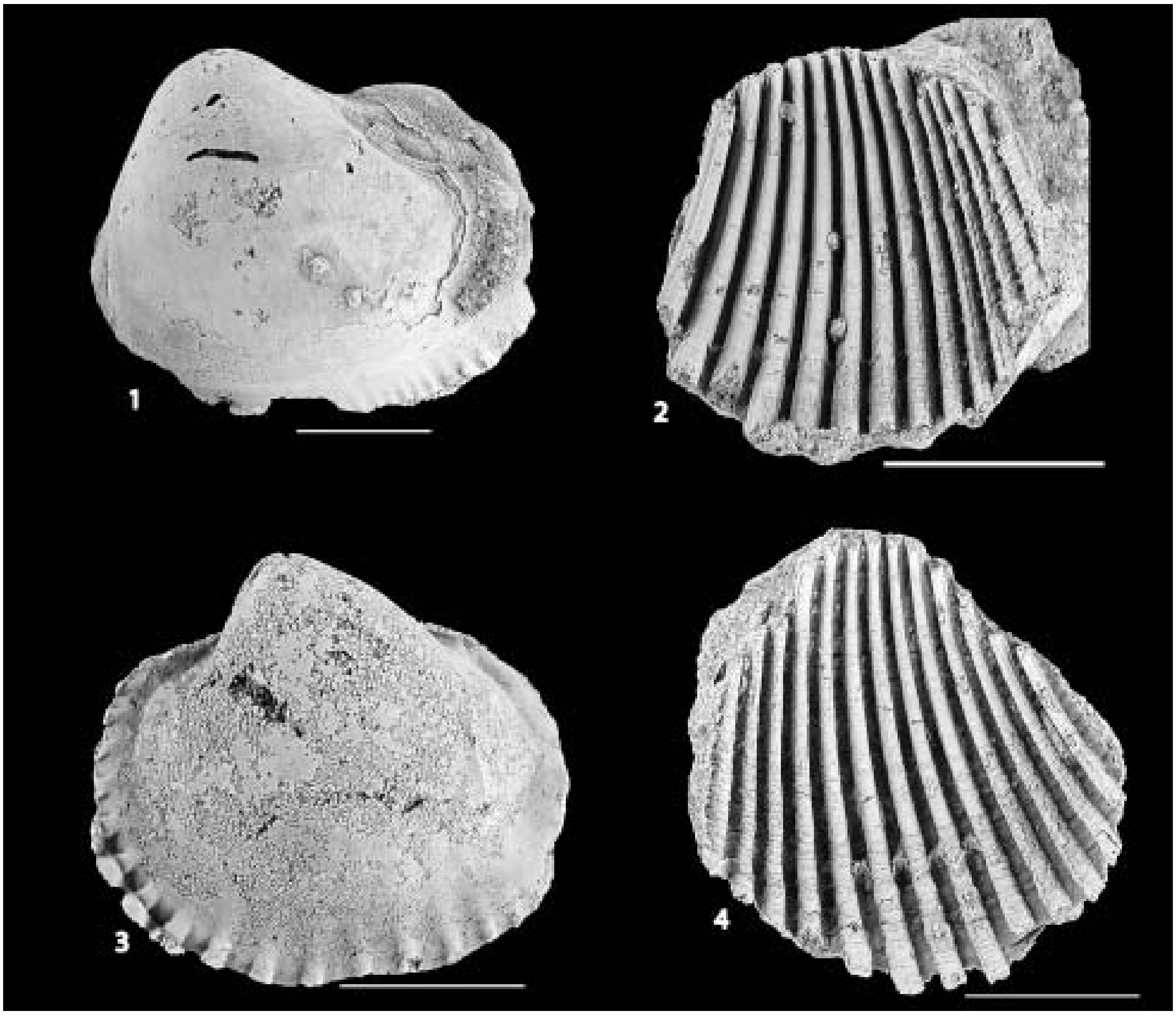


Fig. 3. Common *Venericardia* from the Clayton Formation. 1, 2, *Venericardia smithii* Aldrich, 1894. 1, ISGS 90P4, mold of interior of right valve. 2, ISGS 90P2, incomplete mold of exterior of central portion of valve. 3, 4, *Venericardia mediaplata* Gardner and Bowles, 1939. 3, ISGS 90P7, internal mold of left valve. 4, ISGS 90P6, mold of exterior of partial valve. Bar scale 1 cm.

Dominant Taxa

The assemblage is dominated by nine taxa; one bryozoan, seven mollusks, and a shark account for 93 percent of the total individual fossils. The gastropod, *Turritella alabamiensis* Whitfield, 1865, occurs most commonly as phosphatic internal molds (Figs. 5.1, 5.2), but molds of the exterior can be found at the bases of bryozoans that encrust them. The collection contains 3,370 individuals, but its relative abundance of 39 percent is probably an overestimate of its relative abundance in the fauna because many molds of the interior were broken into two or three fragments. The fragments were counted individually because there was no way to determine the actual number of individuals.

The incrusting to nodular cheilostome bryozoan, *Conopeum damicornis* Canu and Bassler, 1920, incrusts most mollusks and, occasionally, the root of a shark's tooth. Nodular specimens (Fig. 5.15) have been rolled about and have nearly to completely overgrown the original shell substrate. The pelecypod, *Pitar*? *ripleyanus* (Gabb, 1860), is a shallow burrower. Most specimens are molds of the interior (Fig. 2.10). Molds of the exterior (Fig. 4.11) occur at the base of bryozoans that encrusted them. Some have been bored by *Meandropolydora* Voigt, 1965 (Fig. 4.9), and some show evidence of predation by *Natica reversa* Whitfield, 1865. The epifaunal pelecypod, *Ostrea pulaskensis* Harris, 1894, occurs mostly as single valves (Fig. 4.3), and most are incrusted by bryozoans. The shallow burrowing pelecypod, *Venericardia smithii* Aldrich, 1894, is represented by internal molds (Fig. 3.1), external molds (Fig. 3.2), and steinkerns. Most are incrusted by bryozoans. The gastropod, *Natica reversa* (Fig. 5.13), an infaunal predator, is represented mostly by internal molds with a few external molds. Only a few are incrusted by bryozoans. *Venericardia* sp. is represented by incomplete internal molds (Fig. 4.2) that do not show ribs, and distinction could not be made between *V. smithii*, *V. mediaplata* Gardner and Bowles, 1939, or *V. wilcoxensis* Dall, 1903. Most are incrusted by bryozoans, and some show evidence of predation by *Natica reversa* (Fig. 4.2) or have been bored by *Meandropolydora*. The gastropod, *Strepsidura contorea* Aldrich, 1895, is represented mostly by internal molds (Fig. 5.14) but external molds are found at the base of bryozoans that incrusted them.

Many of the teeth of the shark, *Lamna cuspidata* Agassiz, 1843, could have come from one individual so its relative abundance is probably overestimated. The recovered teeth include a wide range of sizes of maxillary teeth with lateral cusps (Fig. 7.5) and mandibular parasymphyseal teeth (Fig. 7.6). Some of the teeth are incrusted by the bryozoan, *Conopeum damicornis*, which preferred to incrust the base of the tooth but could then overgrow nearly all of it.

Less Common Clayton Invertebrates

Other Clayton invertebrates (Table 1) include the pelecypods *Venericardia mediaplata* (Figs. 3.3, 3.4); *Venericardia wilcoxensis*; *Glycymeris idonea* (Conrad, 1833) (Fig. 4.5); *Ostrea crenulimarginata* Gabb, 1860 (Fig. 4.6); *Jupiteria smirna* (Dall, 1898) (Fig. 4.7); *Clavipholas* cf. *C. pectorosa* Conrad, 1852 (Fig. 4.8); *Teredo mississippiensis* Conrad, 1854 (Fig. 4.12); and *Teredolites* sp. in wood. Other Clayton gastropods include some rare forms represented by incomplete internal molds, making the identification of a few of them quite difficult and preliminary. They are identified as *Turritella aldrichi* Bowles, 1939 (Figs. 5.3, 5.4); *Epitonium*? cf. *E. bexarense* Stephenson, 1941 (Fig. 5.5); *Orthosurcula*? sp. (Fig. 5.6); *Ranella showalteri* (Conrad, 1860); *Calyptraea sp.; Spironema*? cf. *S. perryi* Stephenson, 1941; cf. *Eulima clara* Wade, 1926 (Fig. 5.7); *Cylichna* cf. *C. secalina* Shumard, 1861 (Fig. 5.10); cf. *Latirus biplicatus* Aldrich, 1886 (Fig. 5.11); *Bullata*? cf. *B. semen* Lea, 1833; and cf. *Tornatellaea cretacea appressa* Stephenson, 1941, (Fig. 5.12). Annelids are represented by *Meandropolydora* sp. (Figs. 4.4, 4.9)

Several of the species of decapod crustaceans, the identity of which is certain, have previously been described only from Cretaceous sediments. They are relicts and, as such, have important implications for the effects of the end-Cretaceous mass extinction. For this reason, the Clayton fossils are a valuable resource as a potential test for the magnitude of the extinction event.

The clawed lobster, *Hoploparia tennesseensis* Rathbun *in* Wade, 1926, is identified on the basis of three fragments of chelipeds (Figs. 6.5–6.7), all with broken fingers. The long, slender, relatively smooth left propodus of the most complete specimen from the Clayton Formation is nearly identical to those illustrated by Rathbun *in* Wade (1926). Although no carapace material is available in the Clayton, the identification of the species can be made with certainty. This species is known from the Cretaceous Coon Creek Tongue of the Ripley Formation and, thus, represents a species that survived the K/P event. This is not particularly surprising because the genus is well known in Paleogene rocks of the world and has recently been recognized in rocks as young as Miocene in Antarctica (Feldmann and Crame, 1998).

The ghost shrimp, *Callianassa* cf. *Callianassa mortoni* Pilsbry, 1901, is documented by four specimens, two right propodi (Fig. 6.4), one left propodus, and one dactyl. The specimens conform closely to the description and illustration of this species. However, callianassids are difficult to identify solely on the basis of isolated hands. Manning and Felder (1991) identified several key morphological points to place extant species within genera but those characters were largely found on the merus and carpus of the first pereiopod. Thus, fossils lacking these elements can only be assigned to *Callianassa* sensu lato. *Callianassa mortoni* has been identified in Upper Cretaceous rocks along the Atlantic and Gulf Coastal Plain from New Jersey to Texas (Rathbun, 1935). To our knowledge, there have been no reports of Danian occurrences of the species. For this reason alone, it is prudent to compare the Clayton material to the species rather than to state that identification with certainty. There is no doubt that, coupled with the occurrence of *Hoploparia tennesseensis* and *Linuparus canadensis* (Whiteaves, 1885), the decapod fauna exhibits a distinctly Cretaceous aspect.

The spiny lobster, *Linuparus canadensis*, is documented by one partial cephalothorax (Fig. 6.1) and one partial abdomen. The identification is based upon the coarsely spinose axial and lateral keels on the thoracic portion of the cephalothorax and on the coarsely spinose ridges that define the ovate gastric region on the cephalic portion of the carapace. Other species known from eastern North America, including *L. kleinfelderi* Rathbun, 1931, from the Late Cretaceous of New York; *L. vancouverensis* (Whiteaves, 1884 (1885)), from the Late Cretaceous of Oklahoma; *L. adkinsi* Rathbun, 1935, from the Late Cretaceous of Texas; and *L. wilcoxensis* Rathbun, 1935, from the Paleocene Sucarnoochee Formation in Alabama, possess keels that are granular but not coarsely spinose. *Linuparus canadensis* is known from a variety of Late Cretaceous localities in the continental interior of the United States and Canada, including the Coon Creek Tongue of the Ripley Formation, as well as in the Pacific Northwest in Canada (Schweitzer *et al*., 2003). It represents another survivor of the K/P event. The genus is well known in rocks ranging in age from Cretaceous to Recent (Glaessner, 1969).

The hermit crab, *Paguristes johnsoni* Rathbun, 1935, is recognized on the basis of one well preserved propodus (Fig. 6.2) and one fragment of carpus. The latter (Fig. 6.3) is questionably assigned to this taxon. The specimens representing this species are fragmentary; however, that is the nature of preservation of nearly all pagurid fossils. The carapace and most of the appendages are weakly calcified and the only strongly calcified remains are the chelipeds. The granular ornamentation, outline of the hand, and downturned and slightly curved conformation of the fixed finger are closely comparable to those of the type material illustrated by Rathbun (1935). *Paguristes johnsoni* was originally described from material collected from the Paleocene Sucarnoochee Formation, in Wilcox County, Alabama, so that the presence in the Clayton Formation does not substantially extend the stratigraphic range of the taxon.

One section of a burrow was studied that is of the type referred to *Thalassinoides* Ehrenberg, 1944. The outer diameter of the burrow is about 11 mm, and the inside diameter is about 5 mm. The structure is nearly circular in cross section, generally smooth on the outside, and composed of grey silty material containing abundant tiny, spherical to irregular glauconite grains. Although the segment of tube that is preserved is very short and no branching is observed, the general morphology is that of a decapod burrow. The glauconite grains may be altered fecal material. The most likely candidate as a tracemaker would be *Callianassa mortoni* and, although the height of the largest chelae in the present collection is too large to have fit in the burrow, those of the smaller individuals are the appropriate size to have been the tracemaker. Burrows of this type are widespread in Cretaceous and Tertiary sediments and do not provide any useful information regarding geologic age. Although many callianassids inhabit shallow water environments, some are known from shelf and slope depths (Manning and Felder, 1991).

Less Common Clayton Vertebrates

Clayton reptiles are documented by a neural bone and other fragments of the green sea turtle, *Chelonia* sp.; one bony plate of the leatherback river turtle, cf. *Trionyx*; and two piercing teeth of a crocodilian. These were studied by J. Alan Holman (personal communication to JEU; Holman, 2002), who reported that they were survivors of the K/P mass extinction.

Remains of Clayton bony fishes include one ceratohyal bone of cf. *Pachyrhizodus caninus* Cope, 1872 (Fig. 7.1); bone fragments of *Bananogmius* cf. *B. crieleyi* Applegate, 1970 (Fig. 7.2); fragments of hyoid elements (Fig. 7.3), shoulder girdles (Fig. 7.8), and a frontal of *Propenser hewletti* Applegate, 1970; and unidentified fish plates and teeth (Fig. 7.4). All of the bony fishes we were able to identify are survivors from the Cretaceous.

Chondrichthyes from the Clayton Formation include teeth of the ray, *Ptychodus* sp.; teeth of the ratfish, *Ischyodus williamsae* Case, 1991 (Figs. 7.10, 7.11); and 11 unidentified shark vertebrae (Figs. 7.7, 7.9). Both *Ptychodus* and *Ischyodus*, as well as the more abundant *Lamna*, have been reported previously from the Cretaceous.

Discussion

The Clayton fossils are dominantly phosphatic molds, or phosphatic or phosphatized shell, cuticle, and bone, suggesting low rates of sedimentation and active circulation of sea water. The abundant glauconite in the Clayton suggests marine salinities and low rates of sedimentation.

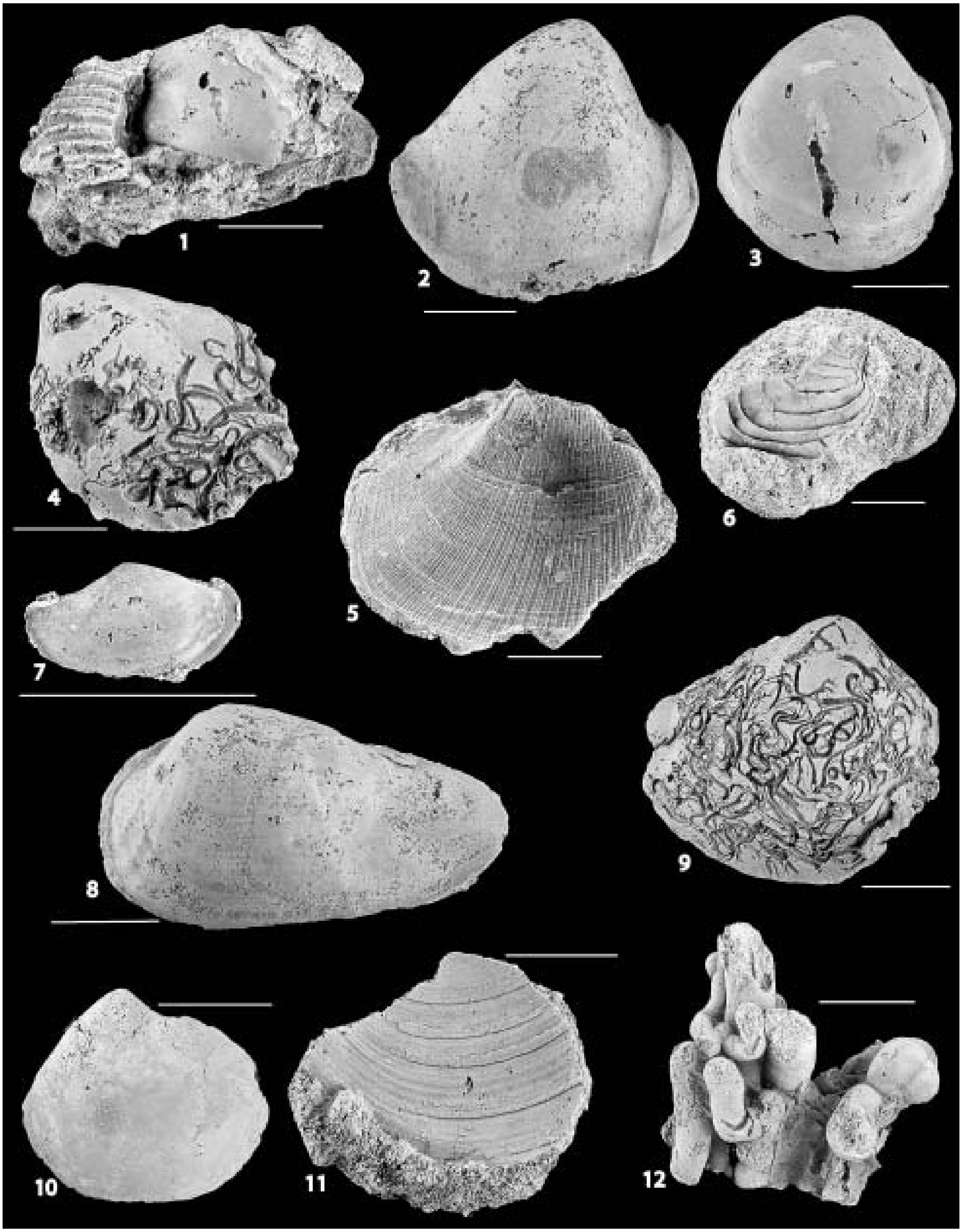
Alternating sand and clay suggest episodic sedimentation and alternating sandy and muddy substrate conditions. At times, the clay bottom may have been stiff, as suggested by the presence of the pholad *Clavipholas*. These boring pelecypods were not incrusted by bryozoans.

Most of the mollusks (except for molds of the interior and deep infaunal forms) are incrusted by bryozoans and many nodular bryozoans have been moved about, suggesting low rates of sedimentation. The fish, turtles, and crustaceans are not incrusted by bryozoans.

The pelecypod steinkerns, the ratio of left valves to right valves of pelecypods, the wide range in size of individuals of most taxa, the lack of abrasion, and the small number of broken or crushed shells (see Cope, 1999, for details) suggest that these fossils were not transported a great distance. They probably represent a within-habitat, time-averaged assemblage.

The fauna of the Clayton Formation in the eastern Gulf Coast region (Georgia, Alabama, and Mississippi) is well preserved, well known, and much more diverse than the Clayton fauna here. Canu and Bassler (1920) reported 31 species of cheilostome and 19 species of cyclostome bryozoans from the Clayton Formation in that region. Toulmin (1977) reported 19 species of pelecypods and 21 species of gastropods from the Clayton of Alabama and Georgia. In addition, taxa he found there include two corals, one articulate brachiopod, two cephalopods, and seven echinoids, all suggesting normal marine salinity. The fauna reported here is less diverse, is dominated by a few benthic and one nectonic species and has no corals, echinoderms, cephalopods or brachiopods. This may be a result of preservational bias or of slightly different paleoceanographic conditions in the two areas such as less than normal marine salinity here at the head of the Danian Mississippian Embayment. Holman (2002) concluded that the

➡Fig. 4. Other common pelecypods from the Clayton Formation. 1, *Venericardia wilcoxensis* Dall, 1903, ISGS 90P9, oblique view showing mold of interior near break and external surface to left. 2, *Venericardia* sp., ISGS 90P4, mold of interior of right valve showing muscle scars and boring made by *Natica*. 3, *Ostrea pulaskensis* Harris, 1894, ISGS 90P14, mold of interior of right valve. 4, *Venericardia* sp., ISGS 90P11, internal mold of right valve showing borings made by the annelid *Meandropolydora* Voit, 1965. 5, *Glycymeris idonea* (Conrad, 1833), ISGS 90P12, partial mold of exterior. 6, *Ostrea crenulimarginata* Gabb, 1860, ISGS 90P17, fragment of mold of exterior encrusted by *Conopeum damicornis* Canu and Bassler, 1920. 7, *Jupiteria smirna* (Dall, 1898), ISGS 90P20, lateral view of steinkern. 8, *Clavipholas* cf. *C. pectorosa* Conrad, 1852, ISGS 90P22, lateral view of left side of steinkern. 9–11, *Pitar*? *ripleyanus* (Gabb, 1860). 9, ISGS 90P24, internal mold of right valve with borings made by *Meandropolydora*. 10, ISGS 90P25, internal mold of right valve. 11, ISGS 90P27, mold of exterior of right valve encrusted by *Conopeum damicornis* Canu and Bassler, 1920. 12, *Teredo mississippiensis* Conrad, 1854, ISGS 90P30, internal molds of tubes. Scale bar equals 1 cm.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Clayton reptiles suggest tropical to subtropical conditions and proximity to a riverine environment.

Thirty-six of the species recognized in the Clayton Formation in Illinois have been found previously in Paleocene or Cretaceous occurrences in the eastern Gulf Coast region, one species is known also from the Atlantic Coast, one also from the Western Interior Seaway and Pacific Northwest, and 16 co-occur in the western Gulf Coast, suggesting counterclockwise paleocurrent flow in the Mississippi Embayment from the southeast to the head of the embayment and toward the southwest.

Some members of the Clayton mollusk and annelid fauna (*Clavipholis* and *Meandropolydora* are examples) are previously known only from the Cretaceous. Others are K/P survivors known elsewhere in the Paleocene. The decapods, reptiles, bony fish, and the shark, ratfish, and ray also show strong Cretaceous affinities. At the generic level, this fauna strongly resembles Late Cretaceous faunas – 39 genera are K/P survivors and only three are first reported from the Paleocene. It is interesting that the nektic and highly mobile reptiles; the fish, shark, ratfish, and ray; and the decapods are apparently all K/P survivors, and only a few of the sessile benthic forms are. It would be interesting to compare the survivorship and recovery of this fauna with that of other Danian faunas from different paleoenvironmental settings.

Although far more attention has been focused on the extinction of taxa at the end of the Cretaceous than on survivorship, it is clear the the percentage of K/P survivors in the Clayton Formation fauna is very high. Recently, Schweitzer and Feldmann (2005) compiled records of decapod crustacean survivorship from a data set of the 38 families of decapods known from the Late Cretaceous and observed a high level of survivorship; for example, 79 % of the families survived the extinction event. They concluded that some taxa were preadapted for survival, some were ecological generalists, and some were refugium taxa (Harries *et al*., 1996). Those same strategies probably account for the high level of survivorship in the Clayton fauna.

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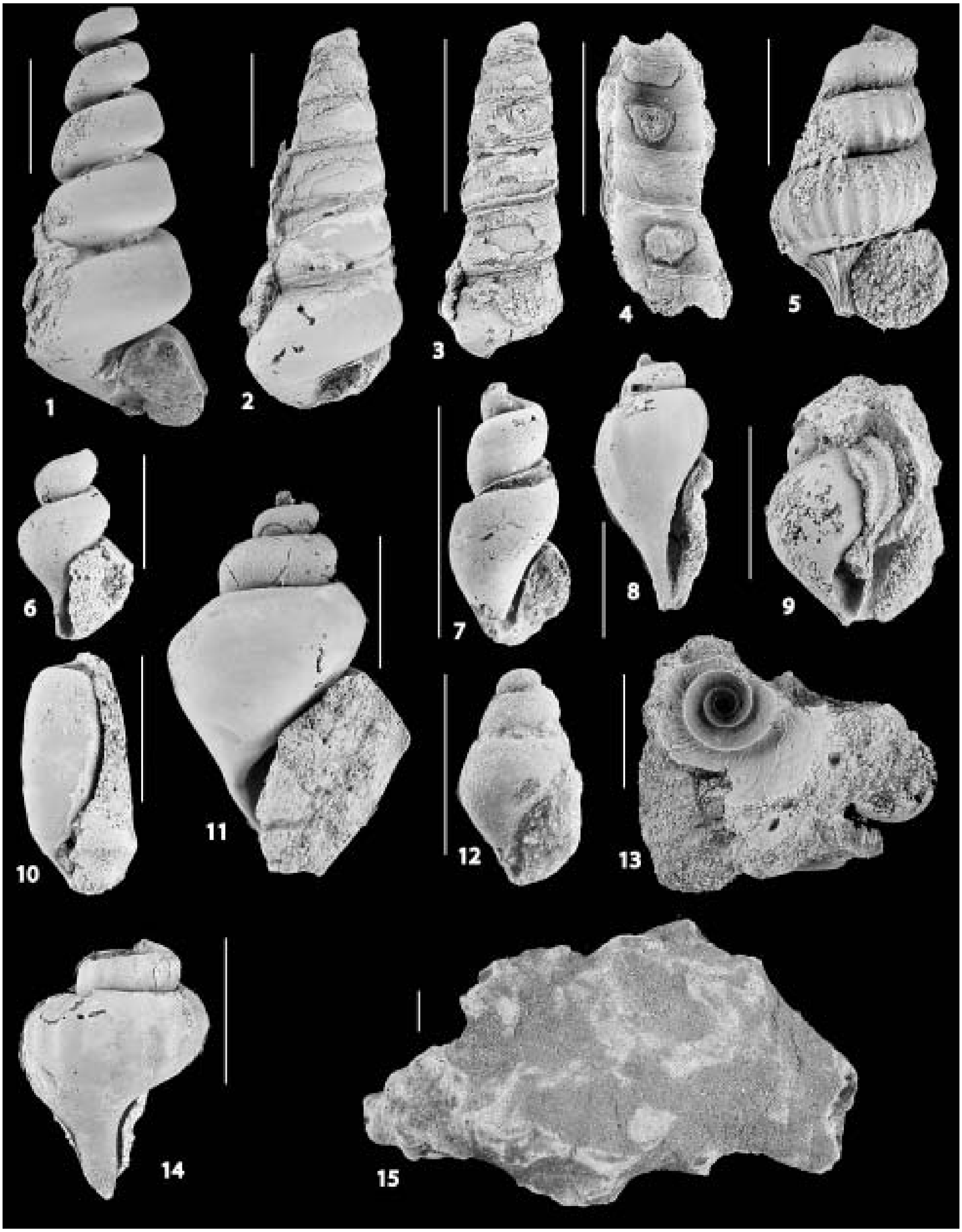
➡Fig. 5. Common gastropods and a bryozoan from the Clayton Formation. 1, 2, *Turritella alabamiensis* Whitfield, 1865, ISGS 90P34. 1, internal mold. 2, ISGS 90P36, internal mold and some shell material. 3, 4, *Turritella aldrichi* Bowles, 1939, ISGS 90P37. 3, internal mold, 4, matching mold of exterior. 5, *Epitonium* cf. *E. bexarense* Stephenson, 1941, ISGS 90P38, internal mold. 6, *Orthosurcula*? sp. ISGS 90P39, mold of interior. 7, cf. *Eulimia clara* Wade, 1926, ISGS 90P51, internal mold. 8, *Ranella showalteri* (Conrad, 1860), ISGS 90P43, internal mold. 9, *Strepsidura contorea* Aldrich, 1895, ISGS 90P41, mold of interior and partial exterior. 10, *Cylichna* cf. *C. secalina* Shumard, 1861, ISGS 90P52, internal mold. 11, cf. *Latirus biplicatus* Aldrich, 1886, ISGS 90P54, internal mold. 12, cf. *Tornatellaea cretacea appressa* Stephenson, 1941, ISGS 90P57, internal mold. 13, *Natica reversa* Whitfield, 1865, ISGS 90P46, mold of exterior of apex. 14, *Strepsidura contorea* Aldrich, 1895, ISGS 90P40, internal mold. 15, *Conopeum damicornis* Canu and Bassler, 1920, ISGS 90P58, external view of nodular zoarium. Bar scale equals 1 cm.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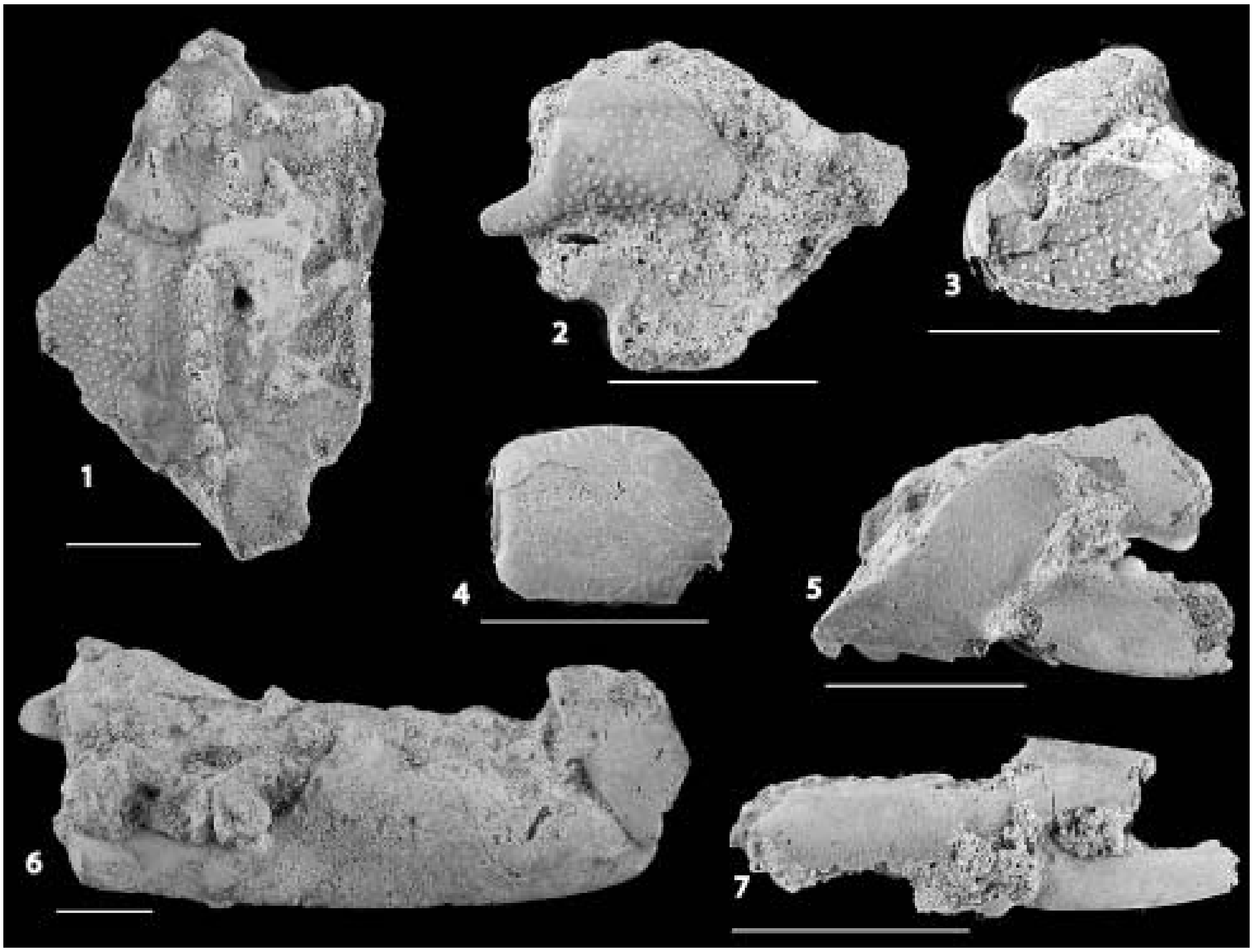

Fig. 6. Decapod crustaceans from the Clayton Formation. 1, *Linuparus canadensis* (Whiteaves, 1885), ISGS 90P70, dorsal surface of anterior part of cephalothorax. 2, *Paguristes johnsoni* Rathbun, 1935, ISGS 90P67, outer surface of left propodus. 3, *Paguristes*? sp., ISGS 90P66, part of outer surface of merus and carpus. 4, *Callianassa* sensu lato, cf. *C. mortoni* Pilsbry, 1901, ISGS 90P68, outer surface of right propodus with fixed finger broken off. 5–7, *Hoploparia tennesseensis* Rathbun *in* Wade, 1926. 5, ISGS 90P60, outer surface of partial propodus and dactylus of right cheliped. 6, ISGS 90P65, inner surface of partial carpus, propodus and dactylus of right cheliped. 7, ISGS 90P63, inner surface of partial propodus and dactylus of left cheliped. Scale bars equal 1 cm.

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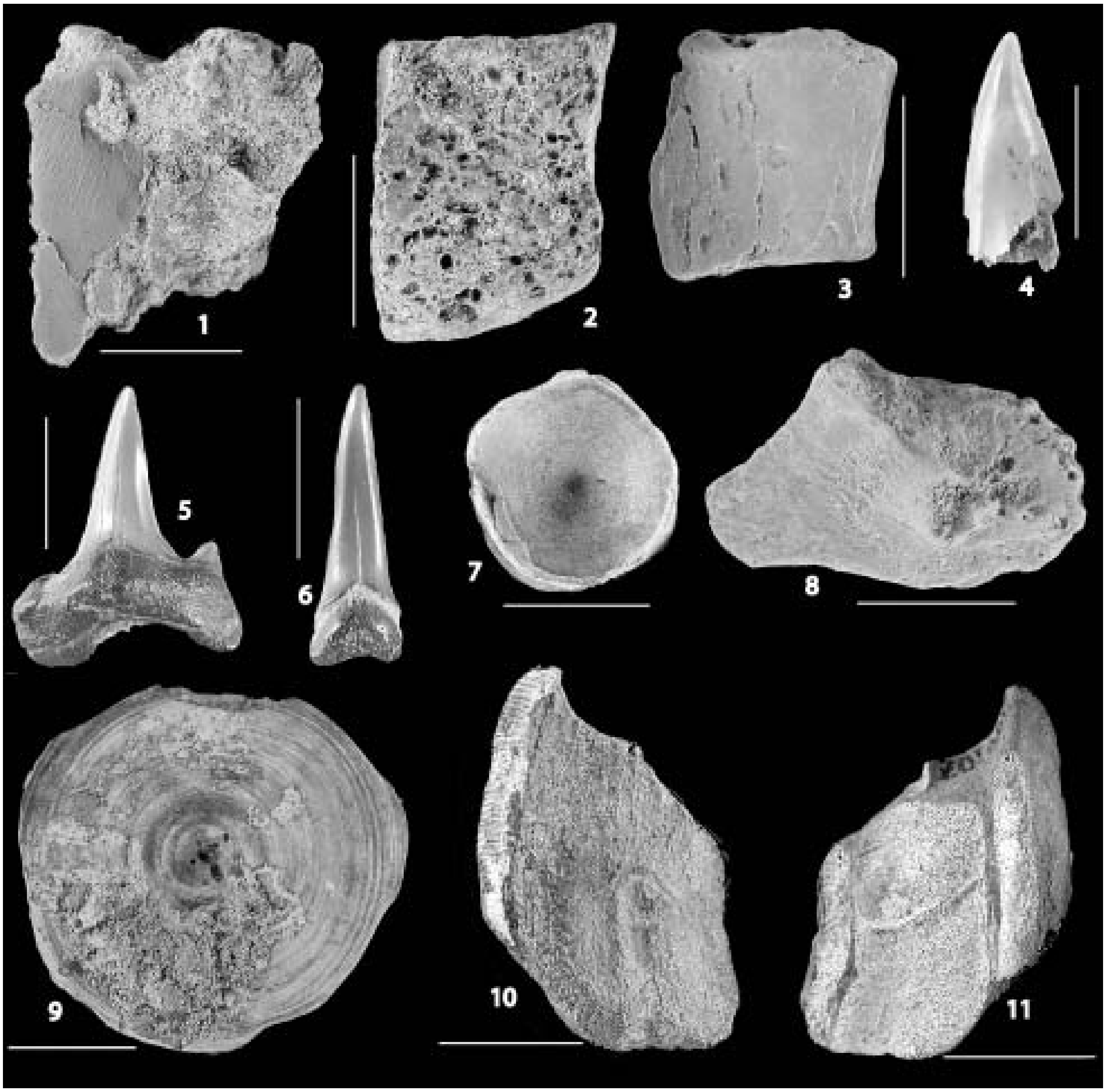

Fig. 7. Bony fish and sharks from the Clayton Formation. 1, cf. *Pachyrhizodus canius* Cope, 1872, ISGS 90P81, fragment of ceratohyal. 2, *Bananogmius* cf. *B. crieleyi* Applegate, 1970, ISGS 90P84, bone fragment. 3, *Propenser hewletti* Applegate, 1970, ISGS 90P88, small hyoid element. 4, Unidentified fish tooth, ISGS 90P101. 5, 6, *Lama cuspidata* Agassiz, 1843. 5, ISGS 90P93, maxillary tooth with broad main cusp and flat secondary lateral cusps. 6, ISGS 90P96, mandibular parasymphyseal tooth. 7, Unidentified shark vertebra, ISGS 90P103. 8, *Propenser hewletti* Applegate, 1970, ISGS 90P89, small shoulder girdle fragment. 9, Unidentified shark vertebra, ISGS 90P102. 10, 11, *Ischyodus williamsae* Case, 1991, ISGS 90P107. 10, labial view of left-hand mandibular plate. 11, lingual view of same plate. Bar scale equals 1 cm.

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