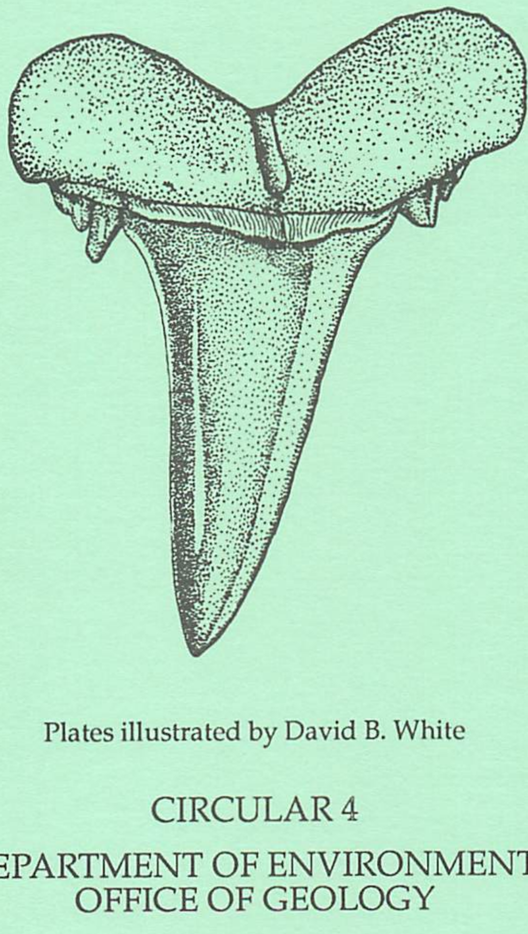
A GUIDE TO THE FRANKSTOWN VERTEBRATE FOSSIL LOCALITY (UPPER CRETACEOUS), PRENTISS COUNTY, MISSISSIPPI

Earl M. Manning

and

David T. Dockery III



Plates illustrated by David B. White

CIRCULAR 4

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF GEOLOGY

S. Cragin Knox
Director

Jackson, Mississippi

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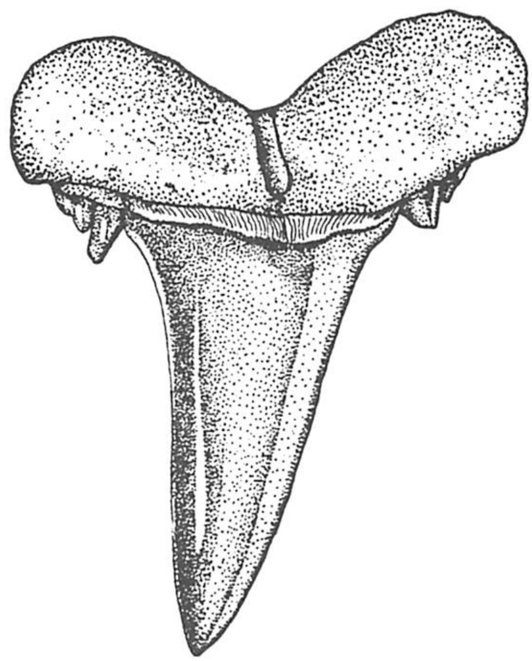

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Cover Illustration: Upper anterior tooth of the goblin shark *Scapanorhynchus raphiodon texanus* (Roemer, 1852). This is the most common tooth found at the Frankstown site.

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LETTER OF TRANSMITTAL

June 4, 1992

Mr. Thomas L. Goldman, Chairman, and
Members of the Commission
Department of Environmental Quality

Commissioners:

The Office of Geology is pleased to transmit to you Circular 4, entitled "A Guide to the Frankstown Vertebrate Fossil Locality (Upper Cretaceous), Prentiss County, Mississippi," by Earl M. Manning and David T. Dockery III.

This circular reports on fossils exposed during and after the excavation of the Highway 45 bypass around Frankstown, Mississippi. The abundance of fossil shark teeth uncovered at this excavation attracted national attention and drew people from distant states, as well as all parts of Mississippi, to collect fossils. The faculty of Booneville High School made a large collection of fossils from the Frankstown site and obtained a National Science Foundation SGER (Small Grants for Exploratory Research) grant to utilize this site as a laboratory for teaching their students about natural history. This was the first such grant ever to be awarded a high school. April 26, 1991, was designated as the day the Booneville High School students would collect fossils from the Frankstown excavation, and ABC News was present to film the event. This story was given national coverage on the ABC Sunday evening news (June 16, 1991).

The publicity given to Booneville High School's Frankstown field trip did not go unnoticed by Booneville Mayor Nelwyn Murphy, who awarded keys to the city to the writers and others who contributed to the project. Booneville High School teacher Patsy Johnson played a major role in the school's involvement with the Frankstown site and has been recognized by the National Association of Geology Teachers as the "1992 Outstanding Earth Science Teacher for Mississippi."

The Highway 45 excavation at Frankstown provided opportunities for professional scientists as well as for students and hobbyists. It opened a window into Mississippi's past to a time 75 million years ago when dinosaurs roamed the land and

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giant reptiles called mosasaurs swam the oceans. Remains of these animals, which lived during the Campanian Stage of the Cretaceous Period, were deposited in the coastal sediments of the Frankstown area.

Fossils from the Frankstown site are illustrated by artist drawings in twelve plates. They provide a means for both professionals and hobbyists to identify fossils collected from the site. The text gives information concerning 64 different fossil taxa listed from Frankstown as well as details on the local geology. Earl Manning, who has ten years experience with the American Museum of Natural History and nine years with the Louisiana State University Museum of Geoscience, is responsible for the discussion of the fossils. Both writers contributed to the discussion of the site's geology. This circular is written to be utilized by secondary students and the lay public.

Respectfully submitted,

S. Cragin Knox
Director and State Geologist

TABLE OF CONTENTS

LIST OF FIGURES

TABLE

A GUIDE TO THE FRANKSTOWN VERTEBRATE FOSSIL LOCALITY (UPPER CRETACEOUS), PRENTISS COUNTY, MISSISSIPPI

Earl M. Manning
David T. Dockery III

INTRODUCTION

This handbook was originally written for the students of Booneville High School to help them understand the nature of the Frankstown site - its geological setting and its fossil faunas. Booneville High School recieved a grant from the National Science Foundation in 1990 to use the construction site on Highway 45 at Frankstown as a laboratory for geological education in their school. This site has gained both local and national attention for its fossil vertebrates, mostly shark teeth, uncovered during the highway construction. We hope that by using this handbook, students and collectors will be able to answer some of the questions they have about the site, such as: What's been found there? Where can I look for more fossils? Why are there so many fossils here? How old are the fossils? How did land animals like dinosaurs get mixed with ocean animals like sharks? Why are fossils like these only found in one small corner of Mississippi? Finally, and most important, how can I identify the fossils I find at the site?

Though the excavation of Highway 45 at the Frankstown site has been completed and the roadbed is paved and the roadcuts are grassed over, future excavations may again expose the shark tooth layer in the Frankstown area or in surrounding counties. This handbook will be useful also to those who have collected shark teeth and other vertebrate fossils elsewhere in beds of similar age in northeastern Mississippi.

LOCATION OF THE SITE

Most fossils from the site have been either dug out of or picked up from the roadbed of the new extension of Highway 45, about seven miles south of Booneville, near the community of Frankstown, in western Prentiss County, northeastern Mississippi. Going north, the road crosses the top of a hill, passes over Twenty Mile Creek, then runs over a raised roadbed above the flood plain of the creek, a low area called Twenty Mile Bottom.

The fossils appeared suddenly at the site during the summer of 1990 because of the building of the road. The road construction crew cut off the top of the hill south of the creek and used it as fill for the raised roadbed on the north side. That kept the highway at an even grade, and lifted it above the flood plain. What made this road construction different from that at other sites was that the top of the hill contained two very concentrated beds of fossils. Just below the graded surface of the roadbed at the top of the hill, collectors discovered a bed full of shark teeth. Just above that layer, on the hillside at the side of the road, an oyster bed could be seen. In spreading material from the hilltop containing these two beds (mixed with less fossil-rich beds) across the bottom in the road construction, the road crew also made available a huge concentration of fossils over a mile-long stretch of roadbed. Through the kindness of the construction company, the roadbed was made available to Booneville High School students and fossil collectors from April 22 to May 2, 1991, to study and collect. It was later graded and the roadside was covered with soil and seeded with grass.

Most fossil collectors who visited the Frankstown site collected from the surface of the raised roadbed north of Twenty Mile Creek. Fossils here are out of place and do not show their stratigraphic position. To understand the geology of the site, in-place beds need to be examined.

STRATIGRAPHY

Stratigraphy is the study of the layers, or strata, of sediment or rock that make up the crust of the earth. Geologists, the people who study the earth's physical properties, divide rocks into three basic types: sedimentary, metamorphic, and igneous. **Igneous rocks** are "fire" formed - lava and ash from volcanoes, and rock cooled from molten rock deep in the earth. **Metamorphic rocks** are heat and pressure formed - those that have been altered by the processes of mountain building: slates, marbles, schists. Because of the nature of igneous and metamorphic rocks they rarely contain fossils. Most fossils are found in the third type - **sedimentary rocks**. These beds are sediment formed - made up of particles that dropped to the ocean floor or river bottom, or slipped down from a high area to a low one. All beds exposed at the surface in northeastern Mississippi, including the Frankstown site, are sedimentary beds.

Ma	Era	Period	Epoch	Age	Events
	Cenozoic				← People appear
65-					← Dinosaurs become extinct
				Maastrichtian	
75-				Campanian	← **The Frankstown site**
			Late	Santonian	Rocky Mountains start to form
85-		Cretaceous			
				Coniacian	
95-	Mesozoic			Turonian	← American West covered by ocean
105-				Cenomanian	
					← Gulf Coastal Plain appears
			Early		
150-					
		Jurassic			
200-					← Dinosaurs, birds, mammals appear
		Triassic			
250-					
	Paleozoic				← Appalachian Mts. start to form
600-					

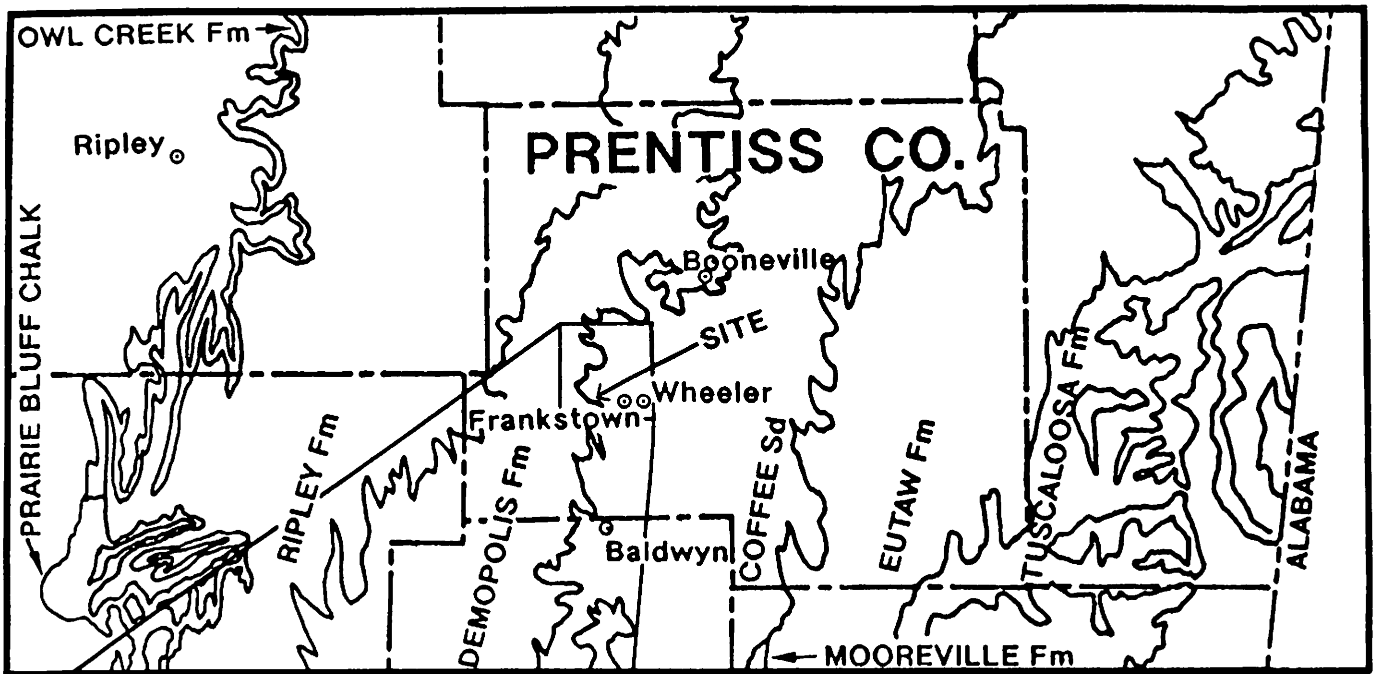
Figure 1. Age of the Frankstown site: late Campanian Age (about 75 million years ago) near the end of the Late Cretaceous Period, the last period of the Mesozoic Era.

Fossils like those at Frankstown are found only in beds that are about 65 to 100 million years old, a span of geologic time known as the Late Cretaceous Period (see Text figure 1). In Mississippi, these beds occur at the surface only in the northeastern part of the state. In the western, central, and southern regions of the state, they dip below the surface and are buried beneath younger beds. Here they are known only from samples obtained during the drilling of deep holes in the exploration for water, oil, or gas.

Eight major westward-dipping Late Cretaceous beds, called formations by geologists, are exposed in northeastern Mississippi. These formations were deposited as flat-lying layers, but due to subsidence of the lower Mississippi River Valley (the Mississippi Embayment), they now sink toward the west below the Mississippi River and rise to the surface again west of the river in Arkansas. In the site area, they form bands that run north-south, with the older ones to the east and the younger ones to the west. These bands, called outcrops, represent the area where a formation reaches the surface. Younger beds lie on top of older beds. As these beds rise to the east, they are cut off at the surface (truncated) and thin out in an eastward direction until the older bed below it appears. The Late Cretaceous formations, from oldest to youngest, are the: Tuscaloosa, Eutaw, Mooreville, Coffee Sand, Demopolis, Ripley, Prairie Bluff, and Owl Creek (see Text figure 2).

The fossils at Frankstown come from the base of the Demopolis Formation, just above the Coffee Sand. The Coffee Sand can be seen in the exposure along Twenty Mile Creek near where the highway crosses it. One interesting aspect of the Coffee Sand is the large boulder-sized concretions that occur in some of the formation's sand intervals, such as those seen in the bed of Twenty Mile Creek at Frankstown. Concretions are rounded masses of rock that form by the cementation of sediments where lime or silica is concentrated in certain layers by ground water. Though the Coffee Sand concretions are boulder-like in size and shape, unlike "real" boulders, they were not rounded by being rolled along a river bottom but acquired their rounded shape by cementation in place within the formation. The fossil beds at Frankstown are also present in Lee County to the south; similar fossils have been found near Baldwyn, Guntown, Saltillo, and Tupelo.

The Late Cretaceous beds of northeastern Mississippi were deposited in a variety of ways. Some, like the coarse sands and gravels in parts of the Tuscaloosa, were deposited in river channels and along the flood plains of the rivers. Parts of the Eutaw (the fine sands and clays) formed in coastal



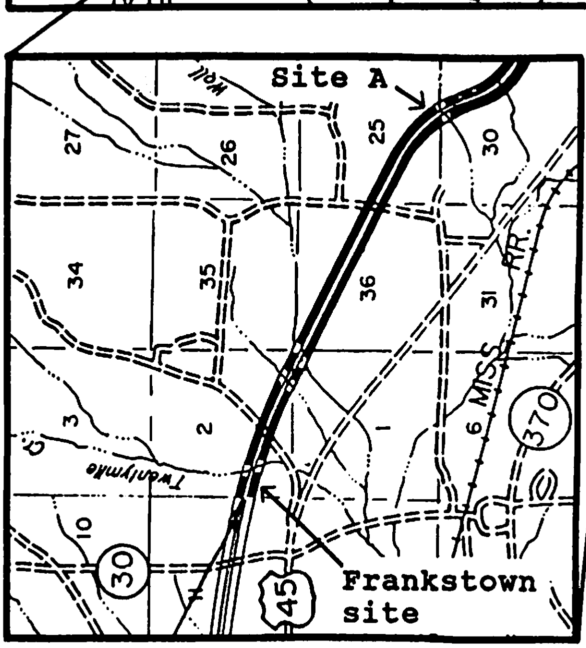


Figure 2. Geologic map of the Prentiss County area (modified from Stephenson and Monroe, 1940). The site is near the middle of the Upper Cretaceous beds, at the base of the Demopolis Formation. The Mooreville, Coffee Sand, Demopolis, Ripley, and Prairie Bluff/Owl Creek formations are placed together in the Selma Group. The inset below is 4 by 4 miles and shows old Highway 45 and the new bypass. Arrows locate the Frankstown site and a second site labelled as site A. Shark teeth from site A are also from the base of the Demopolis Formation and are generally weathered to shades of tan or sometimes pink.

estuaries. The Mooreville and Demopolis chalks and calcareous (limy) clays mostly formed under the Gulf of Mexico, on the floor of what was then a warm, tropical sea. Others, like the Coffee Sand, formed as sand from nearby river deltas poured into the Gulf and mixed with marine sediment. In places, one bed grades laterally into another, as sediments of one source met the sediments from another. The shark teeth at the site are from a one to two-foot thick sand bed at the base of the Demopolis Formation. This sand is informally referred to here as the "Frankstown sand" (see Text figure 3). Not all the fossils from the site come from that bed, however. Just above the "Frankstown sand" is a bed full of fossil oysters. Most of the shells found at the site come from that higher bed.

AGE OF THE SITE

The fossils from the Frankstown site are about 75 million years old. Geologists date fossils in two ways. One way is a relative age that says they are about the same age as similar fossils in dated beds in other places. This permits a correlation (matching up) of these fossils with those of the same age worldwide. The second way is an "absolute" age date that gives an estimate of the age in years.

The relative age of the basal Demopolis Formation can be determined by certain guide fossils within the formation. A guide fossil is one that

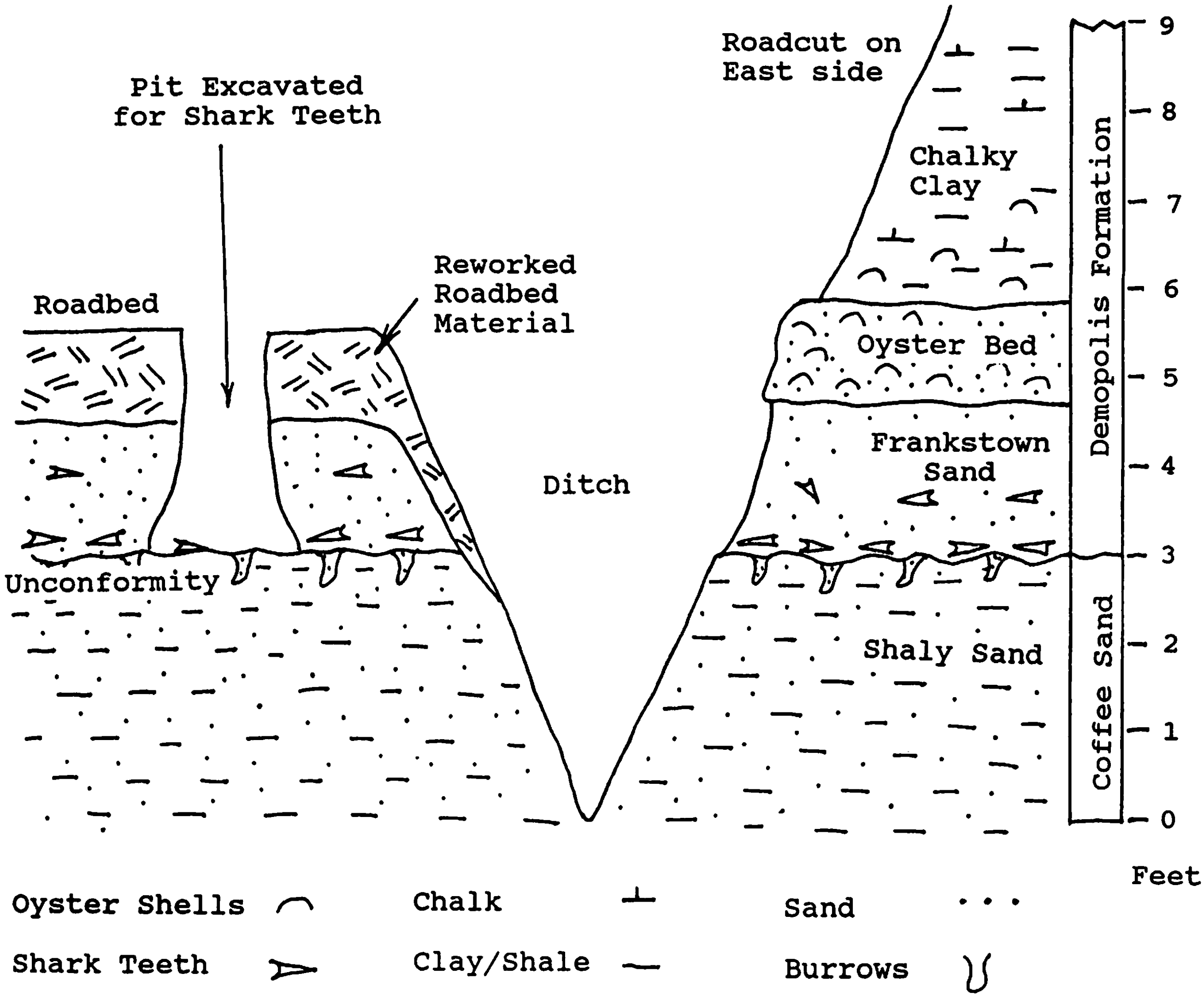


Figure 3. Measured section on Highway 45 construction site near a hilltop in the southeast quarter of the southeast quarter of Section 2, Township 6 South, Range 6 East, Prentiss County, Mississippi, north-northwest of the Frankstown community. This section was measured where the road grade cut the top of the "Frankstown sand" at the base of the Demopolis Formation. It shows the east roadcut and east side of the roadbed of the north-bound lane. Before it was paved, the construction company allowed students and the public to excavate in the roadbed at this point to collect shark teeth and other vertebrate fossils. Numerous pits were dug into the roadbed similar to the one shown here. These pits were dug to the base of the "Frankstown sand" just above the Coffee-Demopolis unconformity, where the vertebrate lag deposit is most concentrated.

occurs only in rocks of a certain age and that can be found over a large area. By using guide fossils, stratigraphers can correlate beds in Mississippi with those of approximately the same age in Alabama, Arkansas, Texas, and around the world. Many fossils from the Frankstown site are from groups of animals that died out in a great extinction at the end of the Mesozoic, showing that the site is no younger than the Cretaceous Period (see Text figure 1). These animals include the oyster *Exogyra*, ammonites, some of the sharks (*Hybodus*, *Squalicorax*), some of the rays (the sclerorhynchid sawfish), some of the bony fishes, the mosasaurs, and the dinosaurs.

The cause of the great extinction at the end of the Cretaceous is currently a matter of heated debate among paleontologists. Some say a huge asteroid hit the earth at the time and spread a layer of soot throughout the world's atmosphere, blocking the sunlight and causing plants (and the animals that depended on them) to die out. Others say that the extinction happened when the earth's continents changed position (in a process called plate tectonics), changing the shape of the mountain ranges and ocean basins and changing the climate. That, in turn, caused an ecological collapse which caused many groups to become extinct. One curious thing about the extinction is that not everything died - gars, turtles, crocodiles, opossums, and many others lived on as if nothing had happened.

Some of the Frankstown animals are found only in Late Cretaceous beds, including the ammonite *Baculites* and the sawfish *Ptychotrygon*. Some are found only in Campanian rocks, such as the oyster *Exogyra ponderosa ponderosa*. By using the time ranges of animals with only very short time spans, a more precise date can be determined. For example, the goblin shark *Scapanorhynchus raphiodon texanus* ranges only from the early Campanian to the early Maastrichtian, the sawfish *Ischyrhiza mira mira* from the middle Campanian to late Maastrichtian, the extinct shark *Squalicorax pristodontus pristodontus* from the late Campanian to late Maastrichtian, and the ray *Brachyrhizodus wichitaensis* from the late Campanian to early Maastrichtian. In combination, these ranges show that the site can only be late Campanian in age. This permits correlation to late Campanian beds around the world.

Absolute dates are obtained by analysis of radioactive isotopes (an isotope is an element with a certain number of protons and neutrons) within tiny crystals of volcanic rocks (lavas and ashes) which are found interbedded with the sediment. Radioactive isotopes are like clocks for the geologist. When freshly formed during volcanic eruptions, they are a pure parent isotope. However, through radioactive decay, the parent isotope breaks down into a daughter product, usually an isotope of a different element. Since this decay occurs at a constant rate that can be observed today, the relative amount of the parent to daughter isotope in a sample gives an indication of how long the decay has been going on and, thus, the age of the rock.

Though no beds of volcanic ash are available at the Frankstown site to provide an absolute age date, such beds are present in Campanian rocks elsewhere. This is how the 75 million year date for the Frankstown fossils was determined.

COLLECTING METHODS

The fossils reported here were obtained in two ways. The larger specimens were dug out of the road bed on the hilltop south of Twenty Mile Creek (see Text figure 3) and picked from the surface of the raised roadbed north of the creek by several sharp-eyed collectors. Most of the material described here was collected by the Booneville High School principal, Mr. Clyde Lindley, and by Mr. Pete Scott of the same school, during a two-day period in early March 1991. Smaller specimens that are hard to see on the surface were obtained by washing about a half ton of sediment from the site over coarse and fine screens, drying it in an oven, and picking the tiny specimens out with fine tweezers under a low-power microscope. By collecting in both ways, all animals in the fauna, both large and tiny, could be included.

For a collection to be scientifically useful, it is important that fossils be labeled as to the bed and location from which they were collected. Collectors should not mix fossils from different beds or different locations. A proper label should include the location where the fossil was found, what bed and/or formation it was in (if it was found in place), who found it, and when it was found. It is easy for collectors looking for shark teeth to ignore the shells and other fossils found with them. However, these fossils provide important information concerning the ancient environment in which they and the sharks lived. The best collecting procedure is to collect the greatest diversity of fossils possible, even if their identities are unknown. Fossils of unknown identity may be identified at a later time.

Fossil-bearing beds are exposed in many areas. Excavations for roads or buildings, exposures on slopes, and places where creeks cut into their banks are all good places to look for fossils. Cretaceous shark teeth are even sometimes found in the gravel of river beds of the Black Belt (a prairie developed on chalky Cretaceous beds), often mixed with much younger (less than one million years old) bones and teeth from the Ice Age. Most of the beds in northeastern Mississippi weather quickly to form a rich soil and become grassed over, so it's best to look over a new exposure of sediment right away. Large fossils, when found, often require professional help in excavating to prevent breakage or destruction (few Frankstown specimens require this kind of care). Students who find unusual fossils should bring them to the attention of their teachers or others who might be able to identify them. Help in fossil indentification can be obtained from the Mississippi Office of Geology.

THE FAUNAS

As noted earlier, the fossils from the Frankstown site came from two separate beds in the lower Demopolis Formation - a shark tooth bed (referred to here as the "Frankstown sand") at the base and an oyster bed above it (see Text figure 3). In Table 1, the faunas of each bed are listed separately. In order to help students and collectors identify the fossils they find, drawings of most of the kinds found there are provided in the plates at the end of the handbook. Remember that not all are easily seen by the naked eye.

Table 1. The biotas of the Frankstown site, from the late Campanian lower Demopolis Formation, Prentiss County, northeastern Mississippi.

The oyster bed biota

- Foraminifera (all benthic)
  - *Nodosaria, Lenticulina, Frondicularia* - tests
- Sponge
  - *Clione* - abundant borings in shells
- Arthropod
  - Ostracod
    - *Bairdea* - rare valves
- Mollusks
  - Bivalves
    - Oysters
      - *Pycnodonte convexa* (Say) - abundant shells
      - *Exogyra ponderosa ponderosa* Roemer - common shells
      - *Exogyra ponderosa erraticostata* Stephenson - rare shells
      - *Gryphaeostrea vomer* (Morton) - common shells
      - *Striostrea plumosa* (Morton) - rare shell fragments
      - *Agerostrea falcata* (Morton) - rare shell fragments
      - *Ostrea* (?) sp. - rare shells
    - Jingle shells
      - *Anomia argentaria* Morton - common shells
      - *Paranomia scabra* (Morton) - common shell fragments
    - Scallop
      - *Neithea* sp. - common shell fragments
- Annelid worm(s)
  - Unidentified polychaete worm(s) - rare borings in shell fragments

The shark tooth bed biota

- Plants
  - Unidentified evergreen(?) trees - abundant water-worn fragments of carbonized and mineralized wood
- Invertebrates
  - Mollusks
    - Gastropods
      - Unidentified snails - rare steinkerns and abundant fecal pellets
    - Scaphopod
      - *Cadulus* sp. - rare shell fragments
    - Bivalves
      - Unidentified pholad clam - common borings in mineralized wood and pebbles
      - Unidentified clams - rare steinkerns
    - Cephalopods
      - *Baculites asper* Morton - rare steinkern fragments
      - Unidentified small coiled ammonite - rare steinkern fragments
  - Arthropods
    - Crustaceans
      - Gooseneck barnacle: *Zeugmatolepas* sp. - common carina fragments
      - Crabs: *Dakoticancer* sp., *Raninella* sp. - rare carapaces
      - Lobster: *Hoploparia* sp. - rare carapaces and abdomens
      - Ghost shrimp: *Callianassa* sp. - rare claws
        - *Ophiomorpha* sp. - common burrow fillings
  - Brachiopods (both inarticulate)
    - *Lingula* sp. - rare steinkerns and shell fragments
    - *Discinisca* sp. - rare shell fragments
  - Bryozoan
    - Unidentified encrusting form - single specimen
- Vertebrates
  - Chimaeroid
    - *Ischyodus bifurcatus* Case, 1978 - rare upper and lower jaw plates
  - Sharks
    - *Hybodus* sp. 1 - common teeth, rare cephalic claspers and dorsal fin spine fragments
    - *Hybodus montanensis* Case, 1978 - rare cephalic claspers
    - *Lissodus babulskii* (Cappetta and Case, 1975) - rare teeth
    - *Squatina hassei* Leriche, 1929 - common small teeth
    - *Heterodontus rugosus* (Agassiz, 1843) - single partial tooth
    - *Chiloscyllium greeni* (Cappetta, 1973) - rare tiny teeth
    - *Cantioscyllium descipiens globidens* (Cappetta and Case, 1975) - rare teeth
    - *Scapanorhynchus raphiodon texanus* (Roemer, 1852) - abundant teeth
    - *Otodus appendiculatus* (Agassiz, 1843) - uncommon teeth
    - *Anomotodon angustidens* (Reuss, 1845) - rare teeth
    - *Squalicorax pristodontus kaupi* (Agassiz, 1843) / *pristodontus* (Agassiz, 1843) - common teeth
    - *Scyliorhinus* sp. - rare teeth
    - Unidentified sharks - common vertebral centra, rare coprolites

Rays
- *Ptychotrygon triangularis* (Reuss, 1845) - common small teeth and rare small rostral denticles
- *Ischyrhiza mira mira* Leidy, 1856 - common small teeth and large rostral denticles
- *Borodinopristis schwimmeri* Case, 1987 - rare small rostral denticles
- *Brachyrhizodus mcnultii* (Thurmond, 1971) - common pavement teeth
- *Brachyrhizodus wichitaensis* Romer, 1942 - rare median and lateral pavement teeth, rare dermal denticles
- Unidentified rays - common placoid scales, common vertebral centra, rare calcified cartilage fragments

Bony fish
- *Lepisosteus* sp. - rare scales
- *Atractosteus* sp. - single scale, tooth, vertebra
- *Hadrodus priscus* Leidy, 1858 - common small oral and pharyngeal teeth
- *Anomoeodus latidens* Gidley, 1913 - rare toothplates and common separate pharyngeal teeth
- *Paralbula casei* Estes, 1969 - common pharyngeal phyllodont teeth
- Unidentified sciaenid or albulid - single tiny tooth
- *Enchodus* sp. - common palatine and dentary fragments, common isolated palatine and dentary fangs, rare jaw fragments, and possible isolated lateral teeth and vertebrae
- *Xiphactinus* sp. - uncommon large tooth fragments and rare whole teeth
- Unidentified bony fish - rare skull and girdle bone fragments, common vertebrae, and rare scales

Reptiles

Turtles
- Pleurosternid (?) - rare shell fragments
- Unidentified trionychid - rare shell fragments
- Unidentified toxocheliid - rare shell fragments
- Unidentified sea turtle(s) - common shell fragments

Mosasaurs
- Unidentified tylosaurid - rare teeth
- *Globidens alabamaensis* Gilmore, 1912 - rare teeth
- Unidentified mosasaur - rare jaw fragment, teeth, and vertebrae

Crocodiles (both eusuchians)
- *Thoracosaurus neocesariensis* (De Kay, 1842) - single osteoscute, rare teeth
- Unidentified small crocodile - uncommon teeth, uncommon osteoscute fragments, and rare vertebrae

Dinosaurs
- Unidentified theropod - single tooth
- Unidentified hadrosaurid - rare cheek teeth, toe bones, jaw fragment, and vertebra

The Oyster Bed Biota

The animals of the oyster bed fauna are generally distinguished by their shells. Unlike most of the invertebrates (animals without backbones) of the shark tooth bed, the original shell material is preserved. In the shark tooth bed, most of the original shell material has been dissolved. The oyster bed is so named for two species of large oysters that are very abundant in the bed - *Pycnodonte convexa* and *Exogyra ponderosa ponderosa.* Shells of these oysters can be seen in a thin layer in exposures of the lower Demopolis over a wide area in northeastern Mississippi.

Microfossils

Foraminifera: The tiny shells (called tests) of these benthic (ocean floor-living) one-celled organisms, related to the amoeba, can be found when screened material from the site is examined under a microscope. They tell the **micropaleontologist** (one who studies tiny fossils, including foraminifera and ostracods, under a microscope) that the deposit is marine, and often much other subtle information about a site - the water depth, bottom conditions, water temperature and salinity (how salty it was), and the like. Unfortunately, these very useful microfossils are fairly rare at the site, and don't tell much.

Ostracod: One relatively large ostracod, *Bairdea,* is fairly common at the site. Ostracods are tiny crustaceans (related to crabs, shrimp, and lobsters) that live in clam-like, two-shelled (called valves) homes that are often preserved as microfossils. The *Bairdea* shows that the bed was a shallow ocean floor with a shelly bottom.

Larger Invertebrates

Sponge: The sponge *Clione* is a soft-bodied animal that finds a home by excavating cavities in shell material. We can indentify *Clione* by the shape of these cavities (Plate 1, figure 1). Today *Clione* still excavates into shells and turns them into fine sand. Fossils, such as the excavations of *Clione,* are called

trace fossils (see Taphonomy section) and include things like tracks, trails, burrows, bite marks, and coprolites (preserved fecal material). A fossil can be any evidence of the presence of any organism of a past geologic age (older than 10,000 years ago) - either direct evidence (such as part of the animal) or indirect evidence (such as a trace fossil).

Oysters: Fossil oysters are very important to Gulf Coastal Plain **biostratigraphy** (the study of the ranges of fossils in the layers of sediment) because they evolve quickly and are widespread in their geographical occurrence. Certain beds can be dated by the presence of a single oyster. Oyster shells are very durable and preserve very well. Unlike the oysters we eat from Gulf Coast estuaries today (*Crassostrea virginica*), the oysters from the Frankstown site lived in ocean water of normal salinity. Modern oysters live in waters of low salinity fairly near shore.

Seven different oysters are found in the oyster bed. The two largest forms make up most of the shell material in the bed and give it its name. *Pycnodonte*, like many primitive oysters of this period, has a deep, concave lower (left) valve (shell) that sat on the ocean floor (Plate 1, figure 5), and a relatively flat upper (right) valve that formed a kind of lid. *Pycnodonte* has an almost circular shell outline and a nearly smooth shell surface. *Exogyra ponderosa ponderosa* is the other large, abundant oyster in the oyster bed. Its shell outline is more oval, and its lower valve starts with a coil (Plate 1, figure 3). The lineage of *Exogyra* species is one of the most important oysters for correlating Late Cretaceous marine beds. While the lower valve of *E. ponderosa ponderosa* is smooth, with only concentric growth lines on its surface, that of a rarer subspecies at the site, *E. ponderosa erraticostata*, has irregular radial ridges (or costae) extending from the shell's apex (or beak) toward the shell's margin (Plate 1, figure 4). *Gryphaeostrea* has a smooth concave lower valve (Plate 1, figure 6) and a flat upper valve with strong concentric ridges (Plate 1, figure 7). *Striostrea* has a teardrop-shaped shell outline and fine radial grooves on its surface (Plate 1, figure 8). *Agerostrea* is rare at Frankstown and is usually seen only as shell fragments. It is curved and has a folded shell margin with v-shaped folds. An unidentified species of *Ostrea* (?) has a flattened, long, and narrow shell (Plate 1, figure 9).

Jingle shells: These shells are thin and are often found at the site as broken fragments. One (*Anomia*) is smooth (Plate 1, figure 10), and the other (*Paranomia*) is spiny (Plate 1, figure 11).

Scallop: These shells are almost always found as small broken shell fragments at the site. They are distinguished by their closely spaced parallel ridges (Plate 1, figure 12).

Annelid worm: The presence of these worms can be determined from their borings (Plate 1, figure 2). Sandworms make similar borings in oyster shells today.

The Shark Tooth Bed Biota

The preservation of the shark tooth bed is different from that of the oyster bed. The bed (the "Frankstown sand") is one to two feet thick and consists of a light brown, well-sorted sand with the traces of crab and shrimp burrows. Fossils in this bed are usually stained a dark color except where bleached by weathering (see Taphonomy section). Most original shell material has been leached (dissolved by the ground water). A lot of the material also looks fairly rounded and worn. Along with the fossils in the shark tooth bed are found a lot of rounded, flat pebbles. These formed as underwater currents dug up chunks of sandy shale from the sea floor and rolled them in the surf zone.

Plants

Wood: Because plants (here, trees) are present in the shark tooth bed, the bed can be said to have a flora (a list of plants from a site) as well as a fauna (a list of animals from a site). The wood (Text figure 4) is almost all in the form of very water-worn, rounded fragments, often bored by pholads (boring clams). Some of the wood is mineralized (petrified by having the insides of the cells filled with some kind of mineral) and some is only carbonized (darkened as if burned, but without added mineral material).

Larger Invertebrates

Snails: Two types of snail fossils are seen in this bed - steinkerns and fecal pellets. Steinkerns are internal molds of shells, which show only what the inside looked like. Here, snail shells were filled with sediment (often the mineral glauconite), then the shell itself was dissolved, leaving only the filling to show that it was there. The fecal pellets are tiny bullet-shaped pellets of sediment swallowed and cast-off by snails and clams (or bivalves), which eat the nutrients in the sediment. Such castings are called **coprolites**.

Tusk shell: One of the few mollusks from the shark tooth bed which is known from original shell material is the small scaphopod *Cadulus* (Plate 2, figure 1). Scaphopods are called tusk shells because many are shaped like elephant tusks.

Bivalves: Two types of bivalves are seen in the shark tooth bed - steinkerns and pholad borings in

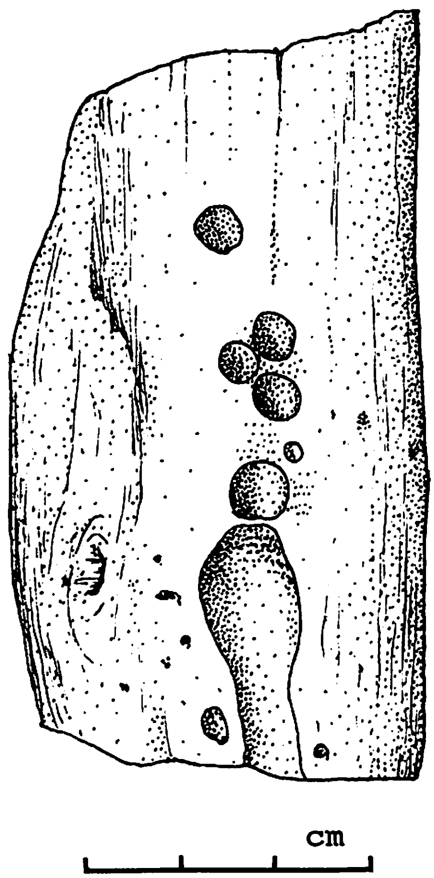


Figure 4. Petrified wood with pholad clam borings from the base of the "Frankstown sand." Petrified wood is common in the "Frankstown sand" just above the Coffee-Demopolis unconformity. It generally consists of well rounded elongate pieces, which look like driftwood. The lack of borings of the "shipworm" *Teredo* (a wood-boring bivalve) indicate that this wood did not drift in the open ocean. Borings of pholad clams are common in wood and rocks along the ocean's intertidal zone and in estuaries. The wood at Frankstown may well have petrified in the sediments of a coastal estuary before being reworked into the vertebrate lag deposit at the base of the Demopolis Formation.

wood (Text figure 4). Both have been mentioned.

Cephalopods: Ammonites are an extinct group of cephalopods (the group including squid, octopus, and the chambered nautilus) that died out in the great extinction at the end of the Cretaceous period. Like fossil oysters, they are often very useful in dating beds because they changed in form quickly and were very widespread. So far, all that have been found of this group at the site are rare steinkern fragments - from a normal, coiled form (Plate 2, figure 2) and from a long, tubular, "uncoiled" form called *Baculites* (Plate 2, figure 3).

Arthropods: Two groups of crustacean arthropods are present at Frankstown - decapods (the group including lobsters, shrimp, and crabs) and gooseneck barnacles. Crustacean material from the site consists of their chitinous exoskeletons (chitin is the material fingernails are made of) and their burrows. Better decapod material from Frankstown is often found preserved as shiny black patches on pebbles.

Crustaceans identified so far from Frankstown include two crabs - *Dakoticancer* (Plate 2, figure 11) and *Raninella* (Plate 2, figure 10); a lobster - *Hoploparia* (Plate 2, figures 6-7); a ghost shrimp - *Callianassa* (Plate 2, figure 8); and a gooseneck barnacle - *Zeugmatolepas* (Plate 2, figure 5). Distinctive burrow fillings, called *Ophiomorpha*, which have walls lined with rows of sediment balls (Plate 2, figure 9), are thought to have been the home burrows of the ghost shrimp. The gooseneck barnacle is represented at the site by small, fragmentary, calcitic plates called carinae. These plates must be picked under a low-power microscope. Unlike other barnacles, gooseneck barnacles attach to the bottom or to floating debris with a long, flexible stalk. The Frankstown barnacles may have floated in on driftwood.

Brachiopods: These advanced bivalved marine animals are rare at the site. They consist only of a few phosphatic shell fragments and a few steinkerns of two types. One form, *Lingula* (Plate 2, figure 4), is still living on ocean mud flats today. It is what paleontologists call a living fossil, in that it has barely evolved at all in 500 million years. This is the exception among animals, which generally change every few million years. An explanation for *Lingula*'s longevity is that it lived in a rare stable environment, which meant there was no need to change.

Bryozoan: This diverse group of tiny colonial invertebrates is known from the site by a single impression of an encrusting form in a pebble of glauconite. Such fossils are called external molds.

Vertebrates

Chimaeroid

These are rare fossils from the site, and only a few of this kind of animal have been reported from the entire Gulf Coastal Plain area. It is known from rare jaw plates (Plate 3, figures 1-3) from the site. Chimaeroids are cartilaginous (boneless) fishes related to sharks and rays. Today they are mostly found near the ocean floor in very deep water. You sometimes see them when you see films taken from deep-water research submarines. Their common name, rat fish, derives from their long, pointed tail. They are almost tear-drop shaped.

Sharks

Hybodus **species 1**: This shark was a member of a dying family 75 million years ago. The group had been the dominant sharks of the Triassic and Jurassic (see Text figure 1), but was on the downslide by the Late Cretaceous after many modern groups of sharks had appeared. It is represented at Frankstown by odd, rootless teeth (Plate 3, figure 4), cephalic claspers (Plate 3, figure 7 - specialized hook-like denticles originally located on the forehead of the males, and used to hold the females in mating), and fragments of dorsal fin spines (Plate 3, figure 6 - most modern sharks have lost these spines). They died out at the end of the Cretaceous.

Hybodus montanensis: This hybodont shark is known at Frankstown only from rarė cephalic claspers (Plate 3, figure 8), which are shaped differently from those of *Hybodus* species 1.

Lissodus: This tiny hybodont shark is known from rare teeth (Plate 3, figure 5) at Frankstown. It is especially interesting because it was a freshwater shark, often found with dinosaur bones in river deposits in western North America.

Squatina: This form is quite similar to the ray-like angel sharks living today. They were bottom feeders, and mostly lived near coastlines. The teeth (Plate 4, figure 8) are small.

Heterodontus: Horn, or Port Jackson, sharks are known from the site only from a single partial tooth (Plate 4, figure 1). Horn sharks (called that because they are one of the few modern sharks that have dorsal fin spines) have very unusual, flattened teeth used to crush snails and clams.

Chiloscyllium: Spotted, or banded, catsharks are known from Frankstown only from very rare, very tiny teeth (Plate 4, figure 2).

Cantioscyllium: This is a primitive nurse shark, whose small teeth (Plate 4, figure 7) are only seen under a microscope. Like angel sharks, nurse sharks are bottom-living (benthic) forms.

Scapanorhynchus: Goblin shark teeth are, by far, the most common fossil teeth from the site. Like the chimaeroids, the goblin sharks have undergone a major habitat change. In the Late Cretaceous, they lived in shallow coastal waters, while today they live only at the bottom of deep oceans. This often happens when an animal is out-competed in its habitat. When other sharks, particularly the sand tiger shark, took over the shallow coastal water, the goblin sharks retreated to the deep ocean floor - a place where few other sharks wanted to live.

One of the most confusing things for people who study fossil shark teeth is the difference between teeth from different parts of the shark's jaws. Upper teeth tend to have broad, flat roots, broad primary (main) cusps on the crown, and strong accessory (side) cusps. Lower jaw teeth often have narrow, U-shaped roots, long and narrow main cusps, and reduced accessory cusps. Teeth from the front of the jaw have crowns nearly perpendicular to the root (see Plate 5, figure 3). From front to back, the primary cusp tends to angle more and more toward the back (see Plate 5, figure 1). Teeth at the very back of the jaws have very short crowns (Plate 5, figure 2). In *Scapanorhynchus*, the lower teeth look quite different from the upper ones. They have strong ridges on one side of the crown and have greatly reduced accessory cusps (Plate 5, figure 4).

Otodus: While uncommon at the Frankstown site, this shark (like *Scapanorhynchus* and *Squalicorax*) is famous for its worldwide distribution. The same species of this shark can be found in beds of the same age all over the world. *Otodus appendiculatus* is also famous for its very long time range (from about 105 to 50 million years ago). For any species to survive for 55 million years (through several extinction periods) is a remarkable feat. Unfortunately, that makes this species nearly useless for dating beds. *Otodus* upper teeth (Plate 4, figure 5) have broader primary cusps than do the lower teeth (Plate 4, figure 6).

Anomotodon: This shark is rare at the site. It is distinguished by its lack of accessory cusps (Plate 4, figures 3-4), something most Cretaceous shark teeth have. It may be related to modern thresher sharks.

Squalicorax: These are the second most common teeth at Frankstown. This extinct shark must have lived something like a tiger shark today, as the teeth look somewhat similar. They are the only shark teeth from the site with serrated edges. They must have been very efficient predators, cutting huge plugs of meat out of the sides of big fish. Meat-eating sharks close their jaws on their prey, then shake their heads from side to side, sawing out their meal.

The teeth of *Squalicorax* from Frankstown offer a rare opportunity to see an evolving lineage. Early Campanian forms, called *S. kaupi*, typically have a strong notch at the side of the crown (as in Plate 5, figure 5). Early Maastrichtian forms, called *S. pristodontus*, typically have broadened the crown and lost the notch (as in Plate 5, figure 7). At Frankstown, both types are present, as are intermediate forms (Plate 5, figure 6). *Squalicorax* in the late Campanian was evolving from one form into another, possibly because of changing from cutting one type of meat to another. When two forms intergrade in this way, they are sometimes interpreted (as they are here) as subspecies of the same species. Because of this intergradation, the Frankstown *Squalicorax* shows that what seemed to be two separate species are really only one variable species.

Scyliorhinus: Common catsharks are represented at Frankstown by a few, worn, very tiny teeth (Plate 5, figure 8).

Unidentified sharks: Generally, sharks are most easily identified by their teeth, the most common shark fossil, but there are other shark fossils as well. Although sharks don't have bones like higher fish, their vertebral column (backbone) is often hardened to stiffen it for swimming. The cartilage is replaced with the mineral calcite, making calcified cartilage. This is why the shark vertebral centra (Plate 6, figure 2 - the disk-shaped part of the vertebra below the spinal cord, the only part where the cartilage has been calcified) are often found at the site. Unlike ray centra, they are circular in outline, sometimes have holes around the edge, and are fairly flat. Another shark fossil from the site is a shark coprolite (Plate 6, figure 1). Shark excrement can be distinguished from other kinds because of its spiral shape. Shark intestines are screw shaped, so their excrement is spiral shaped. The shark coprolites at Frankstown are sometimes round in cross section (as they would have been originally), but some have become flattened in burial.

Rays

Ptychotrygon: This small ray, as well as *Ischyrhiza* and *Borodinopristis* from Frankstown, is a part of a large and successful group of imitation sawfish that lived in the Late Cretaceous, called sclerorhynchids. While they had enlarged denticles sticking perpendicularly out from a long straight snout (called a rostrum) like modern sawfish, their teeth show that they are only distantly related. Sawfish is a good role to play for a fish-eating shark, and it was played by different groups at different times. The independent development of similar structures such as rostral denticles by distantly related animals is called **convergence**. This happens when different kinds of animals adapt to live in the same way. Birds and bats, for example, both use wings to fly, but are related to separate groups of animals. Sawfish swim into a school of fish, slash their snouts back and forth, stun the fish, then eat them at leisure. *Ptychotrygon* teeth (Plate 7, figure 1) and rostral denticles (Plate 7, figure 2) are small and can only be seen under a microscope.

Ischyrhiza: This is a much larger sawfish, whose small teeth (Plate 7, figure 3) and large rostral denticles (Plate 7, figures 4-5) are often found at the site. People sometimes call these rostral denticles "rostral teeth," but this is confusing because they aren't found in the mouth, and look totally different from the tiny real teeth.

Borodinopristis: So far, this sawfish has only been recovered from the Frankstown site in the form of rare, tiny, barbed rostral denticles (Plate 7, figure 6). This genus was only recently described.

Brachyrhizodus mcnultii: Many rays (including the living eagle rays and cow-nosed rays) have flat-topped teeth set into a mosaic-like, flat battery for crushing snails and clams. Such teeth are called pavement teeth. This ray had small (microscopic only), oval-shaped crowns (Plate 8, figure 1).

Brachyrhizodus wichitaensis: This ray had much larger, more complex pavement teeth than the last one, with multiple roots to support a longer crown. Modern eagle rays were probably derived from this form. It apparently had teeth of two shapes - elongate ones in the middle of the jaw (Plate 8, figure 2) and diamond-shaped ones at the sides (Plate 8, figure 3). Also known from the site are spine-like denticles (sometimes called "thorns") from the midline of the back and top of the tail of the ray (Plate 8, figure 4), as well as the tiny secondary ossicles (Plate 8, figure 5), which are sometimes found attached to them.

Unidentified rays: Rays have distinctive scales. Unlike the thin, flexible scales of most higher (bony) fishes, sharks and rays have tooth-like, heavy scales, often with sharp points, called placoid scales. This is why sharks have skin said to feel like sandpaper. In rays these placoid scales are broad and fairly flat. Sharks sometimes bump into a potential prey animal before attacking in order to scrape its skin so it can detect some of its chemicals in the water. These distinctive scales, of several types, are common small fossils from the site. Like teeth, placoid scales have a root and crown. In the more primitive ones, the crown is still cusp-like (Plate 8, figure 8). In others, they have become button-like (Plate 8, figure 6), sometimes crowded together (Plate 8, figure 7). Some at Frankstown have a reduced crown and a thick, blocky base (Plate 8, figure 9). Only when a fossil ray is found with the teeth and denticles together will we know to which ray they belong.

Fragments of calcified cartilage (Plate 6, figure 4) also from the site are probably derived from some part of the ray's head. Like sharks, rays have distinctive vertebral centra made up of calcified cartilage. Rather than all being circular in outline, many are oval (Plate 6, figure 3). Two very distinctive large ray vertebrae appear to be the first

(Plate 6, figure 5) and second (Plate 6, figure 6) vertebrae, from just behind the head. These vertebrae probably belong to either *I. mira* or *B. wichitaensis*.

Bony fish

Lepisosteus: Gars are represented at the site by very rare scales, teeth, and vertebrae of two genera. *Lepisosteus*, the smaller one, had smooth, shiny scales (Plate 9, figure 1). Gars, very primitive bony fish still living today, are mainly freshwater fish. Gars have long snouts and eat fish.

Atractosteus: This large form, including the modern alligator gar, had more ornamented scales (Plate 9, figure 2), large teeth (Plate 9, figure 3), and large vertebrae (Plate 9, figure 4). All are rare at the site.

Hadrodus: These small teeth are from two parts of the mouth - the jaws at the front, and toothplates in the back, or pharynx, of the mouth. The front (or oral) teeth (Plate 9, figure 5) are round or oval, and usually have worn, flat tops for crushing food. The back teeth are called pharyngeal teeth. In *Hadrodus*, they are small, flat, hooklike teeth (Plate 9, figure 6) - part of a comb-like structure used for picking food out of the water.

Anomoeodus: These pharyngeal teeth (Plate 9, figure 9) are heavy and flat, like the ray pavement teeth; they were used for crushing heavy-shelled invertebrates. These bony fishes, the pycnodonts, were very successful in the Jurassic and Cretaceous, but became extinct soon after the Cretaceous, possibly because their prey became extinct. Extinction affects the more specialized organisms, such as animals dependent on a single food source, more than others. If its food source becomes extinct when the environment changes, and the animal is unable to adapt to another source of food, it will die.

Paralbula: These tiny pharyngeal teeth (Plate 9, figure 8) come from a fish related to the modern bonefish. They are round and relatively flat, so they can be stacked up like upside-down plates. Such teeth are called phyllodont.

Unidentified sciaenid or albulid: A single, very tiny pharyngeal tooth of non-phyllodont type (Plate 9, figure 7) from the site suggests the presence of a drum fish or other type of bonefish.

Enchodus: This was a large predatory fish somewhat like today's pike. It became extinct at the end of the Cretaceous. While most of the fish was fairly normal looking, what really made it stand out were its fangs. It was a "sabre-toothed" fish with two upper and lower fangs, one on either side of the front of the upper and lower jaws. How it used those fangs to kill prey fish is not known. *Enchodus*, like many of the Frankstown sharks, had worldwide distribution in the Late Cretaceous. Similar fish are well known from Lebanon in the Near East. Another peculiarity about *Enchodus* is its extreme size variation. Similarly shaped fangs range in length from a few millimeters to six centimeters. Many fishes lack determinant growth - they have no upper growth limit. As long as they keep eating, they keep growing.

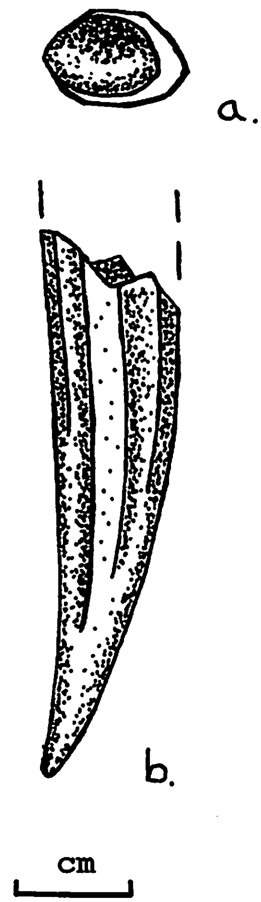


Figure 5. Tooth, MPPM 1992.14.1, of the large Cretaceous bony fish *Xiphactinus*. While fragments of such teeth are common at Frankstown, whole teeth are rare. 5a - Basal view, 5b - lateral view. Even fragments of the teeth can be identified by the distinctive flattened bands running up and down the teeth. Like many Frankstown animals, *Xiphactinus* is known from complete skeletons from Kansas.

The most common *Enchodus* remains from the site are the fangs, found either loose (Plate 10, figure 3) or attached to the upper jaw (Plate 10, figure 1) or lower jaw (Plate 10, figure 2). Pieces of the back part of the lower jaw (Plate 10, figure

4) are less common. Some small loose teeth (Plate 10, figure 5) and vertebrae (Plate 10, figure 6) may also belong to *Enchodus*.

Xiphactinus: This large predaceous fish is better known from the Cretaceous marine beds of Kansas than from the Gulf Coast. It is represented at Frankstown mostly by broken fragments of large, elongate teeth, though rare whole teeth (Text figure 5) have been found. They differ from mosasaur teeth in being less curved and having long, narrow, flat surfaces (facets) on their crowns.

Unidentified bony fish: Fish fossils such as skull and other bone fragments, teeth, vertebrae, and scale fragments are often very difficult to identify. Probably most of them from the site belong to the most common fish, *Enchodus*, but it is hard to be sure.

Reptiles

Turtles: Three very different kinds of turtles occur at the Frankstown site - freshwater pleurosternid (?) and soft-shelled turtles and sea turtles. All are known from fragments of their shells. Most large, unidentified bone fragments from the site are probably from sea turtle shells. Most sea turtle shell fragments (Plate 10, figure 9) are large, thick, and smooth on the outside, though one type is quite thin. Some of the smaller elements (Plate 10, figure 8) could be from either a sea turtle or a pond turtle. The pleurosternid (?), a primitive turtle of an ancient lineage, is known from the site by rare shell fragments (Text figure 6) with a shiny surface marked by tiny, meandering ridges. The soft-shelled turtle shell fragments (Plate 10, figure 7) have a distinctive pitted outside surface.

Mosasaurs: Mosasaurs were giant sea-going lizards, probably closely related to living monitor lizards. They also became extinct at the end of the Cretaceous. They are best known from the Frankstown site by two differently-shaped teeth. The large, recurved, conical ones (Plate 11, figure 1) belong to the big fish-eating tylosaurids, while the shorter, stouter ones (some that are even bulbous) are posterior teeth of the rare shell-crushing *Globidens* (Plate 11, figures 2-3). *Globidens* anterior teeth (Plate 11, figure 4) are less blunt. Large (Plate 11, figure 5) and small (Plate 11, figure 6 - from the end of the tail) mosasaur vertebrae are also found at Frankstown. Often, the vertebrae were rolled around so long by waves or currents that most of the surface bone has worn off.

Crocodilians: Two types of crocodilians are present at Frankstown. One type, *Thoracosaurus*, a

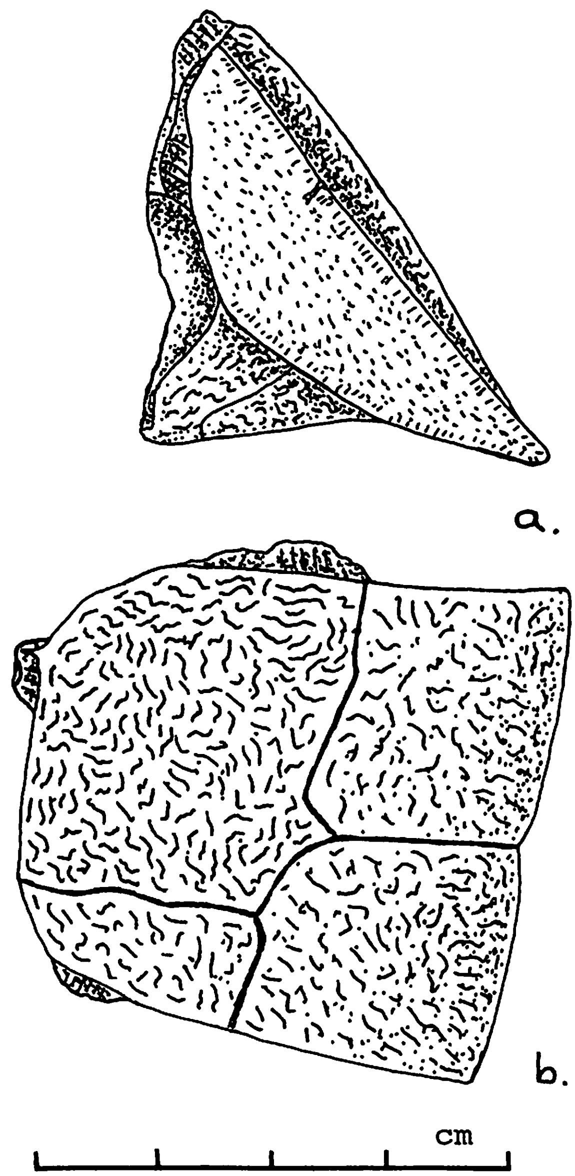


Figure 6. Bone (peripheral, MGS 1904) from the right rear margin of the upper shell (carapace) of a large pleurosternid (?) turtle. 6a - Posterior view, showing the shape of the edge of the shell and the place where one shell bone fit against another, 6b - dorsal view of the top of the shell, showing the grooves that mark the edges of the chitinous scutes (the outer surface of the shell, which doesn't preserve in fossils) over the bone, and its surface pattern. Sea turtle shell fragments are very common at the Frankstown site, while this form is very rare. Sea turtle shell fragments from the site are smooth; soft-shelled turtle shell fragments have pitted surfaces; but this turtle has distinctive shiny shell fragments with fine meandering ridges on the surface.

large sea-going type, is known only from a single large osteoscute (Plate 12, figure 4) and rare elongate teeth (Plate 12, figure 5). Osteoscutes are bony plates which line the backs of crocodilians (including today's crocodiles, alligators, caimans, and gavials). In *Thoracosaurus*, the central ridge of the osteoscute is fairly low. A small crocodilian is also known from the site from rare teeth (Plate 12, figures 1-2), vertebrae (Plate 12, figure 6), and osteoscute fragments (Plate 12, figure 3). This form has a higher central ridge on the osteoscutes. More complete material would be needed to identify it precisely. It may even be the young of the *Thoracosaurus*. It is not an alligator, as true alligators did not appear until about 38 million years ago.

Dinosaurs: Two types of dinosaurs are known from Frankstown. One Frankstown dinosaur is known only from a single flattened, curved tooth with serrations on the posterior (concave) edge (Plate 12, figure 7). The serrations, like those on a steak knife, would have helped the teeth cut meat. This tooth belonged to an unidentified theropod, a meat-eating dinosaur. Rare, flat-topped teeth with side ridges (Plate 12, figure 8) are the cheek teeth (the ones in the back of the jaw) of the other type - the plant-eating duck-billed dinosaurs (Family Hadrosauridae). This kind of tooth helped form a battery of dozens of tightly-fitting teeth in each jaw that created a flat grinding surface used to shred very tough plant food.

Why are dinosaur teeth found more often than the other hard parts? In dinosaurs, as in people, the enamel of the teeth (the shiny outside layer) is the hardest material in the body. Because they are so durable, teeth survive wear better than the bones do. Even so, dinosaur remains are very rare in Mississippi.

TAPHONOMY

To understand how animals lived, you must first understand how they were buried. **Taphonomy** is the relatively new science of how organisms make the change from the living biota into the geologic realm of the sediment. It is important to understand such things because the fossil biota you find may not be a fair representation of the living biota. This is certainly true of the Frankstown biota. Many taxa (groups of closely related organisms) from the living community never become fossils. Many have no hard parts to preserve, such as jellyfish, worms, most shrimp, shell-less snails, etc. Others were initially preserved, but later lost in the process called **diagenesis**, the alteration of sediments and rocks under only moderate temperatures and pressures (i.e., below those that would produce metamorphic rocks). We know certain cephalopods, snails, and clams were lost in the shark tooth bed, because their shells were dissolved and only their fillings (the steinkerns) were left.

Why would some shells preserve (some foraminifera, ostracods, oysters, jingle shells and scallops) and others (most ammonites, snails, and clams) not? The answer is that not all shells are made of the same mineral. Those that are most often preserved are composed of the stable mineral calcite, while most of those that dissolved were made of the unstable mineral aragonite. The loss of the taxa with aragonitic shells alters the composition of the fauna, resulting in an inaccurate picture of the living community. There are a few Cretaceous sites in northeastern Mississippi where the aragonitic fossils have not been destroyed, but they are rare. These sites are important because they preserve far more species than the other localities. Beside shells, another important part of the fauna that has been lost by dissolution are the fish otoliths. **Otoliths** are aragonitic nodules in the inner ears of bony fish. They are so characteristically-shaped that the fish can often be identified with them alone. Because they have all dissolved, a large part of the Frankstown fish fauna will never be known.

What does preserve at Frankstown are the hard parts: bits of wood, teeth, sawfish rostral denticles, vertebrae, shark cephalic claspers and fin spines, osteoscutes (non-bony chitinous scutes are lost), jaw and other bone fragments, toothplates, turtle shell fragments, bits of calcified cartilage, scales, chimaeroid jaw plates, calcified chitin fragments, phosphatic shell fragments, barnacle plates, calcitic shells, and steinkerns. Sharks and rays are represented by more hard parts than many other animals because they have large numbers of teeth, and replace one row of teeth every few weeks. In addition, **trace fossils** (borings, burrows, and coprolites) show that other animals were present. Still, much is lost, as animals without hard parts or burrowing habits die and are buried without leaving a trace behind. Unfortunately, this was the fate of many coastal invertebrates.

Even the very hard shark teeth are subject to gradual dissolution (Text figure 7). This dissolution is a result of deep soil weathering in which the dense, dark-stained teeth first lighten in color, then lose the softer root, then the dentine core inside the crown, and finally are reduced to a splintered pale yellow enamel cap of the tooth crown.

An even more important feature of the site is reburial. How does a concentrated bed of shark teeth

Figure 7. Progressive weathering and dissolution of shark teeth from the Frankstown site. Specimens are arranged with an unweathered tooth on the left and progressive weathering to the right. As they weather, first the teeth become lighter in color; next the roots become soft and start to erode; then the roots are lost; and finally the softer core of the crown is dissolved, leaving only the crown's hollow, splintered enamel exterior.

come to form? Do a huge number of sharks all die suddenly and wash into shallow water? Were sharks from all over the Gulf Coast holding a convention at Frankstown 75 million years ago??? The answer is no, but to understand why, you need to know something about coastal **sedimentation** (the processes by which sediment is deposited).

Unlike the oyster bed, the shark tooth bed is not in the form in which it was originally buried. The oysters lived, died, and were covered by a rain of sediment onto the sea floor. The sharks, on the other hand, did not all live at the same time. The shark tooth bed is what is called a **transgressive lag**, in the terminology of another relatively new science - **sequence stratigraphy**. What sequence stratigraphy tries to show about marine sediment is the cyclic nature of the rise and fall of the ocean. Specific types of sediment are deposited in specific situations - as the ocean rises up on the coast (a process called **transgression**), when it reaches its highest point on land (when the ocean is the deepest), and when the ocean retreats off the land and back into the deep sea bed (a process called **regression**). The part that most concerns vertebrate fossil specialists is what happens as the ocean moves up on shore, in the transgressive phase, the base of each cycle (or sequence).

A transgressive lag forms when the turbulent ocean front first moves up over sediments of nearshore and coastal environments, where food was plentiful and sharks and other fish were common. The term lag used in this sense is the sediment that lags behind when the rest has been washed away. The beating of waves and underwater currents simply rips up the sediment from these beds as the sea moves inland. It winnows out the finer particles, like fine sand, silt, and clay, and concentrates the heavier, pebble- and coarse-sand-sized particles - including shark teeth. The lag forms as long-buried fossil teeth are dug up from underlying beds, winnowed out, and concentrated in a thin bed. Thus, the huge numbers of teeth in the bed do not represent the sudden mass death of many sharks, but the concentration of fossil material from various environments and over a certain length of time. What this does is artificially over-represent larger and more durable fossils in the fauna. This over-representation must be remembered when you attempt to reconstruct the environment.

The shark tooth bed in the basal Demopolis is not the only (or even the most important) vertebratebearing transgressive lag in the Late Cretaceous beds of northeastern Mississippi. Another, at the top of the Eutaw Formation in Monroe, Clay, and Lowndes counties, has produced important early Campanian fossils for over a hundred years. Much of this material has come from bluffs along river banks.

PALEOECOLOGY

What was it like to be where Frankstown is now 75 million years ago? The sea level was high then, and the area was under the Gulf of Mexico, in fairly shallow depths of less than 90 feet of water. It lay about 115 miles northwest of land at the southern end of the Appalachian Mountains, near Birmingham, Alabama. The climate was tropical. Far to the west, the Rocky Mountains were just begining to rise.

Paleoecologists, those paleontologists who try to reconstruct habitats of the past, often divide faunas into two types of communities - proximal and distal. The **proximal community** lived most of its life at the place it was recovered. The **distal communities** primarily lived in other places, but were either transported to or only visiting the site where they happened to be buried.

The proximal community at Frankstown was a shallow marine, nearshore community of crabs, lobsters, chimaeroids, sharks, rays, bony fish, sea turtles, and mosasaurs. That it was a nutrient-rich environment (one with a lot to eat) is suggested by the diversity of the fauna and the number of predators. The fauna appears to be a good balance of carnivores (meat eaters), herbivores (plant eaters), and omnivores (those that eat both plants and animals). One particularly striking thing about the fauna is the large number of shell-crushing (mollusk-eating) taxa, including the chimaeroid, the horn shark, two rays (the two *Brachyrhizodus* species), the pycnodont fish, the bonefish-like *Paralbula*, and the mosasaur *Globidens*. The abundance and diversity of these shell-crushing forms suggest that they lived over a rich mollusk (and possibly also sea urchin) bank. That the water was of normal ocean salinity is suggested by the diversity of sharks and rays.

There appear to have been at least three distal communities at some distance from the mollusk bank. The presence of a **deep-water community**, probably to the southwest of the site, is suggested by the rare ammonites from the site, and probably also by at least some of the mosasaurs and sea turtles. The presence of a **land community** is suggested by the wood and dinosaur remains. These could have been washed out into the Gulf by rivers or could have been dug up by the advancing sea from buried river channel deposits. A **riverine community** is also suggested by the presence of gars, the freshwater shark *Lissodus*, the pleurosternid (?) and soft-shelled turtles, and perhaps by the small crocodilian. The land and river elements could have entered the Gulf at the river deltas or been excavated from deltaic sediments.

Although dinosaurs are rare on the Gulf and Atlantic Coastal Plain, they are known from scattered remains from Missouri, Tennessee, Mississippi, Alabama, Georgia, North Carolina, Maryland, Delaware, and New Jersey (where American dinosaurs were first reported in 1858). They are far better known from the American West, from Alberta (Canada), Montana, Wyoming, New Mexico, and west Texas. The late Campanian, the age of the Frankstown site, was the golden age of the duck-billed dinosaurs. Only 10 million years after the Frankstown fossils were deposited, the dinosaurs became extinct.

While most of the Frankstown fauna became extinct at the end of the Cretaceous, it is worth remembering that some of the fauna did not. Forms very similar to the jingle shell *Anomia*, the angel shark *Squatina*, the horn shark *Heterodontus*, the gars *Lepisosteus* and *Atractosteus*, and the soft-shelled turtle are all still alive today. Others seem different from the living taxa, but may have been early relatives of the living forms, such as the goblin shark *Scapanorhynchus*, the nurse shark *Cantioscyllium*, the eagle ray *Brachyrhizodus*, the sea turtle, and the small crocodile. It is easy to forget that today's fauna is a mixture of newly evolved taxa and relicts of the ancient past.

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A number of people kindly donated material to the Booneville High School (BHS) collection, which is included in this study and is now placed in the

Mississippi Office of Geology (MGS) Figured Specimen Collection. Booneville High School student Ginger McAnally donated a fine *Dakoticancer* specimen. Warren Norwood, of Hurricane, Mississippi, donated a number of unusual specimens figured here: the *Hybodus* sp. 1 dorsal fin spine, *Atractosteus* scale, large *Enchodus* palatine, the pleurosternid (?) peripheral, and small turtle neural. David Shepherd, of Southeastern Louisiana University in Hammond, Louisiana, donated the anterior and larger posterior *Globidens* teeth, as well as the unusually well preserved large mosasaur vertebra. Two Memphis, Tennessee, collectors donated rare specimens to the Memphis Pink Palace Museum (MPPM) collection so they could be figured here; Roger Van Cleef donated the chimaeroid jaw tip and Richard Gunter donated the *Xiphactinus* tooth. Ron Brister, of the MPPM, kindly permitted the publication here of several rare Frankstown specimens from their collection.

The senior author is grateful to several people who generously permitted him to examine their Frankstown collections: Pete Scott, Warren Norwood, Richard Gunter, John Connaway, Lonnie Looper, David Shepherd, Patsy Johnson at BHS, and Ron Brister and Roy Young at the MPPM. A large Frankstown collection, collected by the authors, is on deposit at the Mississippi Office of Geology. The material figured here is mostly in the MGS collection, with a few specimens from the MPPM collection.

Several people assisted with identifications. Roger Van Cleef did many of the preliminary fossil identifications of the BHS and MPPM collections. Roy Young identified the lobster, crab, and ghost shrimp remains from Frankstown. Ray Perreault, of Baton Rouge, identified the gooseneck barnacle. Howard Hutchison of the University of California at Berkeley identified the very unusual pleurosternid (?) turtle. James Dobie of Auburn University, Alabama, offered many helpful comments on the sea turtles, mosasaurs, and hadrosaur.

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PLATE EXPLANATIONS

All specimens figured here are from the lower Demopolis Formation at the Frankstown site in Prentiss County, northeastern Mississippi, and are of Late Cretaceous (upper Campanian) age. Specimens figured on Plate 1 are from the oyster bed that overlies the formation's basal sand. The following plates figure fossils from the basal sand, here informally called the Frankstown sand (Dockery and Manning, 1992), and its associated vertebrate lag deposit. This sand unit is also informally referred to as the shark tooth bed, because shark teeth were concentrated in it as the lag formed. Plates 1 and 2 show invertebrates, and plates 3-12 figure only vertebrates. Each specimen is figured with a bar scale in centimeters (cm) or millimeters (mm) to indicate its size.

The figured specimens of these plates are housed in the Mississippi Office of Geology (MGS) collection in Jackson, Mississippi, and the Memphis Pink Palace Museum (MPPM) collection in Memphis, Tennessee. The relative abundance of each species illustrated here, based on the number of their specimens collected at the Frankstown site, is indicated by capital letters: A-abundant, C-common, U-uncommon, R-rare, and V-very rare.

EXPLANATION PLATE 1

INVERTEBRATE FOSSILS FROM THE OYSTER BED

Invertebrates (animals without backbones)

Sponge

1. *Clione* **sp.** Sponge borings in oyster shell fragment, MGS 1803, A. This sponge makes its home by boring into shells. Fossils like this are indirect evidence of the animal that was present. Such are called trace fossils and also include burrows, trails, tracks, and coprolites.

Annelid Worm

2. **Unidentified Polychaete Worm.** Boring of a marine worm (pointed to by arrow) in an oyster shell fragment, MGS 1815, R. Modern sandworms make similar borings in oysters today.

Mollusks: Bivalves - Ground water has dissolved most of the molluscan shells of the Frankstown site. Only those shells made of calcite, such as those listed below, remain.

Oysters

3-4. ***Exogyra ponderosa*.** The genus *Exogyra* is very useful in determining the age of Late Cretaceous fossiliferous beds in the Gulf Coast. **3.** *Exogyra ponderosa ponderosa*. Partial lower (left) valve (shell), in external view, MGS 1806, C. The two valves of *Exogyra* are differently shaped. The larger lower valve is convex, and starts with a small coil. The smaller upper (right) valve is relatively flat and acts like a lid. **4.** *Exogyra ponderosa erraticostata*. Partial lower valve, in external view, MGS 1807, R. Unlike the more common subspecies at Frankstown, which shows only growth lines, this one has heavy radial ridges called costae.

5. ***Pycnodonte convexa*.** Lower valve, in external view, MGS 1805, A. This is the main oyster that makes up the oyster bed at the site. Unlike *Exogyra*, its shell is more rounded than oval, and does not start with a coil.

6-7. ***Gryphaeostrea vomer*.** **6.** Lower valve, in internal view, MGS 1808, C. **7.** Upper valve, in external view, MGS 1809, C. The nearly flat upper valve has distinctive raised concentric ridges.

8. ***Striostrea plumosa*.** Partial valve, in external view, MGS 1810, R. The shell had distinctive, light, radiating grooves on its external surface.

9. *Ostrea* **(?) sp.** Shell, in external view, MGS 1811, R. An unusual elongate form.

Jingle Shells

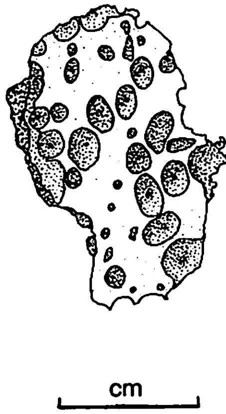
10. ***Anomia argentaria*.** Shell, in external view, MGS 1812, C. A form with a thin, smooth, often pearly-looking shell.

11. ***Paranomia scabra*.** Shell fragment, in external view, MGS 1813, C. Form with a spiny shell, usually found broken at the site and sometimes attached to foreign objects.

Scallop

12. *Neithea* **sp.** Shell fragment, in external view, MGS 1814, C. Related to the scallops that are eaten today; usually found as broken fragments at Frankstown.

Sponge, Polychaete, and Bivalves



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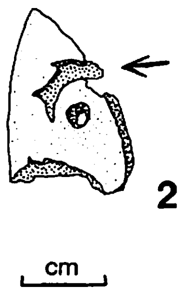

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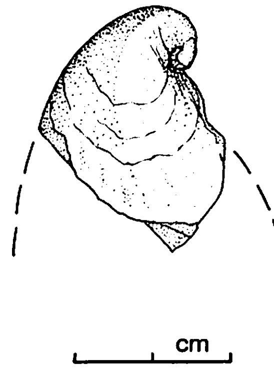

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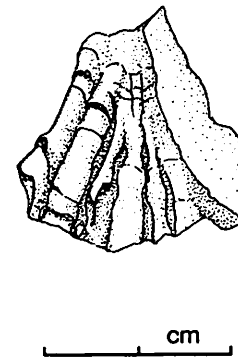

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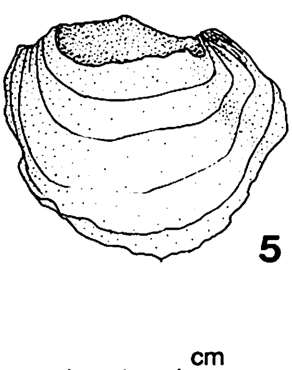

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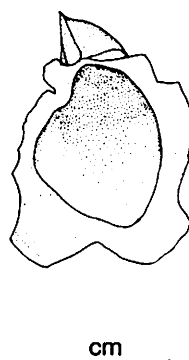

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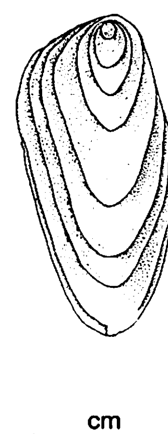

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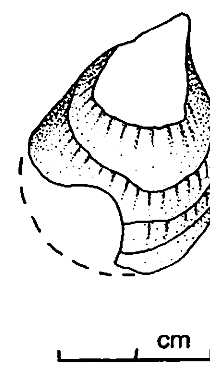

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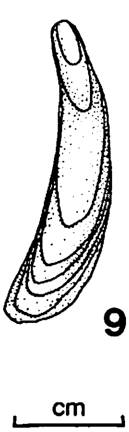

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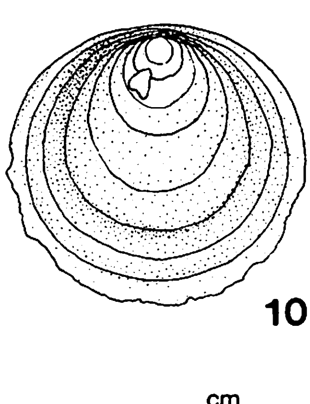

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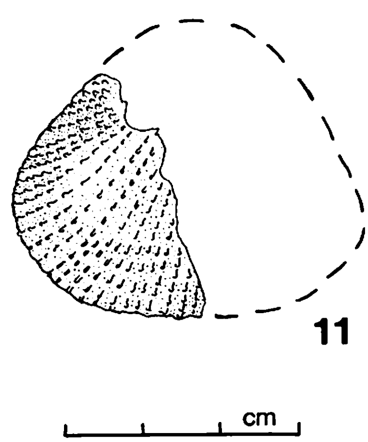

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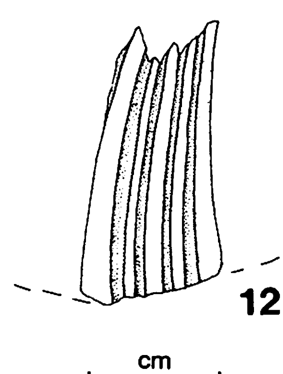

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EXPLANATION PLATE 2

INVERTEBRATE FOSSILS FROM THE SHARK TOOTH BED ("FRANKSTOWN SAND")

Mollusks: Scaphopod (Tusk Shell)

1. ***Cadulus* sp.** Partial shell, in lateral (side) view, MGS 1816, R. One of the few fossils from the site composed of the easily dissolved mineral aragonite. *Cadulus* lives today in the soft mud and sand of the ocean floor, picking food particles out of the sediment.

Mollusks: Cephalopods

2. **Unidentified Ammonite.** Steinkern of a partial chamber of a small coiled ammonite, MGS 1819, R. 2a - Septal view, 2b - internal view. A steinkern is a fossil formed when sediment filling a shell hardens into rock. Ammonites are extinct cephalopods, a group including the modern squid, octopus, and chambered *Nautilus*. Like the chambered *Nautilus*, the ammonite had compartments within its shell that were separated by walls called septa. When the aragonitic shell dissolved, only the fillings of the chambers remained.

3. ***Baculites asper*.** Steinkern of two chambers, MGS 1818, R. 3a - Lateral view, 3b - septal view. This is an "uncoiled" straight form.

Brachiopod

4. ***Lingula* sp.** Nearly complete valve in external view, MGS 1825, R. Unlike bivalve mollusks from the site, this brachiopod has a phosphatic, rather than calcitic, shell. Because it has changed very little over several hundred million years, *Lingula* is considered a living fossil.

Arthropods: Crustaceans

5. ***Zeugmatolepas* sp.** Carina (one of several calcitic plates making up the outer wall), MGS 1824, C. 5a - Internal view, 5b - external view. *Zeugmatolepas* was a gooseneck barnacle. Unlike most modern barnacles, which attach directly by their plates, gooseneck barnacles attach by a long, flexible stalk.

Crustacean: Decapods

6-7. ***Hoploparia* sp.** 6. Lobster carapace (the front part, with the head and legs) and front of the abdomen (tail), slightly flattened, in dorsal view, MGS 1821, R. 7. Lobster abdomen, slightly flattened, in dorso-lateral view, anterior at top, MGS 1822, R. At Frankstown, decapod remains often appear to be only shiny patches of chitin on black pebbles.

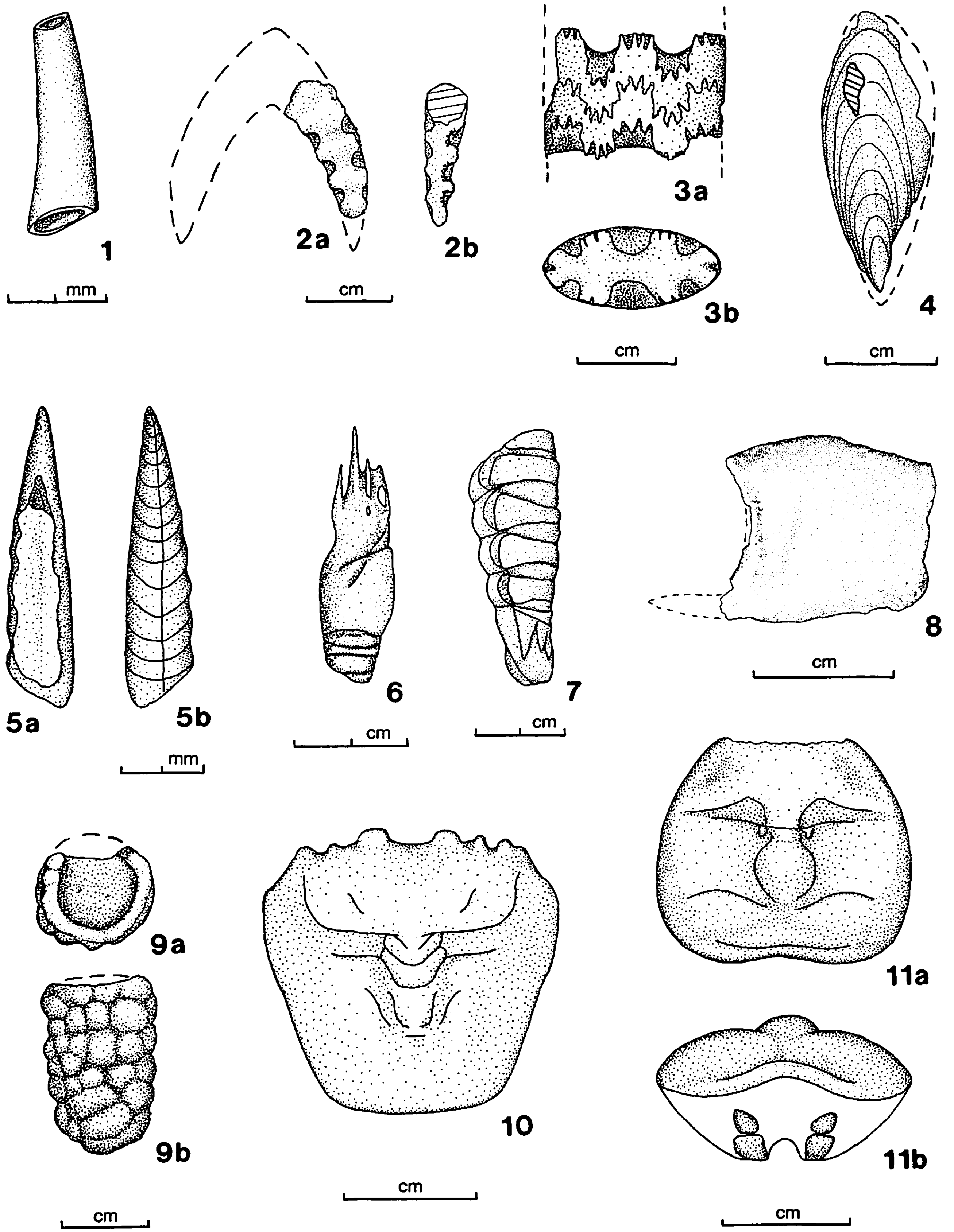
8. ***Callianassa* sp.** Ghost shrimp chela (main part of claw apparatus), in lateral view, anterior at left, MPPM 1991.27.6, R. A burrowing type of shrimp.

9. ***Ophiomorpha* sp.** Burrow filling, possibly of the ghost shrimp *Callianassa*, MGS 1820, C. 9a - Top view, 9b - side view. These trace fossils are distinctive because the wall of the burrow was lined with pellets of sediment.

10. ***Raninella* sp.** Crab carapace, in dorsal view, anterior at top, MPPM 1991.27.7, R. In crabs, the abdomen is tucked underneath the carapace, between the legs. The eyes and antennae are located at the front of the carapace.

11. ***Dakoticancer* sp.** Crab carapace, MGS 1823, R. 11a - Dorsal view, anterior at top, 11b - posterior view (note bases of legs at the bottom, and groove for abdomen). What looks like a face on top of the carapace are grooves that overlie internal ridges, which serve as places for muscle attachment.

Scaphopod, Ammonites, Brachiopod, and Crustaceans Plate 2



EXPLANATION PLATE 3

CHIMAEROID AND HYBODONT SHARKS

Vertebrates (animals with backbones)

Chimaeroid (a group of boneless, cartilaginous fish related to sharks and rays, including the modern rat or rabbit fish)

1-3. ***Ischyodus bifurcatus*****. 1.** Left palatal (an upper jaw plate), anterior at top, midline at left, of a juvenile in occlusal view (looking down on the working surface of a tooth or mouthplate), MGS 1828, R. The areas filled with spots or lines are hardened areas used for chewing, called tritors. **2.** Anterior tip of the left mandibular (the lower jaw plate), in labial view (looking at a tooth or mouthplate from the side, outside the mouth) anterior at left, MPPM 1991.27.5, R. The vertical plates inside the jaw help form the anterior tritor as the jaw wears down. **3.** Partial left juvenile mandibular, anterior at right, in lingual view (looking at a tooth or mouthplate from the inside of the mouth), MGS 1829, R. The tritors were originally filled with a hardening mineral (probably aragonite), which has almost always dissolved in the Frankstown specimens.

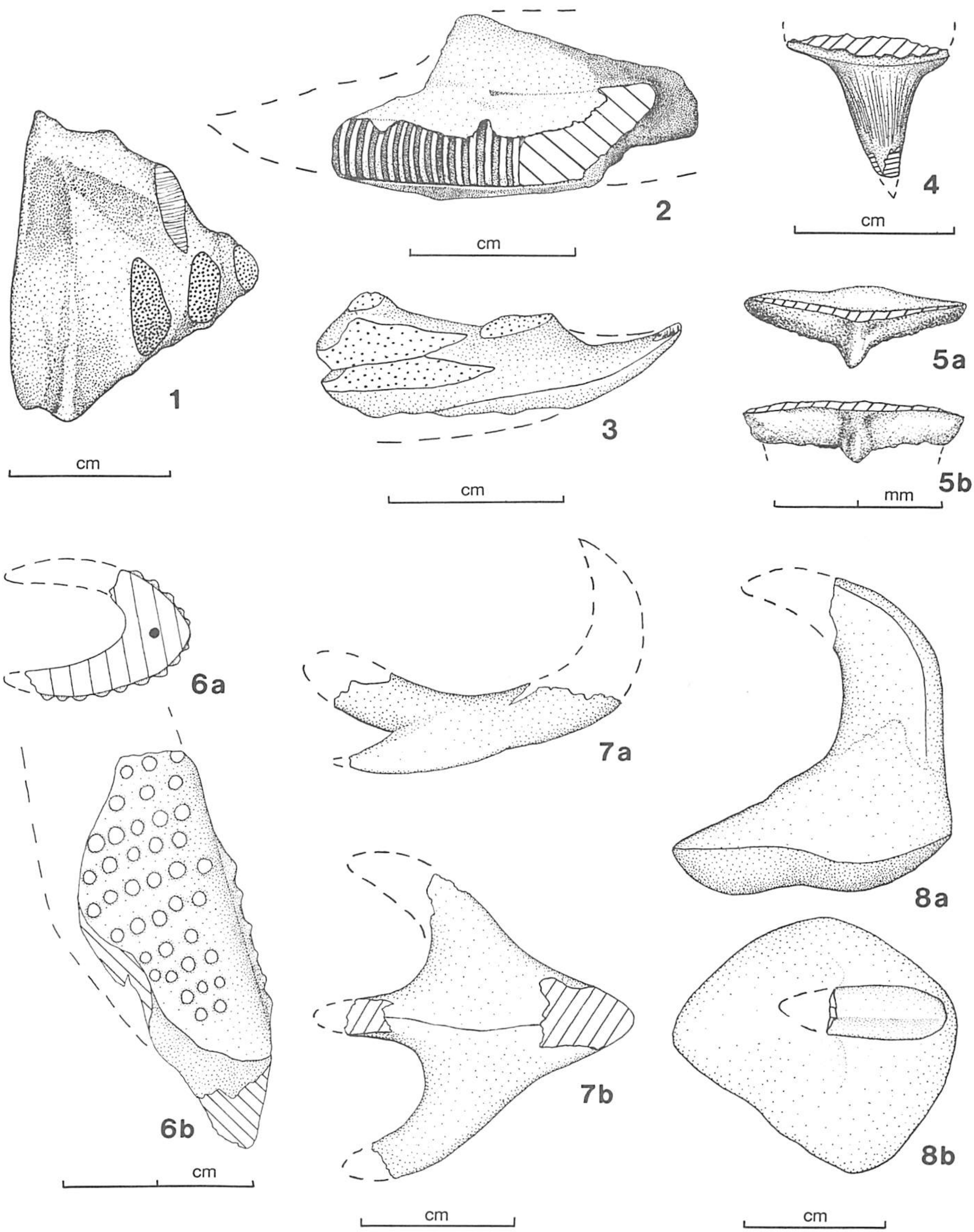
Hybodont Sharks These were the most common sharks in the early Mesozoic. They became less common in the late Mesozoic, the age of the Frankstown site.

5. ***Lissodus babulskii*****.** Advanced hybodont shark tooth missing root, MGS 1835, R. 5a - Occlusal view, 5b - labial view. A small shark with teeth designed to crush, rather than hold or cut, its food. It is unusual in that it lived in fresh water. Like many of the Frankstown teeth, these must be picked under a low-power microscope.

4,6-7. ***Hybodus*** **sp. 1.** A very widespread Cretaceous shark, first described from England. **4.** Tooth, missing root, in lingual view, MGS 1830, C. Hybodonts have poorly calcified tooth roots, so they are often broken off. **6.** Base of the dorsal fin spine, MGS 1832, R. 6a - Dorsal view (cross section of spine), 6b - lateral (side) view. The part at the bottom was embedded in the muscles of the shark's back just in front of the dorsal fin. Even small fragments of these spines can be identified by the rows of shiny bumps. **7.** Cephalic (head) clasper, missing cusp, MGS 1831, C. 7a Lateral view, anterior at right, 7b - dorsal view (looking down on the back or top surface). These specialized dermal denticles (an enlarged scale, whose base was embedded in the skin) were located in pairs on the forehead of males, and were used in holding the females during mating. They are not present on modern sharks.

8. ***Hybodus montanensis*****.** Cephalic clasper, missing tip of cusp, MGS 1834, R. 8a - Lateral view, anterior at right, 8b - dorsal view. This species has a simpler base and heavier crown on its clasper that does *Hybodus* sp. 1.

Chimaeroids and Hybodont Sharks   Plate 3



EXPLANATION PLATE 4

MODERN - TYPE SHARKS

1. ***Heterodontus rugosus.*** Horn shark partial lateral tooth, MGS 1838, V. 1a - Lateral view, 1b - occlusal view, 1c - basal view (looking down on the roots of a tooth). Horn sharks (called that because they are one of the few modern sharks with dorsal fine spines) live on the ocean bottom and eat mollusks with their unusual, flattened teeth.

2. ***Chiloscyllium greeni.*** Partial tooth crown, missing root, MGS 1839, R. 2a - Labial view, 2b - lateral view. This small, widespread spotted or banded catshark is known from the site only from a few tiny teeth.

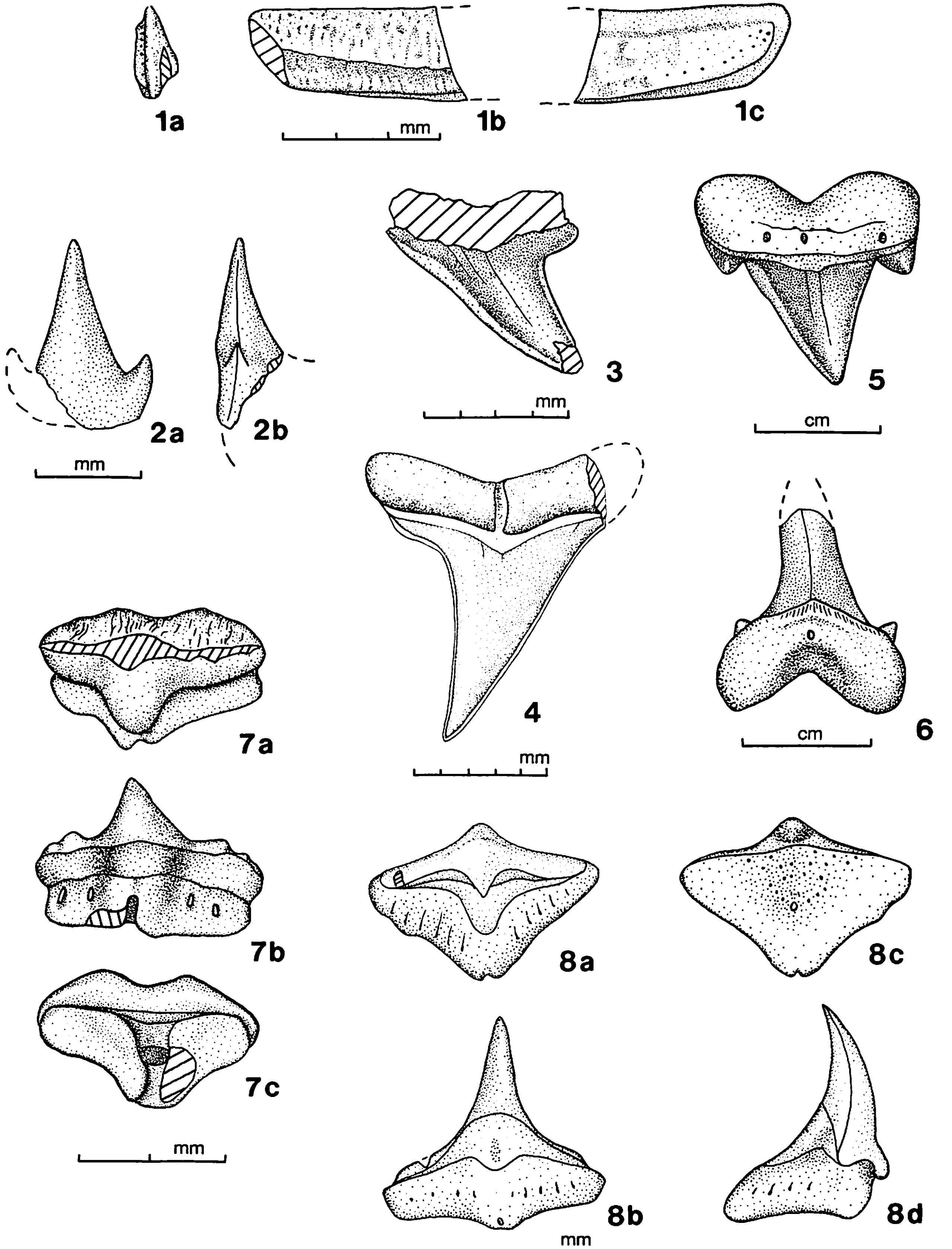
3-4. ***Anomotodon angustidens.*** A form possibly related to thresher sharks. **3.** Partial posterior tooth in lingual view, MGS 1847, R. **4.** Lateral tooth, in lingual view, MGS 1845, R. This form typically has a crown with a thin, sharp, clear edge and lacks the accessory cusps (the small cusps at the sides of the main, or primary, cusp) seen in most other Frankstown sharks.

5-6. ***Otodus appendiculatus.*** **5.** Upper lateral tooth, in lingual view, MGS 1848, U. **6.** Lower anterior tooth, missing tip, in lingual view, MGS 1849, U. A long-lived shark species with a worldwide distribution. Distinctive for its strong accessory cusps and heavy root with a reduced root groove. In most advanced sharks, this groove separates two distinct roots. In this shark, the groove has been reduced to a small central hole (for a ligament that holds the tooth to the cartilaginous jaw).

7. ***Cantioscyllium descipiens globidens.*** Primitive nurse shark lateral tooth, MGS 1840, R. 7a - Occlusal view, lingual side at bottom, 7b - lingual view, 7c - basal view. Primitive sharks have the crown of the tooth perpendicular to the flat base of the tooth roots. In most living sharks, the crown has rotated lingually, so that it is nearly parallel to the base of the roots. This makes tooth replacement easier.

8. ***Squatina hassei.*** Angel shark lateral tooth, MGS 1836, C. 8a - Occlusal view, lingual at bottom, 8b - lingual view, 8 - basal view, 8d - lateral view, anterior at right. As in *Cantioscyllium,* the crown of *Squatina* is perpendicular to the root. Angel shark teeth are some of the most common small shark teeth at Frankstown. Angel sharks are flattened, ray-like sharks that live in shallow coastal waters. One species still lives along the Gulf Coast today.

Sharks Plate 4



EXPLANATION PLATE 5

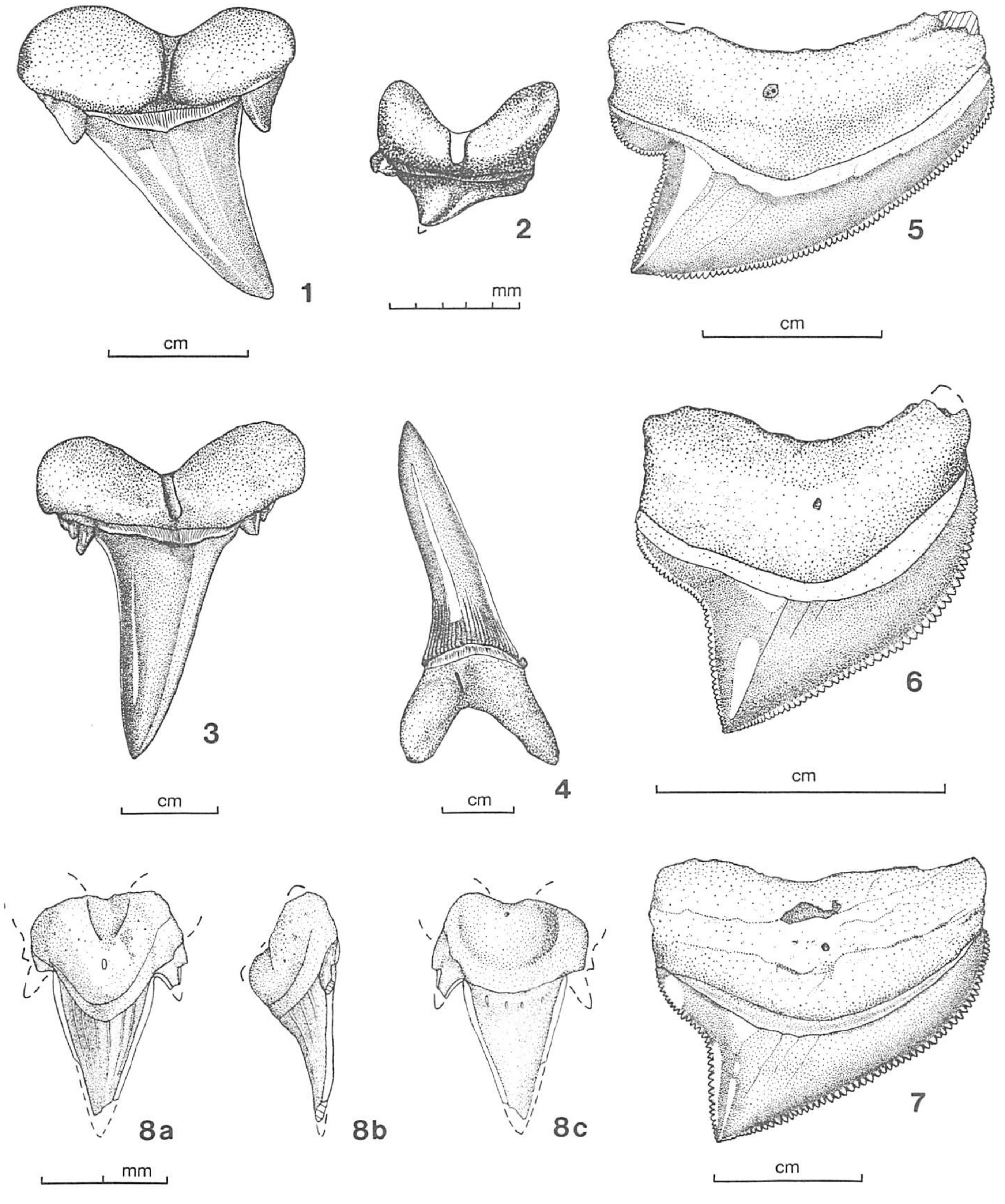
MODERN - TYPE SHARKS

1-4. ***Scapanorhynchus raphiodon texanus.*** Goblin shark teeth, all in lingual view. **1.** Upper lateral tooth, MGS 1842, A. **2.** Upper posterior tooth, MGS 1843, U. **3.** Upper anterior tooth, MGS 1841, A. **4.** Lower anterior tooth, MGS 1844, A. Goblin shark teeth are, by far, the most common teeth found at the Frankstown site. As in most other modern-type sharks, the teeth of this form look quite different from each other, depending on their position in the mouth. The upper teeth (figures 3 and 1) have a broad primary cusp, which is smooth on the lingual surface, large accessory cusps, and a broad, flattened root. The lower teeth (figure 4) have a narrow primary cusp with strong ridges on the lingual surface, very small accessory cusps (or none at all), and a narrow, U-shaped root with a high knob in the center. The difference has to do with their differing functions. The narrow lower teeth are used mainly for holding the prey (like a fork), while the broader upper teeth are used for cutting (like a knife). There are also differences between front and back teeth. The primary cusp angles more toward the back of the mouth in the more posterior teeth (figure 1) than anterior ones (figure 3). The small teeth at the back of the jaw (figure 2) are also shaped differently.

5-7. ***Squalicorax pristodontus kaupi / pristodontus.*** Extinct predaceous shark teeth, all in lingual view. This is the second most common shark at the site. It is the only Frankstown shark with serrated teeth. From the similarity of the teeth, one might guess that it lived something like a modern tiger shark. The roots are very broad and flat. The root groove has been reduced to a small hole. The serrations help make these teeth efficient meat cutters, like steak knives. The Frankstown *Squalicorax* teeth are quite variable, and represent a place where the lineage is changing from one type to another. **5.** *Squalicorax pristodontus kaupi* tooth, MGS 1850, U. This is the more primitive subspecies, with a well-developed notch at the posterior edge of the crown. **6.** *Squalicorax pristodontus kaupi/pristodontus* tooth, MGS 1851, C. This is the intermediate form. **7.** *Squalicorax pristodontus pristodontus* tooth, MGS 1852, C. This is the advanced subspecies, with the crown so broadened that the notch is nearly lost. Earlier *Squalicorax* teeth generally look like figure 5, while later ones look like figure 7. At Frankstown, it is hard to separate the two types.

8. *Scyliorhinus* sp. Common catshark partial tooth, with eroded root, MGS 1853, R. 8a - Lingual view (note ridges), 8b - lateral view, lingual at left, 8c - labial view. Represented at the site by only a few tiny teeth. Most catsharks today are also quite small.

Scapanorhynchus, Squalicorax, and *Scyliorhinus* Plate 5



EXPLANATION PLATE 6

UNIDENTIFIED SHARKS AND RAYS

1. **Shark Coprolite.** Fossil excrement, MGS 1856, R. Sharks have a screw-shaped intestine, giving their excrement a spiral appearance. They are originally bullet-shaped, but often become flattened in fossilization. The coprolites preserve because they are largely composed of ground-up bone.

2. **Shark Vertebral Centrum.** Specimen MGS 1855, C. 2a - Anterior or posterior view, 2b - ventral view. Sharks and rays have cartilaginous skeletons. In order to prevent their spines from compressing as they swim, they replace the cartilage of the central part of the vertebra below the spinal cord (the centrum) with prisms of the mineral calcite. This calcified cartilage, while not as strong as bone, is more rigid than normal cartilage. The edge of the centrum sometimes has paired holes for uncalcified cartilage elements. Shark vertebrae are much the same today.

3. **Large Ray Vertebral Centrum.** Specimen MGS 1875, U. 3a - Anterior or posterior view, 3b - ventral view. While shark centra are usually circular in outline, ray centra are usually oval. Most of the centra in the spine of a ray are shaped like this one.

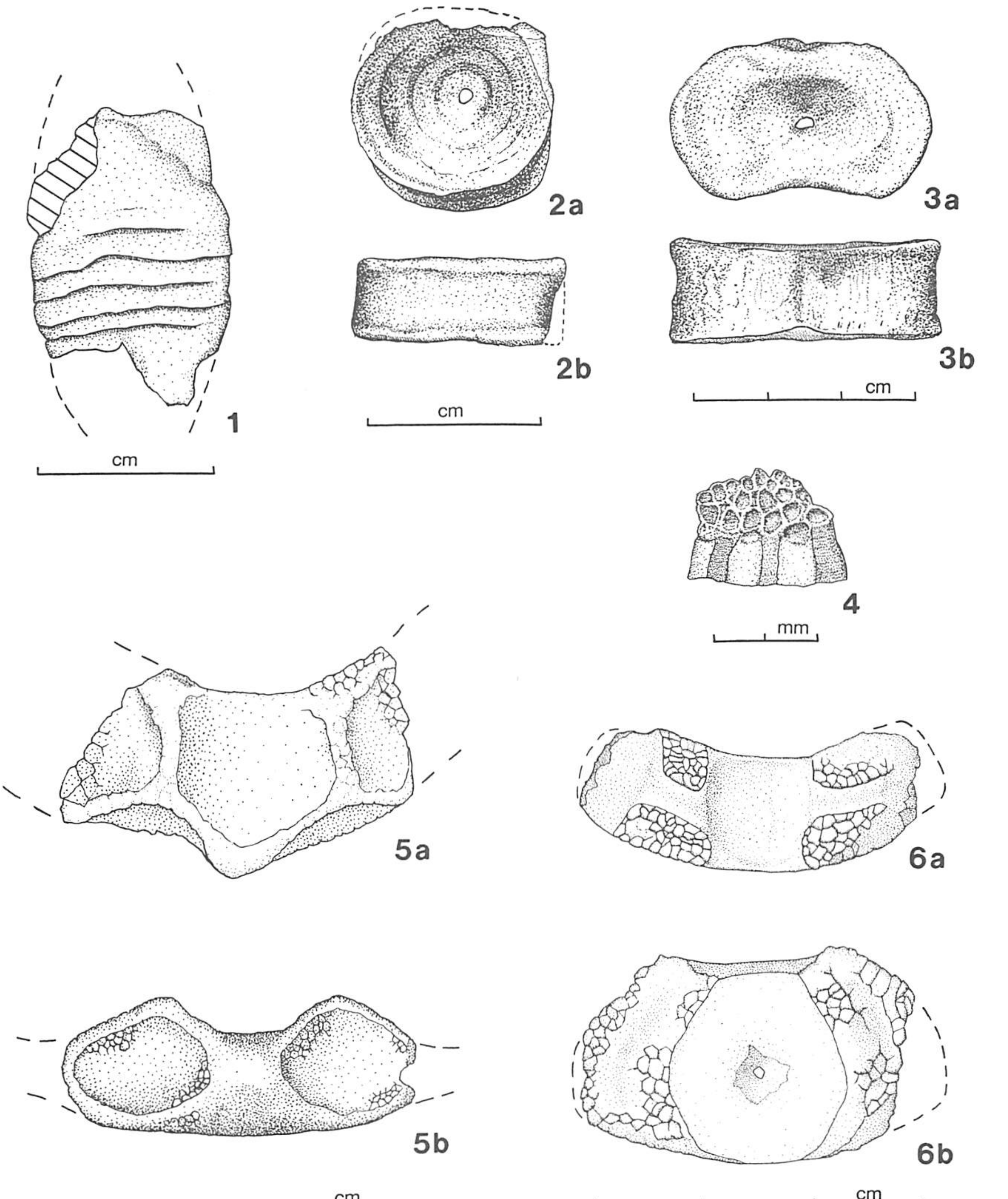
4. **Calcified Cartilage.** Fragment, probably from the head of a large ray, MGS 1876, R. Broken calcified cartilage looks quite different from broken bone. Along the broken edge, one can see pillar-like prisms. The surface of calcified cartilage often shows a mosaic pattern where the tips of the prisms meet the surface. Unfortunately, such broken fragments (unless very complete) are nearly impossible to identify precisely.

5. **Atlas (First) Neck Vertebra of a Large Ray.** Specimen MGS 1873, R. 5a - Dorsal view, anterior at bottom, 5b - anterior view. As in the calcified cartilage fragment, the polygonal pattern is visible at the surface. The notch seen on the broken edge at the right of figure 5b shows the hollow, uncalcified core, where only the surface cartilage was hardened. The two shallow depressions on this figure are the places where the back of the skull-like chondrocranium attached to the spine.

6. **Second (?) Neck Vertebra of a Large Ray.** Specimen MGS 1874, R. 6a - Dorsal view, anterior at bottom, 6b - anterior view. This vertebra appears to fit behind the atlas. The shallow depression over the circular centrum in figure 6b is the place where the spinal cord lay. The small hole in the center of the centrum is a place where the cartilaginous precursor of the vertebra, the notochord, was not fully calcified.

Unidentified Sharks and Rays

Plate 6



EXPLANATION PLATE 7

SCLERORHYNCHID SAWFISH

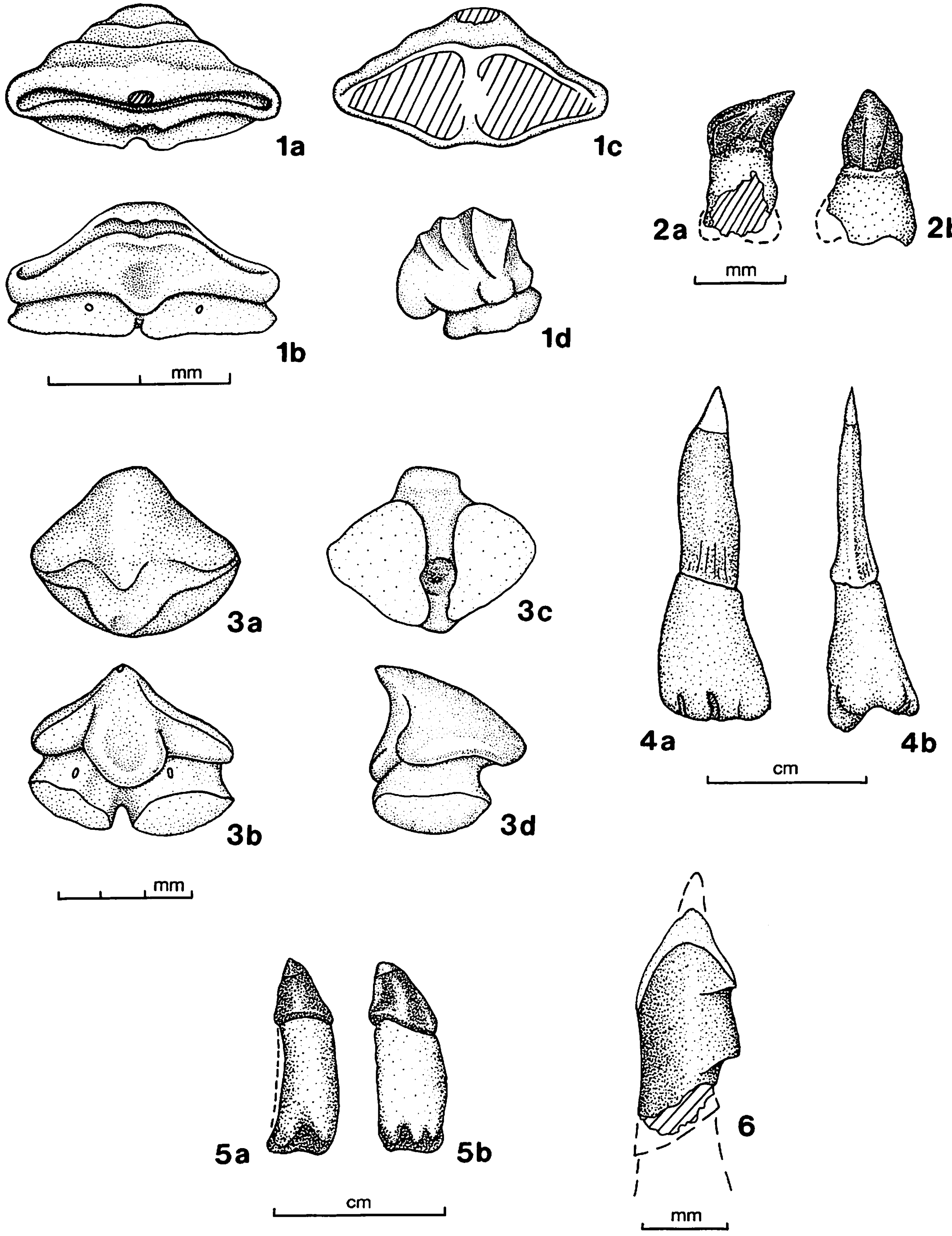
Sclerorhynchid sawfish are an extinct group that looked, and probably lived, like modern (pristid) sawfish, even though they were not closely related. Both have a somewhat flattened body and an elongate snout (called a rostrum) with enlarged scales (called rostral denticles) sticking out on its flattened left and right edges. By slashing this armored snout back and forth as it swims into a school of small fish, a sawfish can catch its prey.

1-2. ***Ptychotrygon triangularis*.** **1.** Lateral tooth, MGS 1857, C. 1a - Occlusal view, lingual at bottom, 1b - lingual view, 1c - basal view, 1d - lateral view, lingual at right. This is a small, long-lived sclerorhynchid with a worldwide distribution. The teeth fit into a battery on the jaws, to form a flat, shell-crushing surface. They lock into place by having the knob at the center of the labial surface fit into a socket at the center of the lingual surface of the tooth in front. These small teeth are, by far, the most common sawfish element at the site. **2.** Rostral denticle, MGS 1858, R. 2a - Dorsal or ventral view, anterior at left, 2b - anterior view. These are the most primitive sawfish rostral denticles from the site, only slightly more specialized than an ordinary shark scale (called a placoid scale).

3-5. ***Ischyrhiza mira mira*.** Largest of the three sclerorhynchids from Frankstown. **3.** Lateral tooth, MGS 1859, C. 3a - Occlusal view, lingual at bottom, 3b - lingual view, 3c - basal view, 3d - lateral view, lingual at left. Sclerorhynchid teeth are variable in the number and shape of ridges on the labial side of the crown. Like modern sawfish teeth, these are far smaller than the rostral denticles, and can only be picked under a microscope. **4.** Rostral denticle, MGS 1860, C. 4a - Dorsal view, anterior at right, 4b - anterior view. **5.** Posterior rostral denticle, MGS 1861, R. 5a - Posterior view, dorsal at right, 5b - dorsal view. Unlike the teeth of *Ischyrhiza mira*, the rostral denticles are large enough (and common enough) to be collected on the surface. The tips of the denticles have a distinctive clear cap, making even the broken crowns indentifiable. The heavy root attaches the denticle to the rostrum. Denticles from the back of the rostrum (figure 5) have a shorter, more primitive, crown than those from the side or front.

6. ***Borodinopristis schwimmeri*.** Partial crown of a rostral denticle, in dorsal or ventral view, anterior at left, MGS 1862, R. The rostral denticles of this tiny form have distinctive barbs on the back edge. They are rare at the site, and are found only with persistent microscope work.

Sclerorhynchids **Plate 7**



EXPLANATION PLATE 8

RAYS

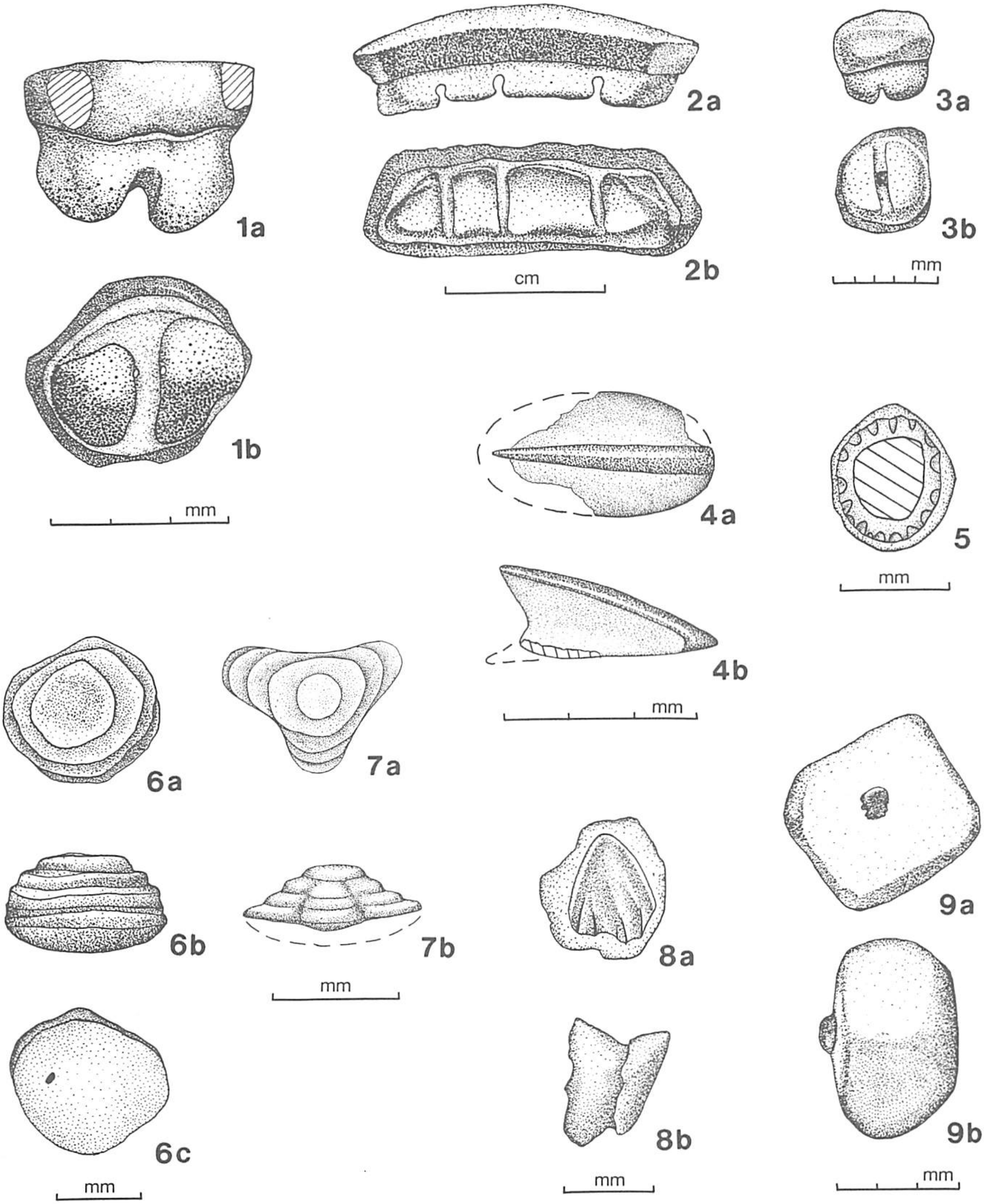
1. ***Brachyrhizodus mcnultii.*** Pavement tooth, MGS 1863, C. 1a - Labial or lingual view, 1b - basal view. Pavement teeth are heavy, flat-topped teeth set into a mosaic-like battery in the jaws, designed to crush solid objects, like mollusk shells. *Brachyrhizodus mcnultii* teeth are very common in screened samples from the Frankstown site. They must be picked with a fine tweezers under a low-power microscope.

2-5. ***Brachyrhizodus wichitaensis.*** A primitive eagle ray, a form with a greatly flattened body, broad wing-like pectoral (side) fins, and a whip-like tail armed with one or more spines. **2.** Median pavement tooth, MGS 1864, R. 2a - Labial or lingual view, 2b - basal view. **3.** Lateral pavement tooth, MGS 1865, R. 3a - Labial or lingual view, 3b - basal view. In order to stablize the pavement surface, the median teeth (those closest to the midline of the jaws) are enlarged in advanced rays, to take the place of several smaller teeth. To more firmly attach the elongate tooth to the jaw, two new root grooves have been added, resulting in four roots (figure 2b). As the pavement teeth are worn out at the front of the mouth, the toothplate moves forward from the rear. **4.** Partial mid-dorsal denticle, MGS 1866, R. 4a - Dorsal view, anterior at right, 4b - right lateral view. **5.** Secondary mid-dorsal denticle scale, MGS 1868, V. Modern eagle rays have similar (though more complex) enlarged dermal denticles (sometimes called "thorns") along the midline of the upper rear of the body and the base of the tail. It is from such denticles that the larger tail spine derived. The larger denticles carry tiny secondary denticles (figure 5) on their dorsal surface, surrounding the central spine.

6-9. **Unidentified Ray Dermal Denticles.** These denticles, which are enlarged placoid scales whose base is embedded in the skin, are generally broader and flatter than shark placoid scales. Because they have not been associated with any teeth, it is impossible to say from which kind of ray they came. These denticles are some of the most abundant small fossils from the site. Like teeth, the denticles generally have roots and crowns, though their bases are shaped differently from tooth roots. **6.** Circular button-type denticle, MGS 1870, C. 6a - Dorsal view, 6b - lateral view, 6c - basal view. **7.** Triangular button-type denticle, missing base, MGS 1871, R. 7a - Dorsal view, 7b - lateral view. **8.** Primitive-type denticle, with cusp, MGS 1869, R. 8a - Dorsal view, anterior at bottom, 8b - lateral view. **9.** Blocky-type denticle, MGS 1872, C. 9a - Dorsal view, 9b - lateral view. The primitive type (figure 8) is the closest to a normal placoid scale, with only a slightly flattened crown. The button type (figures 6 and 7) has completely flattened the crown, with peculiar triangular-shaped ones apparently forming when they were crowded together. The blocky-type is the most specialized (figure 9), with a greatly enlarged, cube-like base, and a crown reduced to a tiny nubbin.

Rays

Plate 8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EXPLANATION PLATE 9

BONY FISH

1. *Lepisosteus* sp. Gar scale, in external view, MGS 1877, R. Gars are river fish that have long snouts full of needle-like teeth, which they use to capture small fish. Like many primitive bony fish, gars have distinctive heavy, diamond-shaped, shiny-surfaced scales (called ganoid scales), which interlock to form a very sturdy hide. In contrast, most of the living bony fish (those with skeletons of bone rather than cartilage) have very thin, flexible scales.

2-4. *Atractosteus* sp. Alligator gars differ from other gars partly because of their broader (alligator-like) heads, larger size, and more ornamented scales. 2. Alligator gar scale, in external view, anterior at left, MGS 1878, V. 3. Alligator gar tooth, in lateral view, MGS 1879, V. 4. Worn alligator gar vertebra, MPPM 1991.27.1, V. 4a - Dorsal view, anterior at bottom, 4b - anterior view, 4c - lateral view. Like many bony fish teeth, gar teeth have a long, opaque base and a short, clear crown. Gar vertebrae are very different from typical bony fish vertebrae (compare to Plate 10, figure 6). They somewhat resemble small reptile vertebrae (see plates 11 and 12), but are concave at the back of the centrum, and not at the front.

5-6. *Hadrodus* sp. 5. Oral tooth, MGS 1880, C. 5a - Occlusal view, showing wear surface, 5b - lateral view, 5c - basal view. 6. Pharyngeal tooth, in side view, MGS 1881, C. *Hadrodus* is an extinct fish, with different kinds of teeth in different parts of its mouth. At the front, in the oral cavity, the crushing teeth are short and blunt, with fairly clear crowns (those at the very front look a bit like human front teeth). At the back of the mouth, in the pharynx, is an unusual comb-like structure (somewhat like that found in carp today) that helps pick food particles out of the water. At the tips of the comb "teeth" are distinctive flat, hook-like teeth, like the one in figure 6. Different parts of *Hadrodus* have been described at different times by different people under several names.

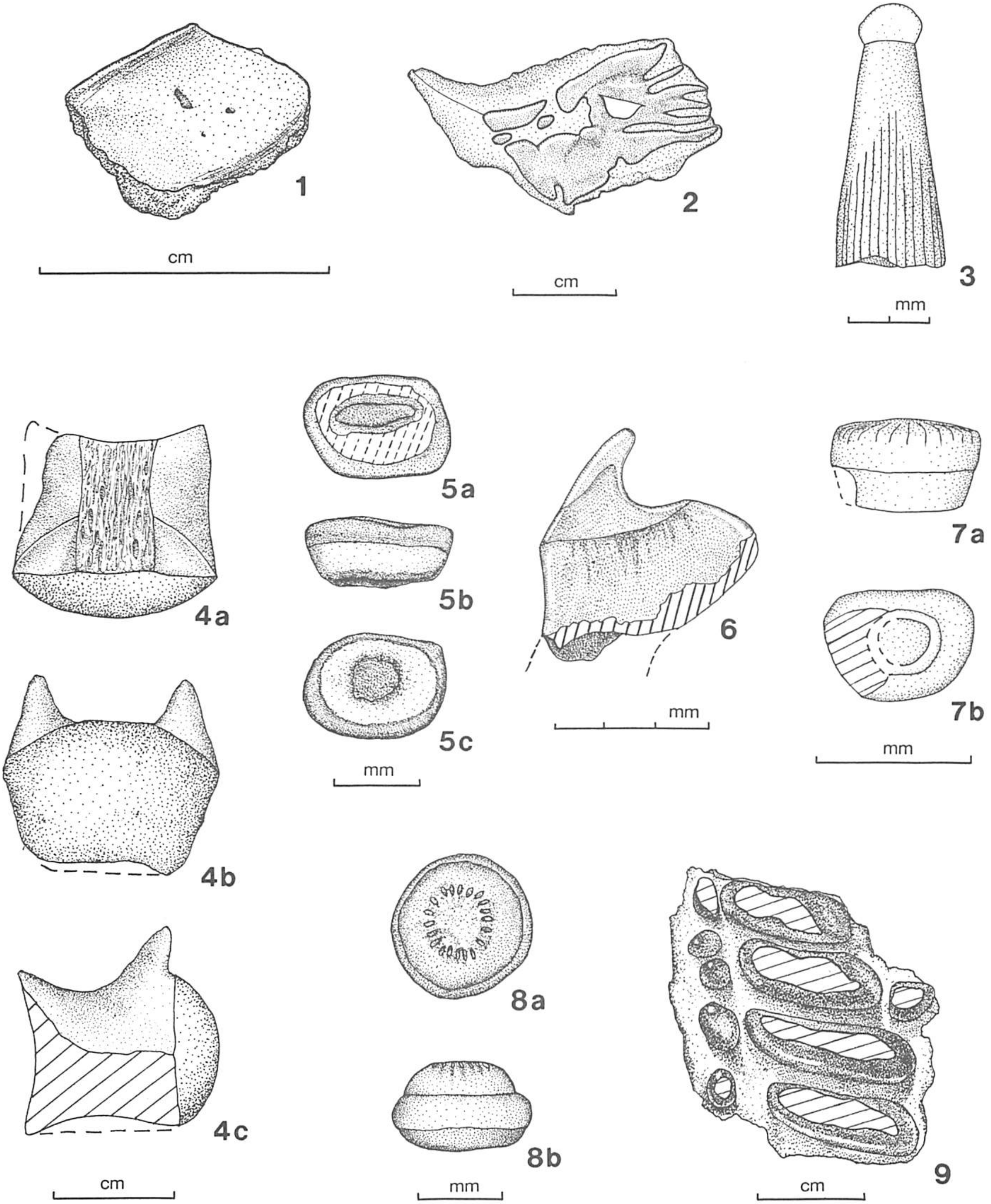
7. Unidentified Sciaenid or Albulid. Partial pharyngeal tooth, MGS 1883, V. 7a - Lateral view, 7b - basal view. A form related to drumfish or bonefish.

8. *Paralbula casei*. Phyllodont tooth, from tooth plate, MGS 1884, C. 8a - Occlusal view, 8b - lateral view. Phyllodont teeth are small, rootless teeth, which are stacked one on top of another, like upside-down plates, on an oval tooth plate. When one wears out, the one below comes into use. *Paralbula* is probably related to modern bonefish.

9. *Anomoeodus latidens*. Spenial tooth plate (at the back of the lower jaw) of a pycnodont fish, in occlusal view, MGS 1882, R. Pycondonts are extinct, deep-bodied fish whose distinctive pharyngeal tooth plates were used to crush shells. While complete tooth plates are rare at the site, isolated teeth from the plates are common.

Bony Fish

Plate 9



EXPLANATION PLATE 10

ENCHODUS (A BONY FISH) AND TURTLES

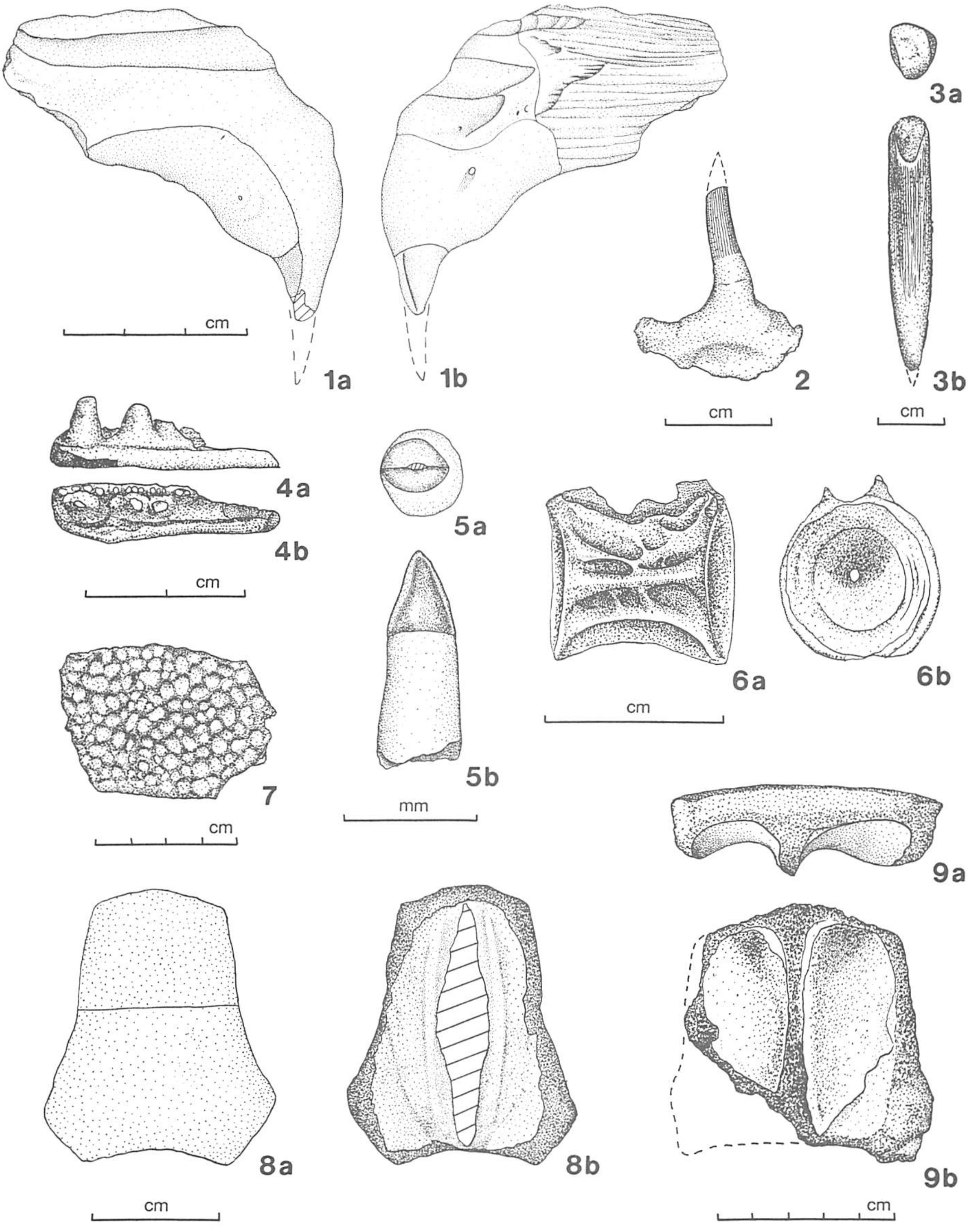
1-4. ***Enchodus* sp.** An extinct "sabre-toothed" predatory fish, with worldwide distribution in the Late Cretaceous. It is most widely known from its fangs (the rest of the fish is fairly normal-looking), which are common fossils in most Late Cretaceous shallow marine faunas. There were two upper and two lower fangs, one on either side of the front of the upper and lower jaws. **1.** Very large right palatine (at the front of the upper jaw), with a broken fang, MGS 1885, C. 1a - Lateral view, anterior at right, 1b - medial view. One unusual thing about *Enchodus* is its very broad size range. The fangs, for example, can vary in length from a few millimeters to six centimeters. **2.** Dentary (lower jaw) fragment with fang, in medial view, MGS 1886, C. **3.** Isolated palatine fang, MGS 1887, C. 3a - Basal view, 3b - posterior view. The fangs are found both attached to the jaws and as separate elements. **4.** Dentary fragment with lateral teeth, MGS 1888, R. 4a - Medial view, 4b - occlusal view, lateral at top. Fragments of the jaws behind the fangs are much less often seen at Frankstown.

5-6. ***Enchodus*? sp.** **5.** Lateral tooth, MGS 1889, C. 5a - Occlusal view, 5b - lateral view. **6.** Vertebra, MGS 1890, C. 6a - Lateral view, 6b - anterior or posterior view. Teeth and vertebrae of this type are common at Frankstown, but are of types typical of most bony fish. This makes identification difficult. They are thought to belong to *Enchodus* here only because it is the most common bony fish at the site.

7. **Unidentified Trionychid (Soft-Shelled) Turtle.** Partial costal (the part of the upper shell over, and including, the ribs), in dorsal view, MGS 1892, R. The shell of soft-shelled turtles has a distinctive pitted texture, indentifiable even in small fragments. Soft-shelled turtles are river turtles with leathery skin over a reduced shell. Turtle shells are made up of a series of separate bony elements, which have been fused together.

8. **Unidentified Small Turtle.** Neural (a midline element of the upper shell, over the backbone), anterior at top, MGS 1891, R. 8a - External (dorsal) view, 8b - internal (ventral) view. A shell element of this type, with a smooth surface, could belong to a small sea turtle or a fresh-water turtle.

9. **Unidentified Toxocheliid Turtle.** Partial neural, MGS 1893, R. 9a - Anterior view, 9b - internal (ventral) view, anterior at top. Toxocheliids were common large sea turtles in the Late Cretaceous, with a thick, heavy shell. As with the specimen in figure 8a, the surface bone is smooth.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EXPLANATION PLATE 11

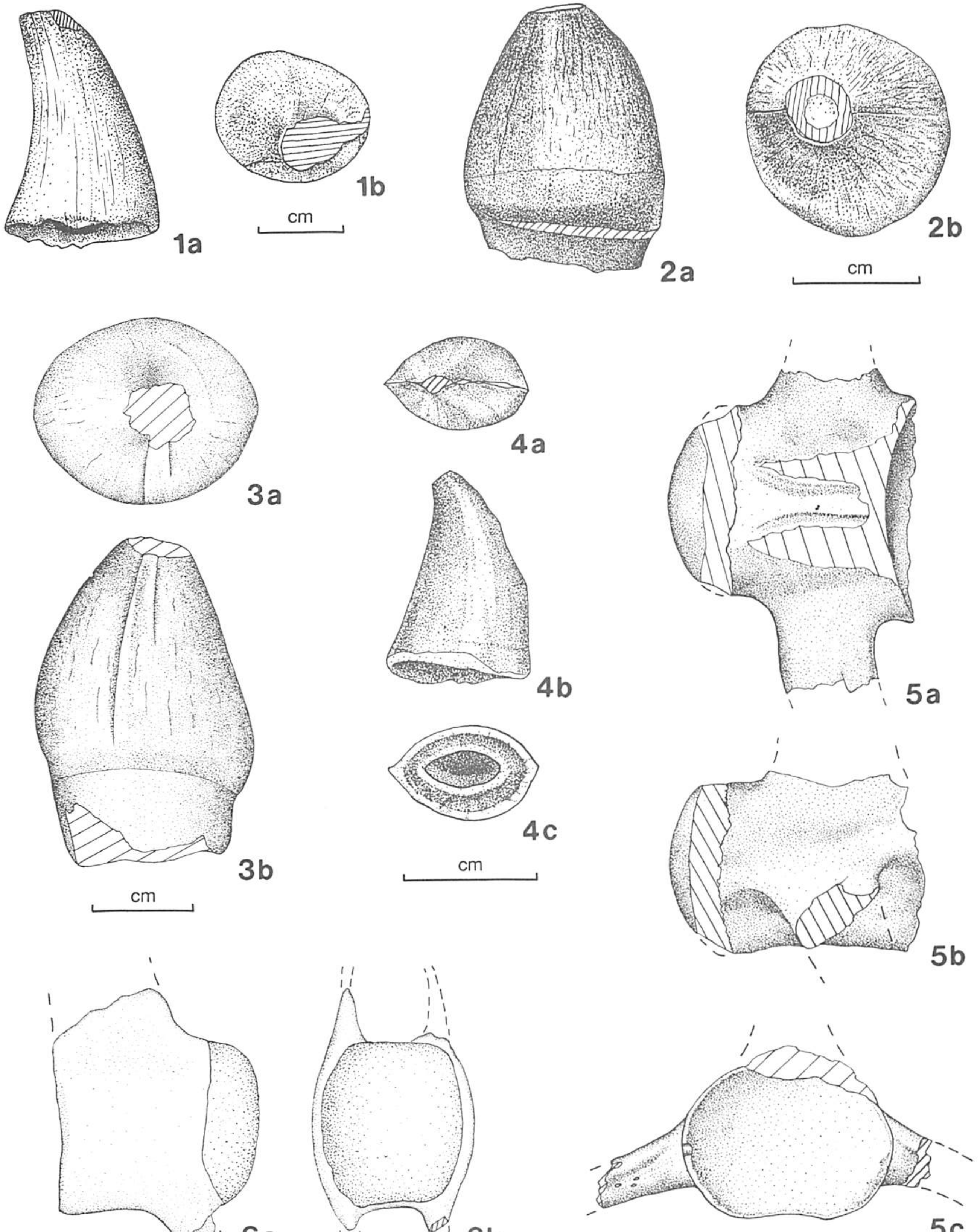
MOSASAURS

Mosasaurs were giant sea-going lizards, which became extinct at the end of the Cretaceous. They are thought to be related to the modern komodo dragons, giant lizards of the South Pacific. Most are thought to have eaten fish, though large ammonite shells with mosasaur bite-marks are known.

1. **Unidentified Tylosaurid.** Tooth crown, missing root, MGS 1894, R. 1a - Lateral view, 1b - occlusal view, anterior at right. This type of tooth - large, conical, and recurved posteriorly - is typical of the large, fish-eating mosasaurs. The recurved teeth help hold onto squirming prey while swimming.

2-4. ***Globidens alabamaensis.*** Unlike most mosasaurs, *Globidens* was a bottom feeder, using its huge, blunt teeth to crush the shells of snails and clams. **2.** Small lateral tooth, MGS 1896, R. 2a - Lateral view, 2b - occlusal view. **3.** Large posterior tooth, MGS 1897, R. 3a - Occlusal view, posterior at bottom, 3b - posterior view. **4.** Anterior tooth crown, missing root, MGS 1895, R. 4a - Occlusal view, 4b - lingual view, anterior at right, 4c - basal view. The anterior teeth are less blunt than those behind, which are sometimes inflated almost to the shape of a mushroom. These inflated teeth (figures 2 and 3) are the strangest of all mosasaur teeth.

5-6. **Unidentified Mosasaur Vertebrae.** Because several mosasaurs had similar vertebrae, isolated ones are often difficult to identify. Adding to the problem, those from Frankstown often appear to have rolled around on the sea floor for some time, making them badly worn. Like most reptile vertebrae, mosasaur vertebrae are procoelus, meaning that the front of the centrum is concave and the back convex. **5.** Lumbar (lower back) or anterior caudal (tail) vertebra of a mosasaur, missing the neural arch (the bony ridge over the spinal cord), MGS 1898, R. 5a - Dorsal view, anterior at right, 5b - right lateral view, 5c - anterior view. **6.** Posterior caudal vertebra of a mosasaur, MGS 1899, R. 6a - Left lateral view, anterior at left, 6b - posterior view. The size and shape of the vertebrae change considerably from the front of the backbone to the back.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EXPLANATION PLATE 12

CROCODILIANS AND DINOSAURS

1-3, 6. **Unidentified Small Crocodilian.** **1.** Partial pointed-type tooth crown, MGS 1900, U. 1a - Lateral view, 1b - occlusal view. **2.** Partial blunt-type tooth crown, MGS 1901, R. 2a - Lateral view, 2b - basal view. **3.** Partial osteoscute, in dorsal view, anterior at top, MGS 1902, U. **6.** Partial vertebra, MPPM 1991.27.3, R. 6a - Left lateral view, anterior at left, 6b - posterior view. Small crocodilian (a group including modern alligators, crocodiles, and gavials) teeth from the site include two types, the more typical pointed kind (figure 1), and a rarer blunt kind (figure 2). Baby crocodilian teeth are often of the blunt type. Both types may have been present in a single individual, with the pointed ones for holding and the blunt ones for crushing. The osteoscutes (figure 3) are bony plates embedded in the skin over the neck, back, and tail of the animal. In this form, they are rectangular, with a smooth anterior surface (where the osteoscute in front of it overlaps), and a sharp median keel on the pitted posterior surface. Unlike the pits in the outer surface of soft-shelled turtle shell fragments, those of crocodilian osteoscutes are usually well separated. Crocodilian vertebrae (figure 6) are more lightly built than those of the mosasaurs. The hole over the knob-like centrum in figure 6b is the place through which the spinal cord ran.

4-5. ***Thoracosaurus neocesariensis*****.** This is a large, gavial-like, sea crocodile. Gavials are large fish-eating river crocodilians with long narrow snouts, living today in India. **4.** Partial osteoscute, MPPM 1990.47.2, V. 4a - Anterior view, 4b - dorsal view, anterior at top. **5.** Tooth crown, MPPM 1991.27.2, R. 5a - Occlusal view, 5b - anterior or posterior view. This form is far larger than the previous one. The teeth are long, conical, and have a strong ridge on the front and back. They are not recurved as in the mosasaur teeth. The osteoscute is oval, with no overlap surface, and has a very reduced median ridge.

7. **Unidentified Theropod Dinosaur.** Partial tooth, missing tip, MPPM 1991.27.4, V. 7a - Lateral view, anterior at left, 7b - basal view.

8. **Unidentified Hadrosaur Dinosaur.** Upper cheek (posterior) tooth, MGS 1903, R. 8a - Labial view, 8b - occlusal view.

The two types of dinosaur teeth at Frankstown are designed very differently, for their different functions. The meat-eating (carnivorous) type (figure 7) is simple, flattened, recurved, and has a serrated posterior edge - like a steak knife. The plant-eating (herbivorous) type (figure 8) is part of a complex, flat-surfaced battery placed in the middle of each jaw, and is used to shred very tough plant material by grinding it between the upper and lower batteries. This process quickly wears out the teeth, so the batteries are designed to have a new set of teeth come up below the old one as soon as it wears out. Hadrosaurs, or duck-billed dinosaurs, may have eaten the bark, cones or needles of evergreen trees. They were the dominant herbivorous land animals of Frankstown time. The Frankstown theropod was probably similar to the much older meat-eating dinosaur *Allosaurus*.

Crocodiles and Dinosaurs — Plate 12