ROCKS AND FOSSILS FOUND IN MISSISSIPPI'S GRAVEL DEPOSITS

David T. Dockery III, James E. Starnes,
David E. Thompson, and Laura Beiser

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF POLLUTION CONTROL & OFFICE OF GEOLOGY
CIRCULAR 7

Michael B. E. Bograd
Office of Geology Director

Jackson, Mississippi
2008

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Front Cover: Rock and fossil collecting is not only an activity relegated to the geologists of the Office of Geology but is somewhat of a family affair for a number of employees at the Mississippi Department of Environmental Quality. The rock at top is one of several Lake Superior Agates collected by Robert Seyfarth of the Office of Pollution Control. Robert collected these agates around 1965 from the St. Catherine Gravel Company's gravel stockpiles on the banks of the Mississippi River at Natchez, Mississippi. The bottom two figures are different views of a fossil trilobite collected by Ryan Hardy, the son of Mike Hardy of the Office of Pollution Control. This trilobite was found in the family's driveway gravel at their home in Madison County, Mississippi.

Back Cover: This purple-banded rock with quartz veins is a boulder of Sioux Quartzite collected by James Starnes from Clear Creek in Warren County, Mississippi.

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INTRODUCTION

Gravels in Mississippi streams are stones ripped from bedrock from as far away as the Nashville Dome area in Tennessee and the Appalachian Mountains of Alabama. These stones generally range from Silurian (439 million years ago) to Mississippian (323 million years ago) in age. They were brought here by ancient rivers draining into the Gulf of Mexico. Gravels of these ancient rivers are now perched in the hills and hilltops of northeastern, western, and southern Mississippi. These deposits are mined by commercial gravel companies and are the source of our road, driveway, and parking lot gravel as well as the gravel used in concrete. They are also the source of gravel in Mississippi's present-day rivers and streams. Ancient gravel deposits are recycled by erosion and by redeposition in the gravel bars of modern rivers and their tributaries.

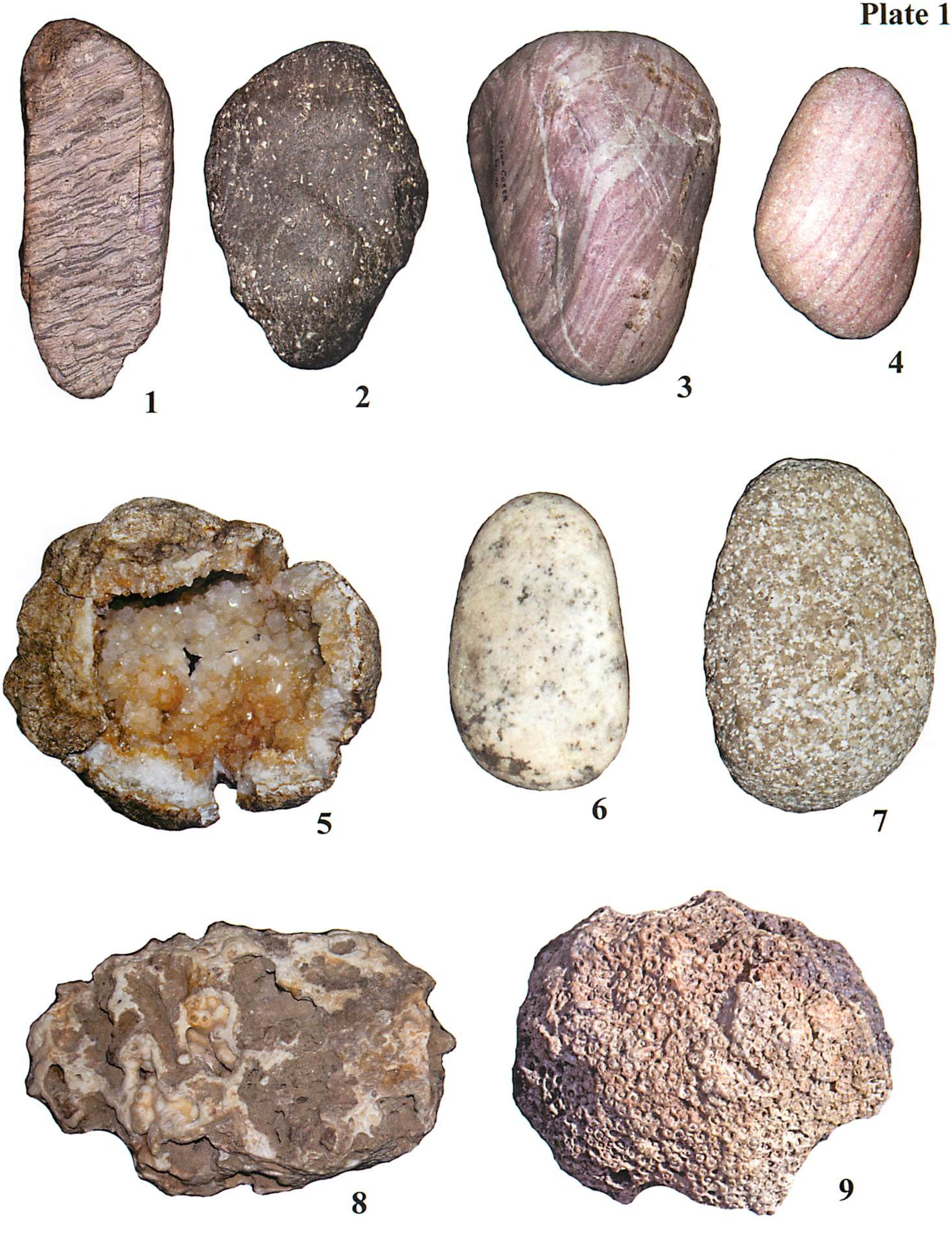
The oldest of the ancient rivers transporting gravel was in the Late Cretaceous Period, the time of the dinosaurs. Cretaceous gravels are found in the Tuscaloosa Formation (93.5 to 85.8 million years old). These gravels now form the hilltops in northeastern Mississippi. The Tuscaloosa terrain is dissected by modern streams and rivers, and its gravels are reworked in the Tombigbee River and its tributaries from Tishomingo County to Lowndes County. Pleistocene age (1.7 million to 10 thousand years ago) terrace deposits of the Tombigbee River contain several gravel mines. It is important to remember that while the ancient gravel deposit may be that of a half-million-year-old Pleistocene-age river, the individual stones in that deposit are some 400-300 million years old.

After the Cretaceous Period, the next major episode of ancient rivers carrying gravel was in the Pliocene Epoch (5.5-1.7 million years ago). Streams loaded with gravel and sand covered the southern half of Mississippi and deposited the Citronelle Formation. This formation now comprises the highest elevations between Interstate 20 and the coast. One flat-topped terrace surface on the Citronelle Formation at the Magee airport in Simpson County is at an elevation of 550 feet above sea level. Citronelle gravels are heavily mined in the Crystal Springs area in Copiah County, where the base of the Citronelle Formation is at 390-400 feet above sea level. The highest point in southern Mississippi is a 570-foot rise on a salt dome at Ruth near Brookhaven in Lincoln County and is capped by Citronelle gravels. Eroded Citronelle gravels are also the source of the prolific gravel bars in southern Mississippi streams.

Pleistocene gravels of the ancient Tennessee River now occupy certain hilltops in northern Tishomingo County, where they can be found at elevations higher than 600 feet above sea level. In contrast, the pool level of the Tennessee River impounded at Pickwick Lake is about 420 feet above sea level. These gravels are iron-stained and well rounded and contain quartzite pebbles as well as chert and quartz gravel.

Plate 1: Large Rocks. Plate 1 contains photographs of cobble- to boulder-sized rocks found in the pre-loess terrace gravels, a formation that underlies the loess in the Bluff Hills on the eastern side of the Mississippi River Alluvial Plain in Mississippi. All of these rocks were transported to Mississippi by the ancient Mississippi from other states, possibly as rocks embedded in floating ice. Specimen **#1** is a welded tuff that was transported by the ancient Mississippi River from the St. Francis Mountains of Missouri. This is an igneous rock from a volcanic eruption. Like other igneous rocks from the St. Francis Mountains, such as the Johnson Shut-ins rhyolite, this welded tuff is over a billion years old. Specimen **#2** is trachyte, a fine-grained igneous rock with feldspar phenocrysts. The origin of this rock is the St. Francis Mountains of Missouri. Specimens **#3** and **#4** are cobbles of Sioux Quartzite. This purple quartzite is 1.7 billion years old and came from southwestern Minnesota. Glaciers carried many boulders of Sioux Quartzite into Kansas; then the rocks were transported down the Missouri and Mississippi rivers to Mississippi. Specimen **#5** is a quartz-crystal lined geode from the Keokuk area of Iowa. Such geodes are known as Keokuk geodes. Specimen **#6** is a white sandstone from Paleozoic bedrock of unknown origin. Specimen **#7** is arkose, a sandstone consisting of both quartz and feldspar sand grains. This arkose contains quartz overgrowths and is typical of Cambrian and Ordovician arkosic strata of the North American Midcontinent. Specimen **#8** is Missouri Lace agate, also known as Potosi druse. It came from the Upper Cambrian Potosi Dolomite in the Missouri Ozarks. Specimen **#9** is a large coral head (more that a foot in diameter) of the genus *Lithostrotionella*, which is common in Mississippian-age rocks to the north of the state.

Plate 1

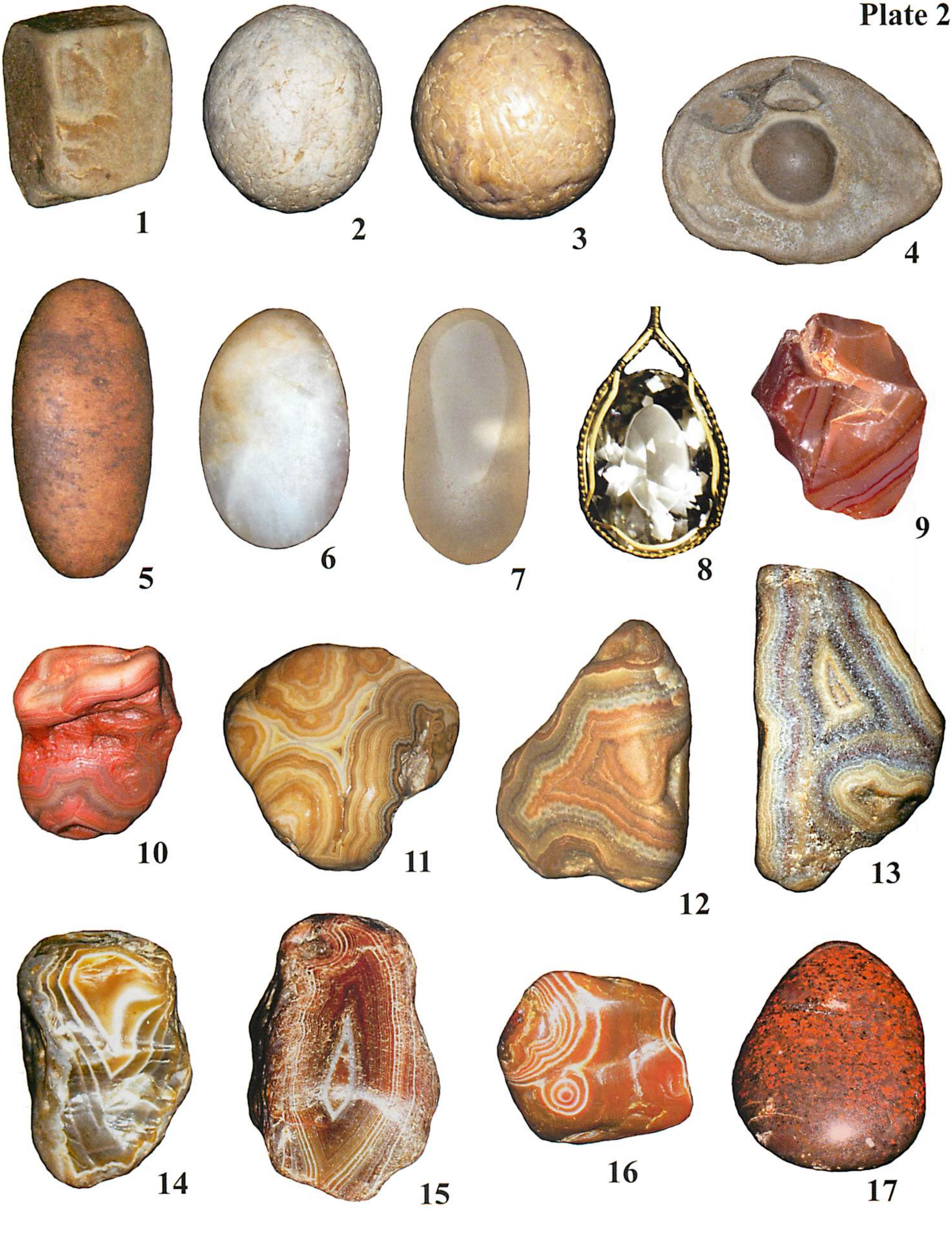


In the Late Pleistocene (600,000 to 10,000 years ago), the ancient Ohio River flowed through northwest Mississippi where it joined the Mississippi River south of Crowleys Ridge in southern Arkansas. Braided river deposits of the Ohio and Mississippi rivers deposited the pre-loess terrace deposits, which occur beneath a layer of loess in the Bluff Hills just east of the Mississippi River Alluvial Plain. Loess is windblown dust that blew off the Mississippi River Alluvial Plain in dry weather during the last Ice Age and settled down across the Bluff Hills. The loess is over 100 feet thick on some hills at Vicksburg, Mississippi. Pre-loess gravel deposits contain large boulders that came down the Ohio and Mississippi rivers in floating blocks of ice, a process known as ice-rafting. Boulders of the characteristically purple Sioux Quartzite came from bedrock in southwestern Minnesota.

Figure 1. Crane operator lowers a 65-foot-long, walnut-like, petrified log, excavated from a sand and gravel pit near Ovett in Jones County, onto a flatbed trailer for transport to the University of Southern Mississippi. *Picture was taken by Dr. Sam Rosso in September of 1987*

Plate 2: Rock Shapes, Rock Types and Semi-precious Stones. The shapes of pebbles in stream gravel depends in part on the original shape of the pebble when dislodged from the bedrock and in part on the amount of rounding it has received while traveling downstream in the bedload of sand and gravel. Stream-rounded pebbles have four general shapes: spheroids, disks, blades, and rollers. Specimen **#1** is a chert pebble without significant stream rounding. It has a cubic shape with square corners, much like a fresh fragment from jointed chert bedrock that has traveled only a short distance downstream. Specimens **#2** and **#3** are chert pebbles that are so rounded that they are spherical. These pebbles are in a shape class known as spheroids. Specimen **#4** is a flat disk that is somewhat circular in shape, a shape class that is simply known as disks. This particular disk has a raised center, which looks like the yoke of a fried egg. Rocks that look like other objects are called mimetoliths. Additional examples of mimetoliths are the brachiopod shells in ***Plate 10, Specimen 4,*** which looks like the initials AE, and the internal mold of a brachiopod in ***Plate 10, Specimen 6,*** which looks like the head of a screw. Specimens **#5** and **#6** are respectively quartzite and milky quartz pebbles that are flat and have an elongate elliptical outline. This shape is known as a blade. Specimen **#7** is a clear quartz crystal. It was once a hexagonal crystal prism but was rounded in the river to form a cylindrical shape with rounded ends known as a roller. Specimen **#8** is a 36.8 carat, faceted, gem-quality, quartz crystal that was cut from a quartz roller like that of specimen #7. Specimen **#9** is a red variety of chalcedony known as carnelian, a precious stone to the ancient Egyptians. Specimens **#10-#13** are common agate types found in Mississippi gravel deposits and in stream gravel. Agates are distinguished from banded chert by a type of very fine banding known as iris banding. Specimens **#14-#16** are Lake Superior agates found by Robert Seyfarth at a gravel mine on the Mississippi River at Natchez, Mississippi. These agates were ripped from billion-year-old lava flows in the bed of Lake Superior by glaciers and traveled down the Mississippi River to Natchez. They are characterized by brilliant white and often bright-red bands. Specimen **#17** is bloodstone that was polished in a rock tumbler. Bloodstone is a jasper with red specks on a green or black background.

Plate 2



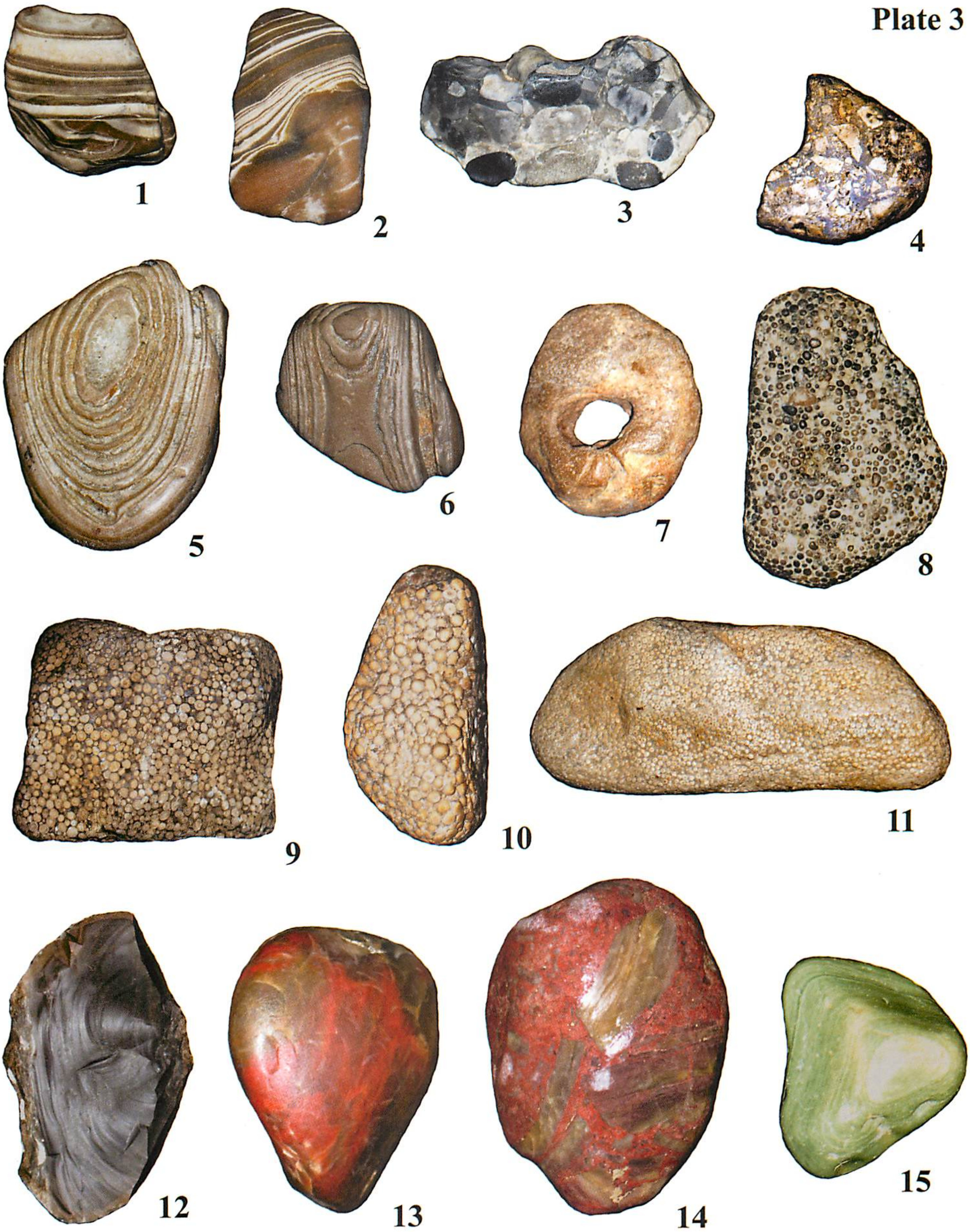
PETRIFIED WOOD

Petrified wood is the official state stone of Mississippi and is commonly found in gravel deposits, ranging in size from pebbles to large logs. When found as pebbles, petrified wood can easily be identified by the wood grain. In the process in which the wood was replaced by silica and turned to stone, the structure of the original woody tissue is often perfectly preserved. A 65-foot-long, walnut-like-hardwood, petrified log was excavated from a gravel pit near Ovett in Jones County and moved to the campus of the *University of Southern Mississippi*, where it can be seen today next to the Danforth Chapel. Fossil palm is also present in the gravels of southern Mississippi and extending as far north as Yazoo County. Fossil palm "wood" is not true petrified wood, as a palm trunk has tissue more like that of a corn stalk than a tree. Fossil palm differs from petrified wood in having large widely spaced veins called fibrovascular bundles. Like petrified wood, it is found in sizes from pebbles to logs and sometimes as rounded stumps.

Figure 2. Highwall exposed at the Hammett Gravel Company Zieglerville pit in Yazoo County. The upper half of the highwall consists of a 25-foot-thick section of loess. A brown ancient soil (paleosol) can be seen at the loess-gravel contact. The lower 25 feet of the highwall contains pre-loess gravel. The water table can be seen in the bottom of the pit, below which is more gravel. *Picture was taken on November 9, 2007.*

Plate 3 : Rock Types and Semi-Precious Stones. Specimens **#1** and **#2** are banded chert. This chert lacks the iris banding that defines an agate. Specimen **#3** is conglomerate with rounded pea-sized pebbles. Specimen **#4** is breccia. Breccia is different from conglomerate in that it contains angular rather than rounded pebbles. Specimens **#5** and **#6** are concentrically layered concretions, the latter specimen containing two concretionary centers with a saddle layer in between the centers. Such concretions form as silica nodules in limestone bedrock. Specimen **#7** is a chert pebble with a natural hole. Rocks with holes are not uncommon in stream and driveway gravel. Holes form when a soft place in the rock is scoured away by stream action, or the hole may be the empty external mold of a fossil. Specimens **#8-#11** are oolitic chert, a silicic replacement of what was once oolitic limestone. The ooids that make up the oolite are small, spherical, pearl-like grains that form naturally in the shallow water of tropical seas associated with coral reefs. Specimen **#12** is a flake from a flint nodule. Flint is a black variety of chert with a good conchoidal fracture. Native Americans knapped (chipped) it for projectile points and struck two flints together for sparks to start fires. Specimens **#13-#15** are jasper, a red or sometimes green variety of chert. Specimen **#14** is a jasper breccia.

Plate 3



USE OF GRAVEL AS AN EDUCATIONAL RESOURCE

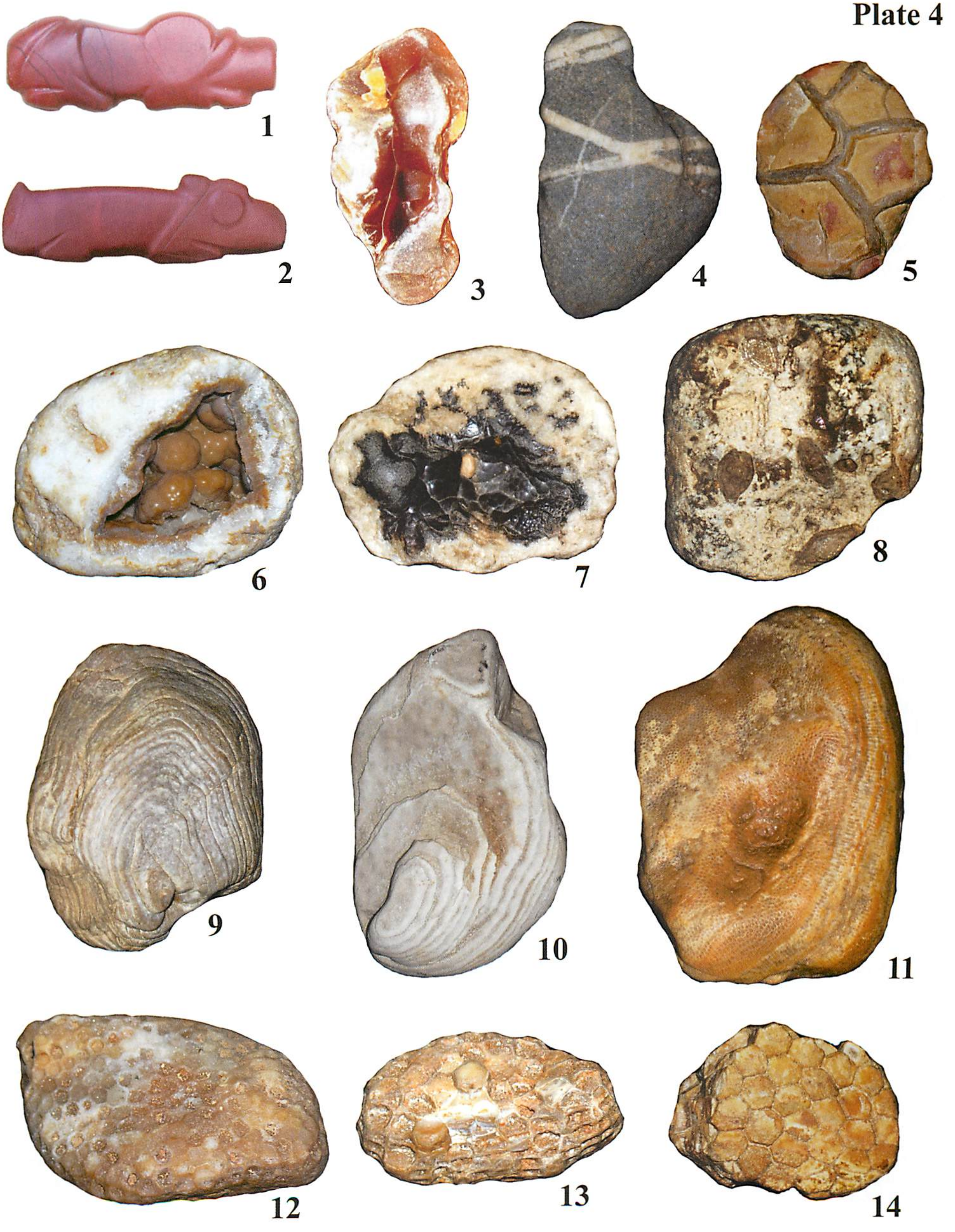
Children are naturally curious and are fascinated with natural objects such as rocks, shells, bugs, reptiles, and such. Rock collecting can tap into this curiosity to teach elements of geology and of the natural sciences as a whole. A convenient collecting concept devised by John Davis, formally a science teacher at St. Andrew's Middle School in Ridgeland, Mississippi, is the egg-carton collection of 12 correctly-labeled rocks and fossils. To assist with the identification of rocks and fossils, two articles were printed respectively in the June 1995 and December 1996 issue of *Mississippi Geology*, entitled "Rocks and fossils collected from Mississippi gravel" and "More rocks and fossils from Mississippi gravel." The first article is in its third reprinting and the second article is in its second reprinting; both articles contain black and white illustrations. These publications have been given out as resource materials in numerous teacher workshops and are widely circulated. The present publication in color serves as a new field guide for the identification of rocks and fossils, replacing the older black and white versions.

Children generally have good eyesight and are closer to the ground, allowing them to better see items of interest in pebble-size rocks. If their eyes are properly trained through the study of guide-book illustrations, they can find important items, which taller and more poorly sighted adults may pass over. A class field trip need be no farther from school than the nearest gravel driveway or parking lot.

Figure 3. Gravel washing operation located at the Zieglerville pit in Yazoo County. Gravel is transported to this site by a conveyer belt from the active mine, which is more than a mile away. *Picture was taken on November 9, 2007*

Plate 4 : Rock Types and Fossil Foraminifera, Stromatoporids and Corals. Specimens **#1** and **#2** are effigy beads made of jasper by native Americans and found in Mississippi. Each has a tiny hand-drilled hole through the center. Specimen **#3** is translucent carnelian. Specimen **#4** is a black chert with veins of milky quartz. Specimen **#5** is the center of a septarian concretion. A septarian concretion has a desiccation-cracked center in which the cracks were subsequently filled with minerals such as calcite or quartz. Specimen **#6** is a geode lined with chalcedony. Specimen **#7** is a geode lined with hematite. Specimen **#8** is a chert pebble with fusulinid Foraminifera. The fusulinids are the dark-brown flying-saucer-shaped objects, the uppermost of which shows the internal structure. These fusulinids are probably of Mississippian age. Specimens **#9** and **#10** are stromatoporids of Devonian age. Stromatoporids were reef-forming sponge-like organisms that were common in the Early and Middle Devonian Period but became extinct before the Late Devonian. Specimens **#11-#14** are tabulate corals like that of the genus *Favosites*. These are extinct colonial corals with polygonal tube-like shells, called coralites, that fit together in a wasp-nest or honeycomb pattern. The name tabulate comes from the shell platforms, or tabulae, that formed multiple floors subdividing the polygonal tubes as the corals grew. These can be seen on the following plate.

Plate 4



The following letter received from Barbara Waldrop, a teacher at Winston Academy, best shows the enthusiasm a teacher can unleash when teaching about rocks and fossils.

Dear Dr. Dockery:

I attended the fall science workshop at St. Andrew's where you conducted the geology session. I wanted to let you know just how much I have been able to use your information. In the fall I showed fifth and sixth grade science students the copy of the June 1995 issue of *Mississippi Geology* which contains pictures of rocks and fossils collected from Mississippi gravel. I had several students show great interest in collecting the rocks. They have been bringing me rocks to classify all year. This is actually my first hands on experience with geology. In fact I thought of it as boring. Was I wrong or what? I must admit, I am as hooked as the students are! They also have shown great interest in the areas of Mississippi that contain fossilized remains of prehistoric animals. Sharks and dinosaurs are by far the most popular.

Now comes the clincher. I teach a third grade science class. I felt that the above mentioned material was too advanced. We started a chapter in our books on rocks. The concepts were rather simple and were based on how rocks were weathered. I never anticipated the "complications" this chapter was about to cause. The students started bringing me rocks by the hundreds to classify. Their main teacher met me one day with her eyes wild and hair standing on end. She asked me (not so calmly) if I were, by any chance, teaching rocks. It seems that her room was as covered with rocks as mine. Have you ever heard 32 desk tops being *pummeled* with rocks while you are trying to teach spelling? Apparently the students had begun to trade, barter, sell, and buy the rocks also. Since we have a rule that no one may sell to students in the classroom, she had to spend a great deal of teaching time just returning money and rocks to the original owners. This was no easy task, since some products had changed hands several times. Actually the beginning entrepreneurs were quite innovative. Four dollars is a good profit on a product that cost you nothing. So that phase of rock collecting by necessity had to come to an end.

I had a better plan. All rocks had to be taken home. I shared the 1995 issue of *Mississippi Geology* with them and took them to a gravel pile. We looked for fossils together. After I was sure they knew what they were looking for, I gave the assignment. They were to bring only three types of rocks, each type in its own ziplock bag labeled with the student's name and type of rock. They were to bring: (1) 10 rocks weathered by water, (2) 10 rocks weathered by ice, and (3) five fossils. Their sharp little eyes were rivaled only by their interest in the project. I got a great response. The next phase will include letting the students classify their rocks by comparing them with the pictures in the June 1995 issue of *Mississippi Geology.*

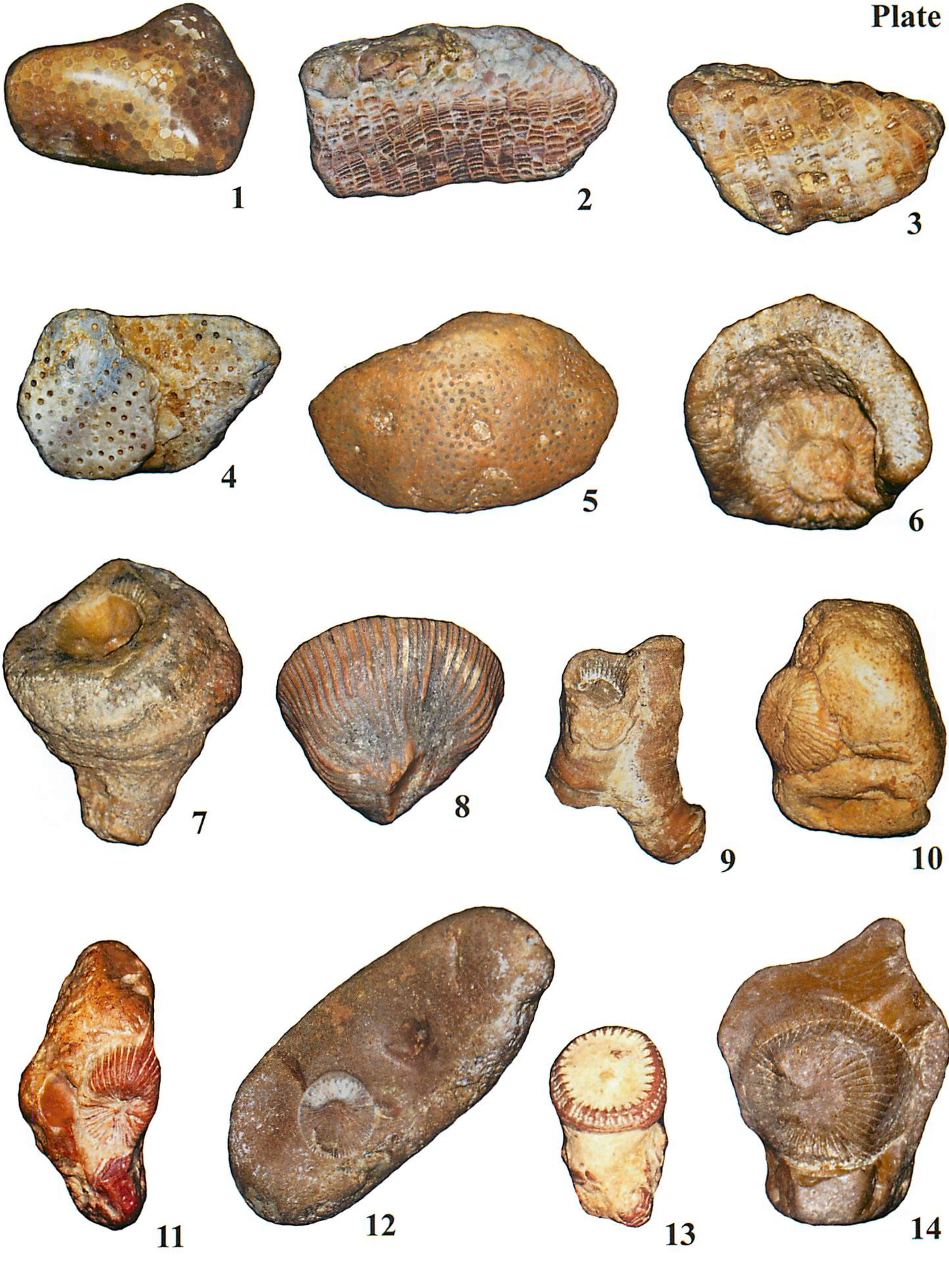
I have included photos of some of the more interesting "finds." I hope you will find the time to let me know how right or wrong I am on my classifications.

Thank you so much for your time.

Sincerely, Barbara Waldrop

Plate 5 : Fossil Tabulate and Solitary Rugose Corals. Specimens **#1-#3** are *Favosites*-like tabulate corals. The first specimen was polished in a rock tumbler. The next two specimens show the tabulae that subdivide the tubes on individual corals of the colony. Specimens **#4** and **#5** are tabulate corals of the Silurian-age genus *Heliolites*. The individual coral tubes, or corallites, in *Heliolites* are broadly spaced. Specimens **#6-#14** are solitary rugose corals. These corals have conical shells that are radially partitioned by septae. The name rugose comes from the irregular bulging growth increments, or rugae, of the coral's exterior shell. The top of the coral shell where the animal resided is called the calyx. Specimen **#6** was photographed looking down into the calycal pit. The calycal pit is at the top of specimen **#7**, which shows the growth rugae of the coral's exterior. In specimen **#8**, the exterior shell is eroded away, showing the septae of the coral's interior. Specimen **#9** consists of two corals that grew together. Specimens **#10**, **#11**, and **#14** show rugose corals with an eroded exterior shell protruding from chert and jasper pebbles. Specimen **#12** is the cross section of a rugose coral in a chert pebble, showing the radial arrangement of the septa. This fossil also shows another geologic phenomenon. When the coral was buried on the sea floor, the bottom of the coral filled with sediment similar to the exterior matrix, while the unfilled void at the top slowly filled with mineral crystals. So the white mineral-filled section tells which side was up in the original bedrock. Such features are called geopetal structures. Specimen **#13** shows the sediment-filled calyx at the top with the septal margins visible.

Plate 5



ROCKS AND FOSSILS AND REAL SCIENCE

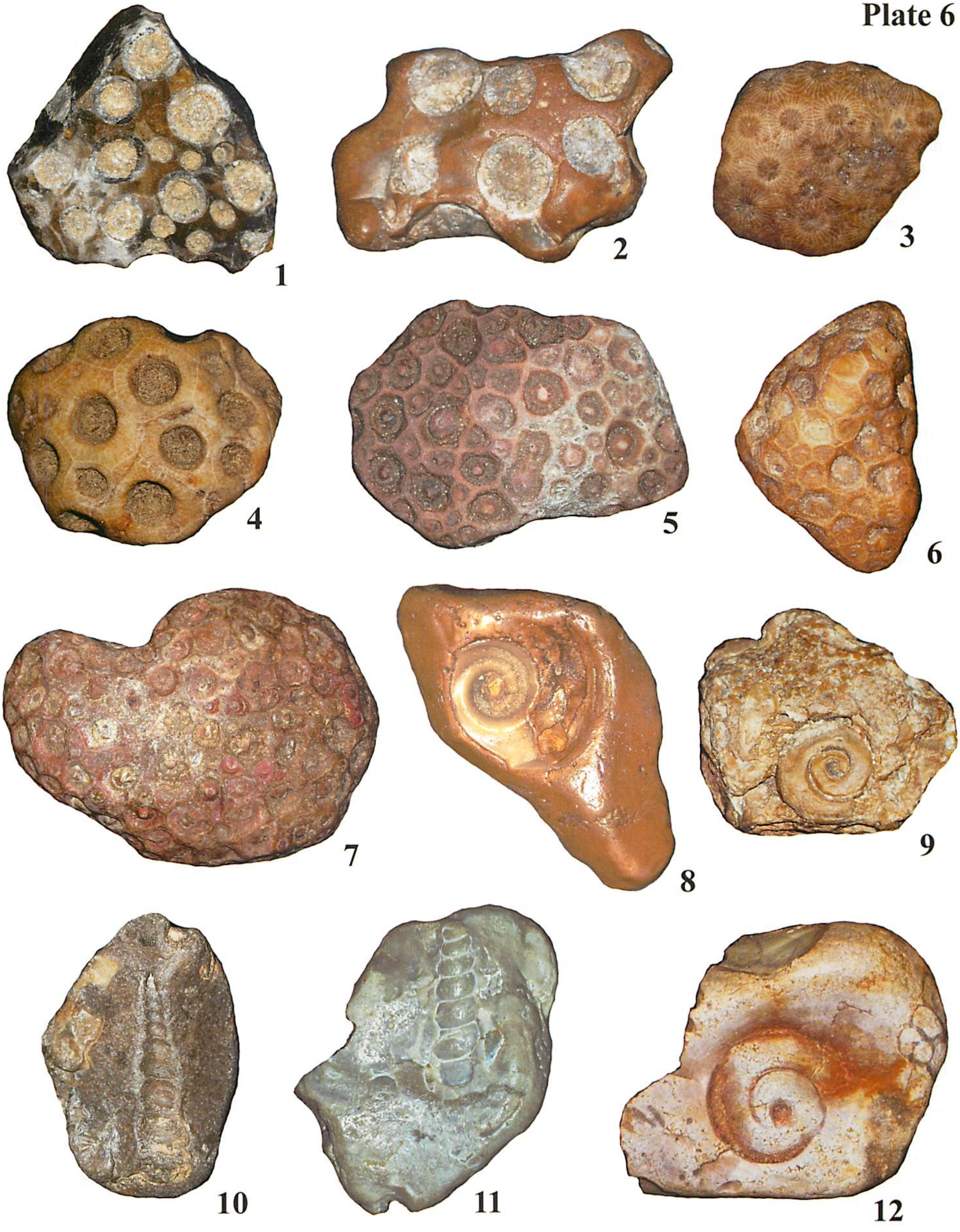
Students often make discoveries of rocks and fossils that are important to ongoing scientific research. Rocks and fossils found in Mississippi gravel deposits are clues to the source rocks from which these items came and to the course of the ancient river systems that brought them to Mississippi. Most fossils found in gravel, as illustrated in the accompanying plates, came from bedrock of Silurian, Devonian, and Mississippian age. Silurian fossils include the tabulate coral *Heliolites*. Devonian fossils include the larger trilobites, the colonial rugose coral *Hexagonaria*, and extinct reef-forming sponges known as stromatoporids. Mississippian fossils contain the smaller trilobites known as proetid trilobites, productid brachiopods, the bryozoan *Archimedes*, those blastoids with very long and well-developed structures called ambrulacra, the colonial rugose coral *Lithostrotionella*, and Foraminifera known as fusulinids. One source for these fossils and the honey-brown chert associated with them is the Nashville Dome in central Tennessee, which has had renewed uplift within the last two million years.

Among fossil blastoids, the calyxes of some are spheroidal or barrel-shaped, while others vary from pentagonal to stellate in shape as viewed from the base. Stellate forms generally have a pentagonal symmetry as is common among other echinoderms. Some rare stellate blastoids found in Mississippi gravel have an hexagonal symmetry and are preserved in rock as a six-rayed star.

Figure 4. Sand draining from gravel wash operation forms a delta at the head of a containment lake. The conveyer belt that transports the gravel to the gravel wash is at the lower right. *Picture was taken on November 9, 2007.*

Plate 6 : Fossil Solitary and Colonial Rugose Corals and Gastropods. Specimens **#1** and **#2** show the cross sections of several solitary rugose corals growing close together. Specimen **#3** is the Devonian-age colonial rugose coral *Hexagonaria*. Surf-rounded specimens of *Hexagonaria* wash up on the shores of Lake Michigan near Petosky, where they are called Petosky stones. Specimens **#4-#7** are the Mississippian-age colonial rugose coral *Lithostrotionella*. Specimens **#8-#12** are gastropods, commonly known as snails. Specimens **#8**, **#9**, and **#12** have low or even flat spires, while specimens **#10-#11** have high spires. Specimen **#11** is unusual in that it has a sinistral coil that turns to the left. Most gastropods have right-handed or dextral coils. Specimen **#8** is special because it was found by my dissertation advisor at Tulane University, Dr. Emily Vokes, when Dr. Vokes was a young girl living in Osyka, Mississippi. She found this fossil especially interesting because part of the mineralized shell was preserved inside the exterior mold at the shell's apex. Later during a long career of teaching and as Department Head of the Tulane Geology Department, Dr. Vokes published many papers on fossil gastropods. Perhaps this small fossil started that distinguished career.

Plate 6



Pebbles of milky quartz and rose quartz, collectively known as vein quartz, and some quartzite pebbles have a Piedmont source, a terrain of metamorphic and igneous rocks stretching from Alabama northeastward to Maine. Most of the state's gravel deposits contain a mix predominantly of honey-brown chert with lesser amounts of milky quartz. The proportion of milky quartz increases in southeastern Mississippi toward the Alabama line.

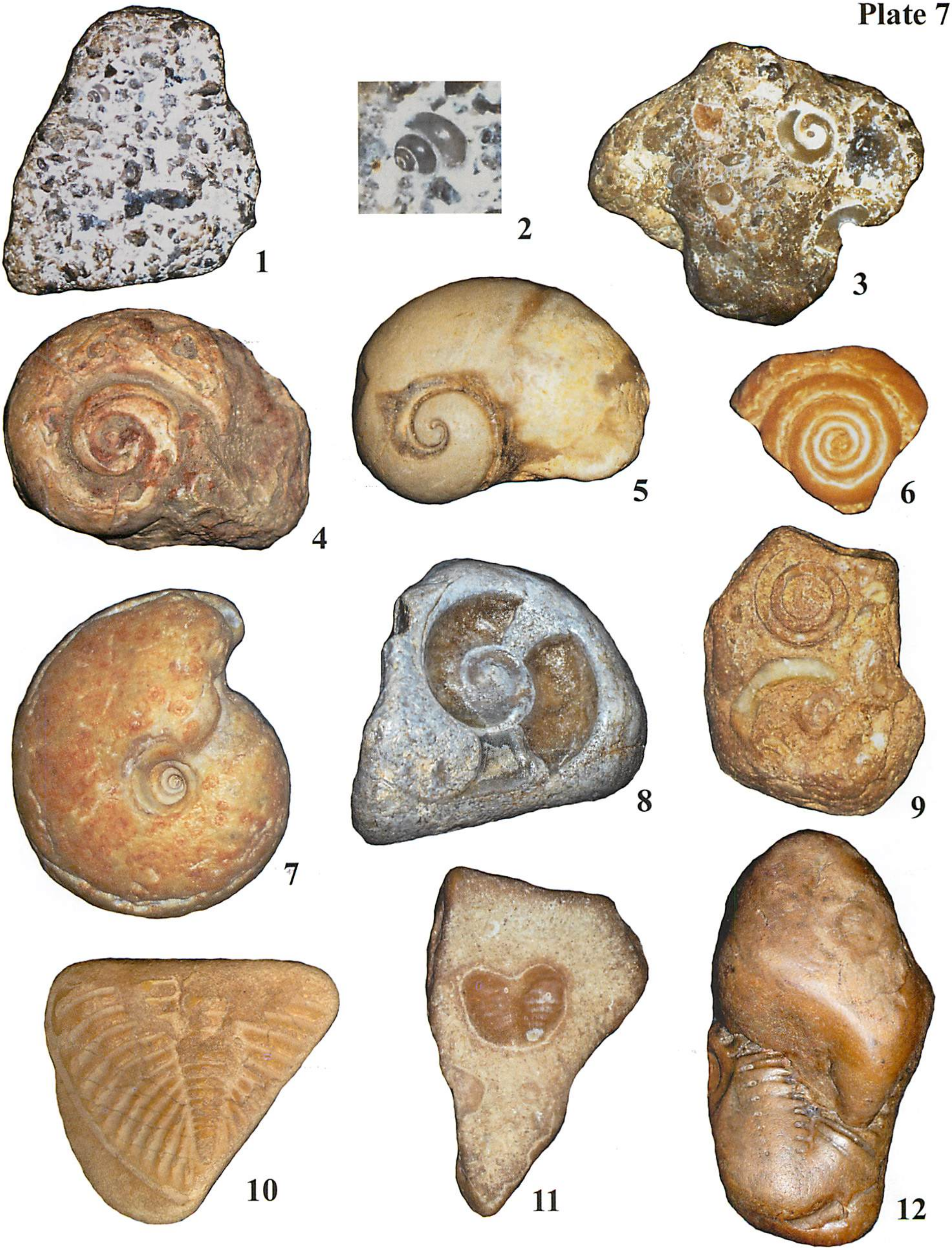
Gravels of Mississippi's pre-loess terrace deposits contain cobbles and boulders that were ice rafted down the ancestral Mississippi River from as far away as Minnesota. Before the spread of glacial ice in the Pleistocene Epoch, the Missouri River flowed north to Hudson Bay in Canada. Ice sheets blocked this northward flow about 600,000 years ago, backing the river up until it cut a divide and joined the present Mississippi River drainage system. Also at this time glaciers scoured Precambrian bedrock outcrops of the 1.7-billion-year-old, purple Sioux Quartzite in southwestern Minnesota and carried quartzite boulders into Kansas, where they were deposited in glacial till as the ice melted. Many of the Sioux Quartzite boulders were carried in ice flows down the ancient Missouri and Mississippi rivers and deposited on gravel bars extending from western Tennessee and western Mississippi to the boot of Louisiana. Today these boulders are present in the pre-loess gravel deposits and in the westward-flowing streams that cut through these deposits. Thus the age of the pre-loess gravel must be 600,000 years old or somewhat younger.

Other rock types record the drainage history of the ancient Mississippi River. Cobbles of the brecciated, 1.7-billion-year-old Baraboo Quartzite came from Precambrian bedrock in the Baraboo Range of Wisconsin. Cobbles of 1.5-billion-year-old Precambrian igneous rocks, including Johnson Shut-ins rhyolite, welded tuff, and trachyte, came from the St. Francis Mountains of Missouri. Cobbles of 570- to 440-million-year-old feldspathic sandstone came from Cambrian and Ordovician bedrock in the mid-continent region of North America. Missouri Lace Agate, also called Potosi Druse, came from the 517- to 510-million-year-old Cambrian Potosi Dolomite in the Missouri Ozarks. Keokuk geodes, hollow rocks lined with quartz crystals, were derived from the Mississippian-age bedrock of the Warsaw Formation in Keokuk, Iowa. Large pebbles of quartz crystal may have come from 280- to 245-million-year-old Paleozoic bedrock in the Ouachita Mountains of Arkansas. Lake Superior agates found in the Natchez Formation of Natchez, Mississippi, came from 1-billion-year-old Precambrian lava flows now beneath Lake Superior.

Present-day gravel bars on the Mississippi contain predominantly chert gravel but also contain up to 10% igneous rocks derived from glacially scoured Precambrian bedrock in Canada. Such gravels are mined from the Mississippi River at Rosedale in Bolivar County, Mississippi, and used for county roads.

Plate 7: Fossil Gastropods, Goniatites and Trilobites. Specimens **#1-#3** are small gastropods in chert pebbles. Specimens **#1** and **#2** are the same with **#2** being an enlargement of the small fossil in the upper left side of **#1**. This fossil as well as specimens **#3-#6** are the internal molds, or the hardened sediment that filled the shell, of low spired gastropods. Such internal molds are called steinkerns. Specimens **#7-#9** are the coiled shells of a group of ammonites called goniatites. Ammonites are an extinct group of cephalopods, a class of mollusks that contain the modern *Nautilus*, octopus, and squid. Like the *Nautilus*, goniatites had an external coiled shell, which contained internal chambers. The animal lived in the last chamber, called the body chamber. The chamber walls are called septa. Specimen **#7** is the internal mold of a goniatite shell, while specimens **#8** and **#9** show a cross section of the shell. Specimens **#10-#12** are the tail sections, called pygidia, of trilobites, with **#12** containing part of the tail and thorax. Specimens **#10** and **#12** are large trilobites of probable Devonian age.

Plate 7



ECONOMIC VALUE OF MISSISSIPPI'S GRAVEL RESOURCES

Sand and gravel are important for economic and industrial growth and rank first in sales among Mississippi's eight industrial mineral commodities. In 2005, according to U. S. Geological Survey statistics, Mississippi produced 14.4 million metric tons of sand and gravel valued at 85.2 million dollars. As of February of 2008, there were 305 sand and gravel operators in the state operating from 769 permitted pits located in 80 of the state's 82 counties and involving a total of 31,947 acres of disturbed land.

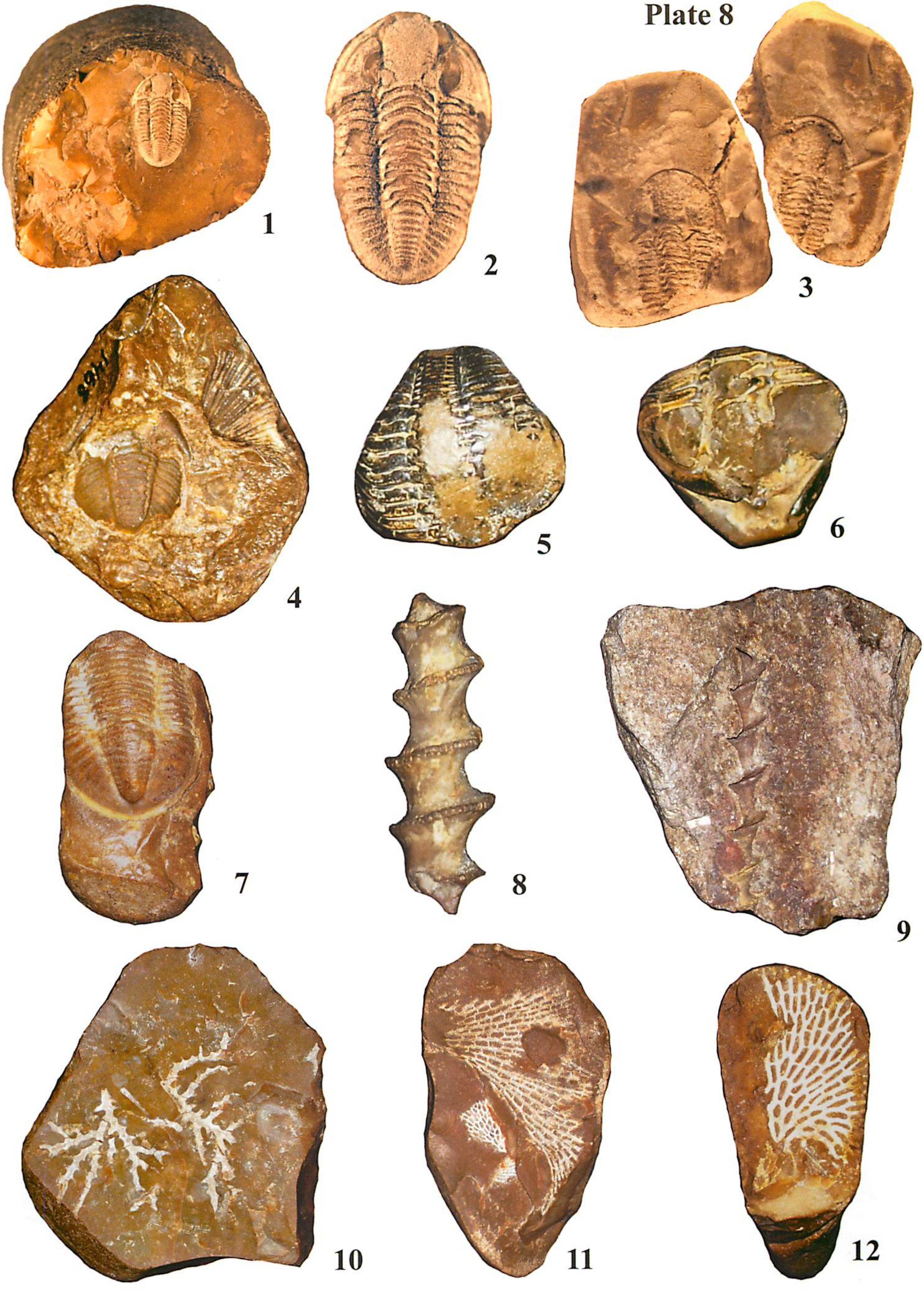
Gravel deposits have a high place value. Unlike gold and silver which can be economically shipped worldwide from the mine site, gravel is sold by the cubic yard, and much of the purchase price pays for the transportation cost. So, gravel deposits are more valuable if they are close to metropolitan centers where the demand for gravel is high. Gravel sold in the Jackson Metropolitan Area generally comes from mines in pre-loess terrace deposits in Yazoo County or from mines in the Citronelle Formation near Crystal Springs in Copiah County.

According to estimates of the U.S. Geological Survey, consumption of aggregate in the United States exceeds ten tons for each person per year. It is projected that we will use as much gravel in the next 25 years as we did in the last 100 years. This increased demand for gravel comes at a time of diminishing resources as gravel deposits are mined out and as urban sprawl prompts city and county officials to zone potentially commercial gravel deposits for residential, business and industrial use.

Figure 5 . Stockpiles of sand dredged from the containment lake at the Zieglerville gravel wash operation. *Picture was taken on November 9, 2007.*

Plate 8 : Fossil Trilobites and Bryozoa. Specimens **#1-#7** are small proetid trilobites of Mississippian age. Specimen **#2** is an enlargement of **#1**, which is a fossil preserved on the fracture plane of a chert pebble found in driveway gravel in Madison County. Specimen **#3** is the positive and negative print of a trilobite in a broken chert pebble, and **#5** and **#6** are the front and back of an enrolled trilobite. Specimens **#8-#12** are cryptostome bryozoans, an extinct group of Paleozoic byrozoans. Bryozoans are colonial animals that produce delicate moss-like fronds or that may be thick and coral-like. The fronds in the Mississippian bryozoan *Archimedes* revolves around a screw-like central axis as is show in **#8** and **#9**. Fossil cryptostome bryozoans are common along the fracture planes of broken chert pebbles as is shown in specimens **#10-#12**.

Plate 8



PROTECTING THE ENVIRONMENT AROUND MINE SITES

A well-operated gravel mine is one that is both economical and environmentally friendly. A poorly operated or poorly sited gravel mine may impact the environment in several ways. These impacts include hydrologic modification, erosion and sedimentation, water quality deterioration, fish and wildlife disturbances, and public nuisances. Hydrologic modifications occur when gravel is mined from gravel bars in streams or rivers or when gravel is mined in the flood plain adjacent to a stream or river. Removal of gravel from a river affects aquatic life and increases erosion upstream and siltation downstream. For these reasons, permits are not issued for in-stream mining of gravel. Even in permitted gravel mines not adjacent to streams, topsoil and exposed bedrock are removed as a result of rainfall and erosion. Sediment from mined areas can clog streams unless measures are taken to prevent sediment runoff from the site. Fish and wildlife are adversely affected when runoff from gravel operations disturb wetlands and streams. Dust, noise, and truck traffic are often sited as public nuisances.

The Mississippi Department of Environmental Quality (MDEQ) is responsible for controlling sand and silt runoff from gravel operations that might potentially leave the mining site and enter the streams, rivers, and other water bodies of the state. This pollution runoff is referred to as Nonpoint Source Pollution or Storm Water Pollution. There are three aspects concerning mine operation erosion and sediment control: storm-water runoff, gravel wash operations, and water use from the local aquifer.

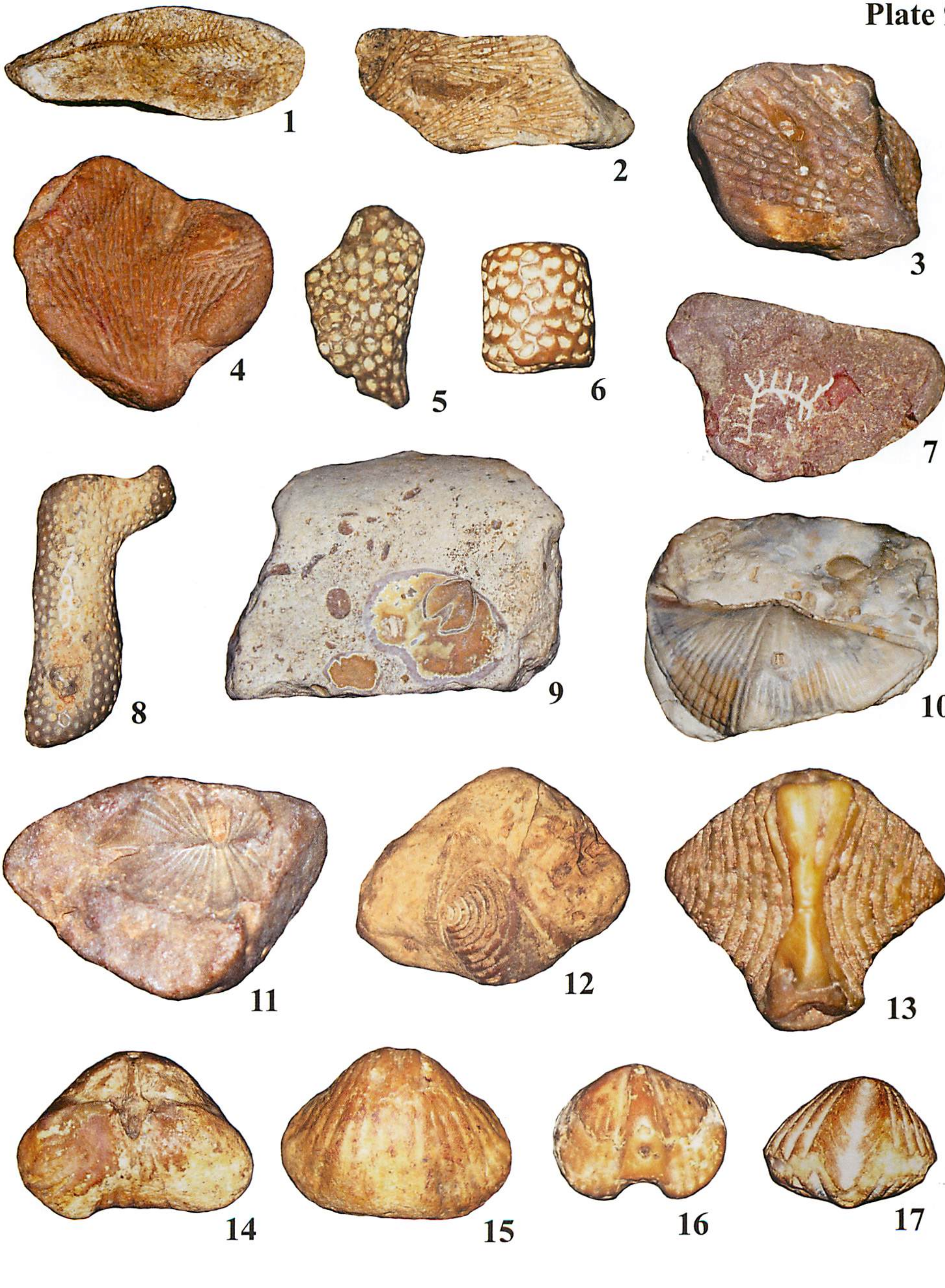
Storm-Water Runoff. Storm-water runoff consists of rainfall that hits the disturbed ground of the gravel mine. This disturbed ground, as well as associated stockpile areas of sand and gravel, are *highly susceptible* to erosion. To prevent erosion, mines must have a Stormwater Pollution Prevention Plan required by MDEQ for a general Stormwater permit. Water flowing from the mine site must be slowed down by the use of check dams (dirt berms), gentle slopes, silt fences, hay bales, rock culverts, and other methods. This water should eventually flow into sediment ponds where the sand, silt, and clay can settle out. Clean water from these ponds can be pumped into streams or rivers.

Gravel-Wash Operations. Gravel-wash operations separate gravel from finer sediments and sort the gravel by size in shakers containing sieves of different sizes. Gravel is sorted into pea-size, pebble-size, and over-sized. The pea-sized and pebble-sized gravel is used in concrete and for gravel driveways. The over-sized gravel is used in drainage systems for landfills or is crushed into angular fragments which are used as aggregate in asphalt for road surfaces. Fine sediments, consisting largely of sand, from the washing operation are drained into a pond or lake dredged for that purpose and do not leave the site. When the pond is full, the sand is dredged out and stockpiled for future use. Sand that is not sold can be used as fill material when the gravel pit is reclaimed.

Mine Dewatering. There are two methods for mining gravel layers that lie below the water table. One method is to dredge the gravel from the flooded pit floor using a pump and a suction pipe that delivers a slurry of gravel, sand, and water to the mine operation. The second method involves dewatering the mine site. This is accomplished by drilling water wells and pumping down the ground-water table until it is below the gravel deposit.

Plate 9 : Fossil Bryozoa and Brachiopods. Specimens **#1-#8** are fossil bryozoans of which **#1-#4** and **#7** are cryptostome bryozoans and **#5-#6**, and **#8** are trepostome bryozoans. Trepostome bryozoans have a thick coral-like and sometimes branching colonial structure, which for bryozoans is called a zoarium. Specimens **#9-#17** are brachiopod shells, with **#14** and **#15** giving different views of the same fossil.

Plate 9



MINE RECLAMATION

Once gravel is mined from a site the site must be reclaimed so that the land can be returned to a useful purpose. This involves sloping the pit's highwalls and planting the slopes with grass and/or trees to prevent erosion. Performance bonds must be posted on pits larger than four acres to insure that the site will be satisfactorily reclaimed. Mine reclamation is regulated by the MDEQ's Office of Geology.

Figure 6. Land reclaimed from the Adkins Pit, mined in the late 1960s and early 1970s by Memphis Stone and Gravel Company, now supports the homes and infrastructure of an upscale neighborhood. The position of what was once the gravel pit's highwall is marked by the tree line seen behind the houses. *Picture was taken by Bill Kelley on January 30, 2006.*

Plate 10 : Brachiopods, Blastoids and Crinoids. Specimens **#1** and **#2** are spirifer brachiopods. Specimen **#3** is a productid brachiopod. Specimens **#4-#6** are pentamerid brachiopods. Specimens **#7** and **#8** are blastoids with barrel-shaped calyxes. Specimens **#9-#11** are blastiods with stellate-shaped calyxes. As with other echinoderms, stellate-shaped blastoid calyxes generally have a fivefold symmetry. Specimens **#9** and **#10** have a rare sixfold symmetry, and Specimen **#11** has a sevenfold symmetry. Specimen **#12** is the attachment column of a crinoid.

Plate 10

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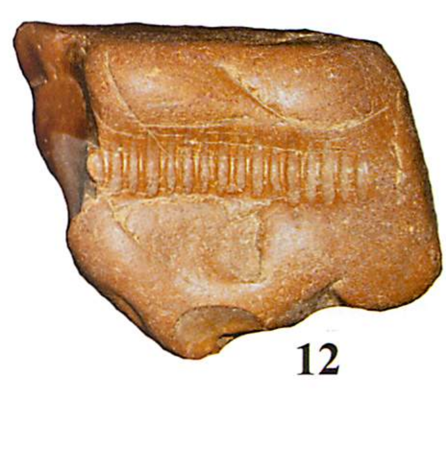

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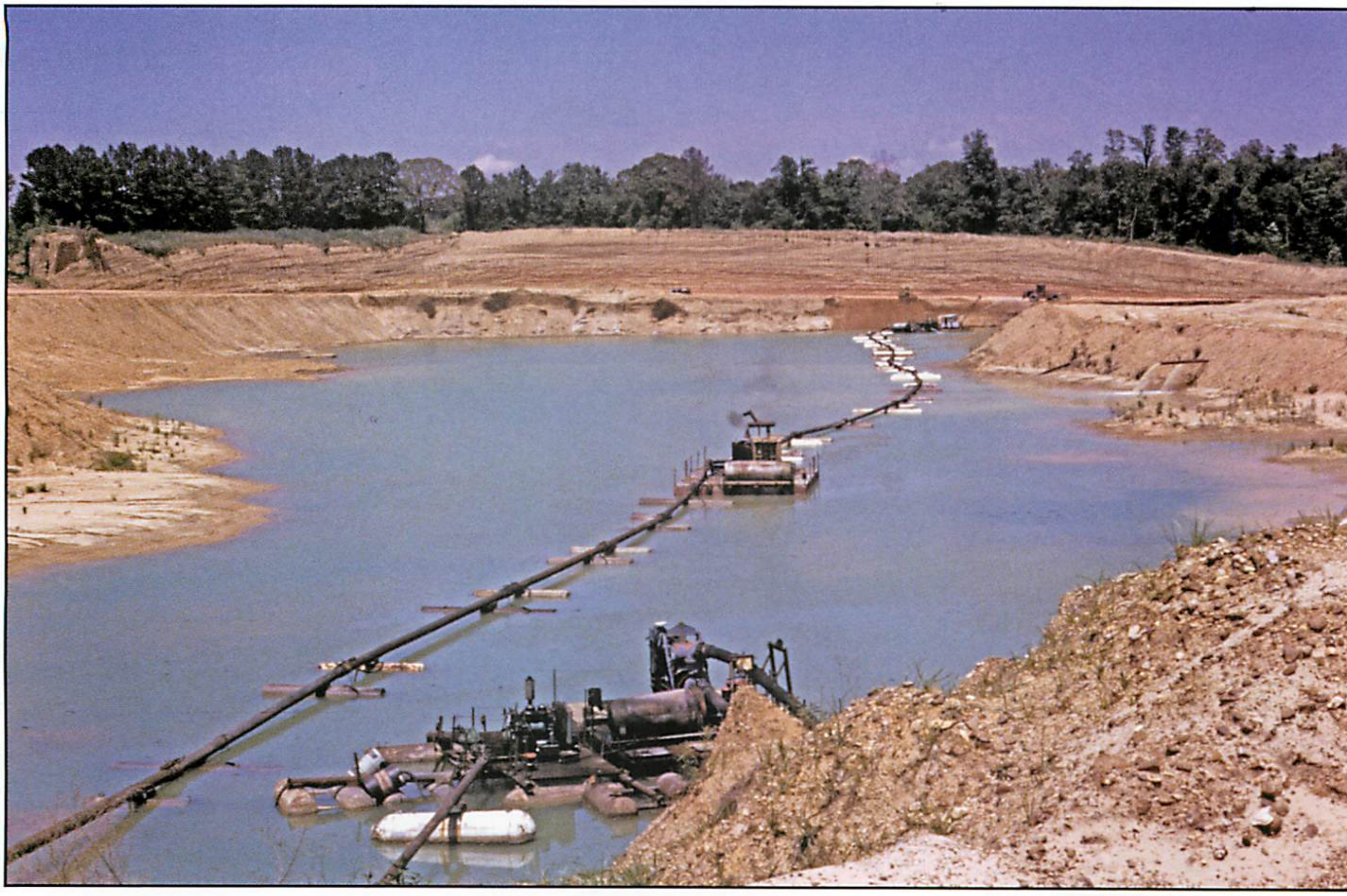

Figure 7. Gravel dredging in pre-loess gravels below the water table at the Hammett pit in Yazoo County. *Picture was taken on May 5, 2004.*

Plate 11 : Crinoid Columns. Crinoid columns, the long flexible stalk that attaches the head or calyx to the ocean floor, can be straight or coiled and be circular or elliptical in cross section. Crinoid columns in specimens **#1-#9** and **#12** are round in cross section. Crinoid columns **#10-#11** are elliptical in cross section and have a locking axial bar and groove. Round columns have radial locking ridges and grooves. Sometimes the column is preserved as in specimens **#2** and **#3**, but often only the external mold of the column is preserved as in specimens **#1**, **#7**, and **#10**. An opening extends through the middle of the column that is called the lunule. This opening is often round as in specimens **#1-#3** but may be stellate as in specimen **#4**. The lunule opening is seen in the half column show in specimen #8 and is infilled as an internal mold in specimen **#12**. Specimens **#13** and **#14** are chert pebbles comprised of crinoid stem fragments. These fragments were once crinoidal limestones.

Plate 11


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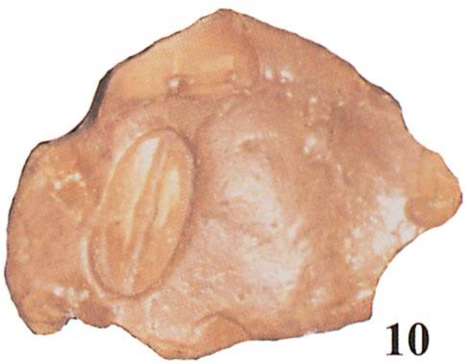
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Figure 8. Samantha Williams is looking at a white sandstone boulder in the pre-loess gravel deposits at the Gibb's gravel pit in western Hinds County, where the base of the gravel deposit is at 330 feet above sea level. The boulder probably floated down the ancient Mississippi River in a block of ice, a process called "ice rafting." *Picture was taken on January 18, 2003.*

Plate 12 : Crinoid Calyxes and Columns. Crinoid Calyxes and Columns. Specimens #1 and #2 show partial exterior molds of crinoid calyxes with knobby exterior plates. Specimen #3 shows the arms extending from the calyx toward the upper right and the attachment socket for the column at the lower left. Specimen #4 shows the five basal plates of a crinoid calyx and the attachment plate in the middle. Specimen #5 shows the arms extending upward from the calyx. Specimen #6 shows the external mold of the column and disassociated plates of the calyx. Specimen #7 shows the external mold of a calyx with a stellate six-rayed design that looks like a six-sided Chrysler emblem. Specimen #8 shows the external molds of two crinoid columns.

Plate 12

Circular 7: ROCKS AND FOSSILS FOUND IN MISSISSIPPI'S GRAVEL DEPOSITS, *Mississippi Office of Geology, 2008*