Catalog of 100 Minerals, Rocks, and Fossils from Oklahoma

by

W. E. Ham

With Glossary
by
Eloise Tittle

Oklahoma Geological Survey
Norman, Oklahoma

1942

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OKLAHOMA GEOLOGICAL SURVEY

ROBERT H. DOTT, DIRECTOR

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INTRODUCTION

This booklet is written to accompany a collection of one hundred rocks, minerals, and fossils collected from Oklahoma. In addition to the discussions for each of the items in the collection, brief discussions on various phases of geology are given in the hope that they will aid the student to a better understanding of the materials with which he is dealing.

The collection of one hundred rocks, minerals, and fossils represents the majority of the common rocks and minerals found in Oklahoma. Most of the important ore mineral raw materials have been included. Each type of specimen has been carefully chosen because it is representative of a group, and the specimens were obtained from areas which furnished the best possible material. The rock and mineral samples furnished are all fresh—that is, they have been broken out of rock not exposed to surface weathering. In the field, the same material may appear somewhat different on the surface because of weathering. A section on the nature of fossils is included to show what fossils are, how they can be used, and their importance in geological work.

The collection is intended for use by science and elementary geology classes in high schools and colleges in Oklahoma. The students may thus become acquainted with the diversity and importance of Oklahoma's rock and mineral resources and they may also obtain a brief introduction to the science of Geology.

The specimens are arranged into three groups. The first group consists of minerals and crystals; the second contains rocks; and the third contains fossils. Each specimen is assigned a number, and this number should be marked permanently* on the specimen so that identification can always be made by use of this catalog.

Study of the collection should be done systematically. For example, the student should learn the common minerals before he attempts to learn rocks, because rocks are made up of minerals, and this procedure gives him the necessary background. Furthermore, while specimens are being studied the corresponding description should be obtained immediately from the booklet. Specimens in the collection have been collected and authentically described by the Oklahoma Geological Survey.

General interest may be aroused by encouraging students to make collections for themselves. This can be done by organizing field trips to local outcrops along roads and streams, in stone quarries, brick pits, mines, etc., and collecting specimens to be identified at home or in the classroom. A full appreciation of rocks and minerals comes only after they have been observed in the field.

Oklahoma high schools and colleges may obtain the collection, with the descriptive booklet, free of charge by writing to the Director, Oklahoma Geological Survey, Norman, Oklahoma. Some person connected with the administrative staff of the school, however, must sign an application, agreeing to (1) pay transportation charges and (2) provide a suitable place for display, use, and preservation of the collection. Additional copies of the booklet may be obtained for $0.30, postpaid.

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* A satisfactory method consists of applying a small amount of white enamel with a small brush on a corner of the specimen and allowing it to dry. Numbers may then be put on this white background with black india ink.

GEOLOGY—WHAT IT IS

Geology is the science which deals with the composition, origin, structure, history, and past life of the earth. The word geology comes from two Greek roots meaning *earth* and *study*. Geologists are, of course, limited in their study to the outermost "crust" or skin of the earth, which they can observe. The study of geology is divided into many specialized branches, some of which are described below.

Mineralogy is the study of minerals. Rocks are composed of minerals and are classified in a large measure by the mineral composition. Ore deposits and other economic deposits are also dependent upon the mineral content. Further aspects of minerals are described in the section on mineralogy.

Petrology is the study of rocks. It deals with the origin and classification of the many thousands of rock types known at the present time. The study of rocks is treated in greater detail in the chapter on rocks.

Economic geology deals with the utilization of geologic materials. It is sometimes called *applied geology*, because it utilizes the knowledge of all other phases of the science to obtain products useful to man. The chapter on Economic Geology treats the subject more completely.

Structural geology pertains to the attitude or disposition of rocks, whether undeformed, broken, or folded. Petroleum geology depends largely on the principles of structural studies.

Paleontology deals with the life of past geologic ages, based on study of fossils. It is discussed in the chapter on fossils.

Historical geology deals with the history of the earth, its origin, the age of sedimentary beds and their correlation, the interpretation of past events, and other related topics. Paleontology is a valuable aid in this study. For convenience in description and correlation, a geologic time chart has been devised, and it is used as a standard throughout a large part of the world.

Physiography, or physical geography, treats the classification of the surface features of the earth and the processes which produced them. The influence of mountains, plains, plateaus, rivers, shore features, etc., on human culture is an important phase of physiography.

On the geologic map of Oklahoma (fig. I) is shown the surface distribution of rocks of various ages in the state. The areal outcrops correspond rather closely to physiographic divisions, which may be approximately defined as follows:

Ozark Mountains. Outcrops of Mississippian rocks in northeastern Oklahoma.

Ouachita Mountains. Southeastern Oklahoma, north of the Cretaceous outcrop and south of the Choctaw Fault.

Coastal Plain. East-west strip of Cretaceous rocks in southeastern Oklahoma, extending from Love County to Arkansas.

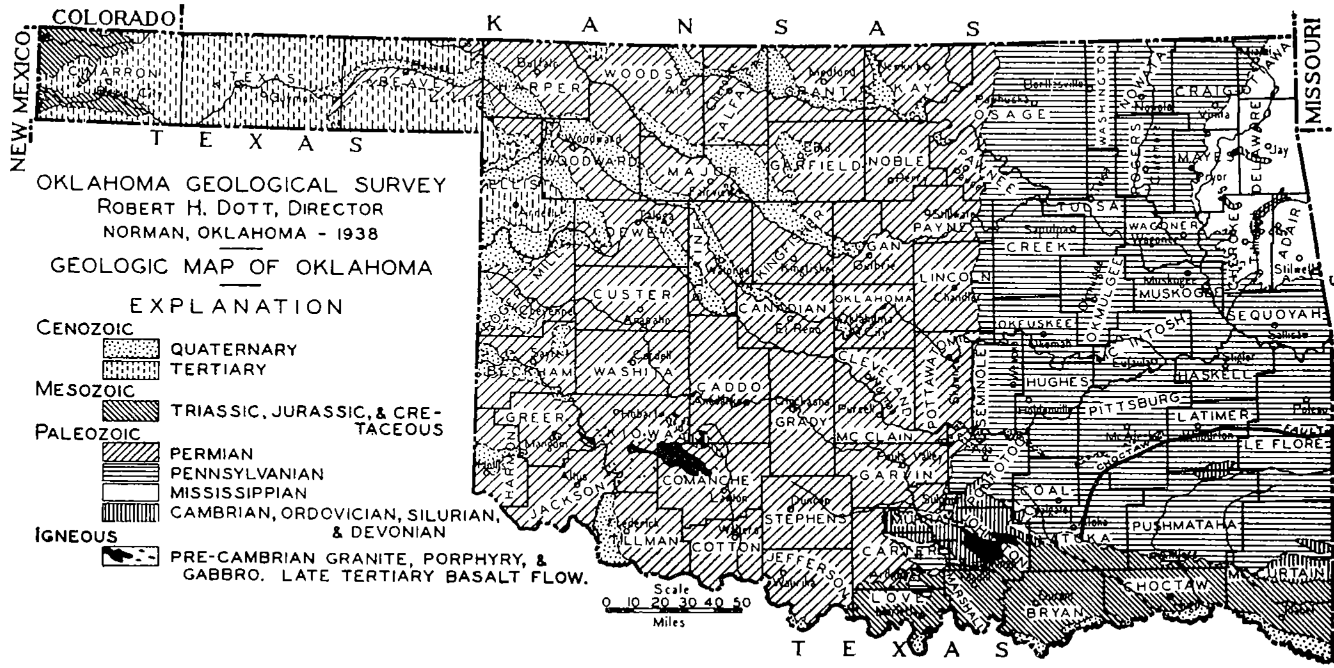
Arbuckle Mountains. Outcrops of pre-Pennsylvanian rocks of south-central Oklahoma, chiefly in Murray, Pontotoc, and Johnston Counties.

Prairie Plains. Outcrops of Pennsylvanian rocks in eastern and central Oklahoma.

Red Bed Plains. Outcrops of Permian rocks in western Oklahoma.

Wichita Mountains. Pre-Cambrian granites, etc., mostly in Comanche and Kiowa Counties.

High Plains. Outcrops of Tertiary rocks in the Panhandle and in Ellis and Woodward Counties.



1. Geologic Map of Oklahoma. The rock outcrops also delimit physiographic areas, Mountain areas of state: **Ozarks,** northeastern, principally outcrops of Mississippian rocks. **Ouachitas,** southeastern, south of Choctaw fault, north of Coastal Plain. Kiamichi Mountains are part of the Ouachita system. **Arbuckles,** south-central, outcrops of pre-Cambrian and lower Paleozoic rocks. **Wichitas,** southwestern, outcrops of pre-Cambrian rocks.

Plains areas of state: **Coastal Plain,** southern row of counties, east of Love County, north of Red River, outcrops of Cretaceous rocks. **Prairie Plains,** outcrops of Pennsylvanian rocks in eastern Oklahoma, outside mountains. **Red Bed Plains,** outcrops of Permian rocks, western Oklahoma. **High Plains,** outcrops of Tertiary rocks in Panhandle counties.

Geologic Time Chart

Era	Periods And Epochs		Estimated Duration (In Years)	Dominant Life
CENOZOIC	Quaternary	RECENT	20,000	Mammals, including man
	Quaternary	PLEISTOCENE (GLACIAL)	1,000,000	Wooly mammoths, elephants, first man
	Tertiary	PLIOCENE	6,000,000	Mammals and Modern trees
	Tertiary	MIOCENE	12,000,000	
	Tertiary	OLIGOCENE	16,000,000	
	Tertiary	EOCENE	20,000,000	
MESOZOIC	Cretaceous	UPPER CRETACEOUS	40,000,000	Ammonites, echinoids, dinosaurs, and flowering plants
	Cretaceous	LOWER CRETACEOUS (COMANCHEAN)	25,000,000	
	JURASSIC		35,000,000	First birds
	TRIASSIC		35,000,000	Beginning of dinosaurs
PALEOZOIC	PERMIAN		25,000,000	Crinoids, blastoids, sharks, amphibians, trees, and ferns
	PENNSYLVANIAN*		35,000,000	
	MISSISSIPPIAN*		50,000,000	
	DEVONIAN		50,000,000	First amphibians; fishes
	SILURIAN		40,000,000	Fishes, brachiopods
	ORDOVICIAN		90,000,000	Trilobites, brachiopods, graptolites
	CAMBRIAN		70,000,000	
PRE-CAMBRIAN			TOTAL AGE OF EARTH APPROXIMATELY 2,000,000,000 years	Beginning of primitive life

*North American terms. The time covered by these two periods is called "Carboniferous" or "Coal Measures" in other continents.

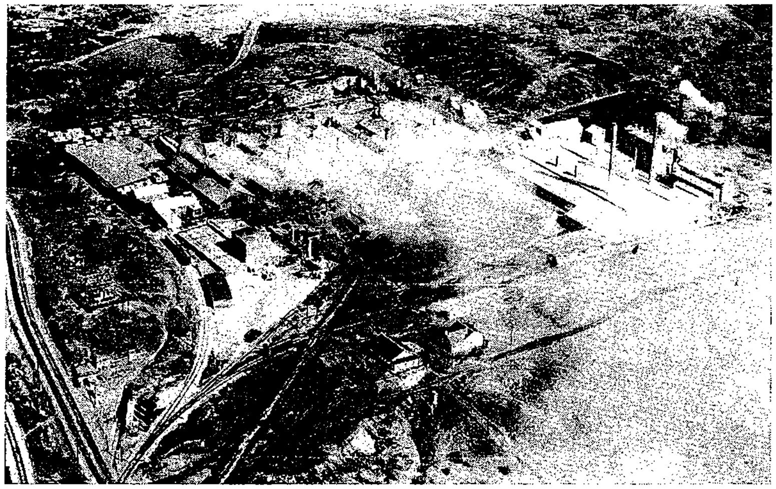
ECONOMIC GEOLOGY

Economic geology deals with rocks, minerals, mineral fuels, and ores utilized by man. Many basic commodities we use in present-day economy can be directly related to geology, and therefore economic geology occupies an unusually high position in the functioning of human society. The successful recovery from the earth of metals, fuels, and structural materials alone proves the importance of geological work.

In the field of geology, approximately 1500 minerals and thousands of rock types are recognized. From these rocks practically every element known to man has been extracted. It is not to be inferred, however, that every rock or mineral is a commercial ore; for most rocks do not readily yield valuable materials. Only if a concentration of useful minerals is great enough to allow a *profitable mining operation* can a rock or mineral be classified as an *ore*. Thus we have gold, silver, copper, and other metals produced in local regions of the world where nature has concentrated their ores.

Most ores occur in *veins* or as irregular deposits. Some ores are exceptionally rich and are known as *bonanzas*. On the other hand, some deposits are very lean and can be worked at a profit only because of technical engineering skill. Practically every metallic deposit consists of: *ore minerals*, which are the valuable materials desired; and *gangue minerals* which are waste material or country rock enclosing the ore. For example, in the Oklahoma zinc-lead field only sphalerite and galena are ore minerals. Of the accompanying gangue minerals, calcite and dolomite are discarded, although the crushed chert, or "chat", a low-value byproduct of the milling operations, is sold for road surface, railroad ballast, concrete aggregate, etc.

Oklahoma has no gold or tin ores, but the state is very fortunate in being the largest zinc producer in the United States. We also have hundreds of oil fields which



2. Zinc Smelting. Smelting and refining zinc is Oklahoma's second most important mineral processing industry. Ores from the Tri-State district of Oklahoma, Kansas, and Missouri and from Rocky Mountain states are refined here.

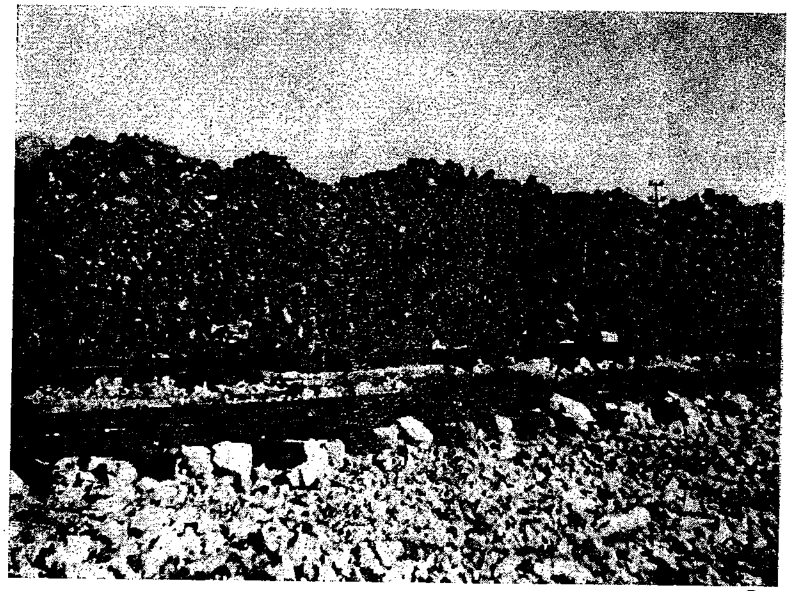
produce approximately 400,000 barrels of oil per day. There are also large reserves of high grade coal, natural gas, gypsum, ceramic clays, limestone, dolomite, sand and gravel, and building stone. Other important resources are iron, manganese, volcanic ash, metabentonite, glass sand, tripoli, asphalt, salt, and wool rock. The total value of our mineral production in 1938 was $273,000,000.

The uses of a mineral or rock often depend upon the chemical composition and the ease of processing. The value of the mineral at the mine compared to cost of production always determines whether the deposit will be profitable. These points are illustrated in the following examples. The mineral sphalerite is composed of zinc and sulfur, and both elements are of great commercial value. Sphalerite is the principal source of the metal zinc, and the zinc is much more valuable than

3. Aerial photograph of an Oklahoma oil refinery. In May, 1941, Oklahoma had 25 operating refineries with a daily capacity of 210,280 barrels of crude oil; and 105 gasoline plants with a daily capacity of nearly 2,000,000 gallons of gasoline.

the sulfur, which is mined cheaply and in large quantities on the Gulf Coast. Hence, sphalerite is mined for its zinc content, although part of the sulfur is utilized, in some smelters, for making sulfuric acid as a by-product. The mineral orthoclase is very abundant in some rocks and contains 17 per cent potash, but is not used at the present time as a source of potash because the extraction of the potash is too expensive in comparison with such potash mineral as sylvite (chloride or muriate of potash). Instead, orthoclase is well suited to making glazes and porcelain ware and in some areas it is used for that purpose. If cheaper and more efficient methods of concentrating and extracting the potash are later devised, and if other sources of potash are exhausted, orthoclase well may become an important source of potash.

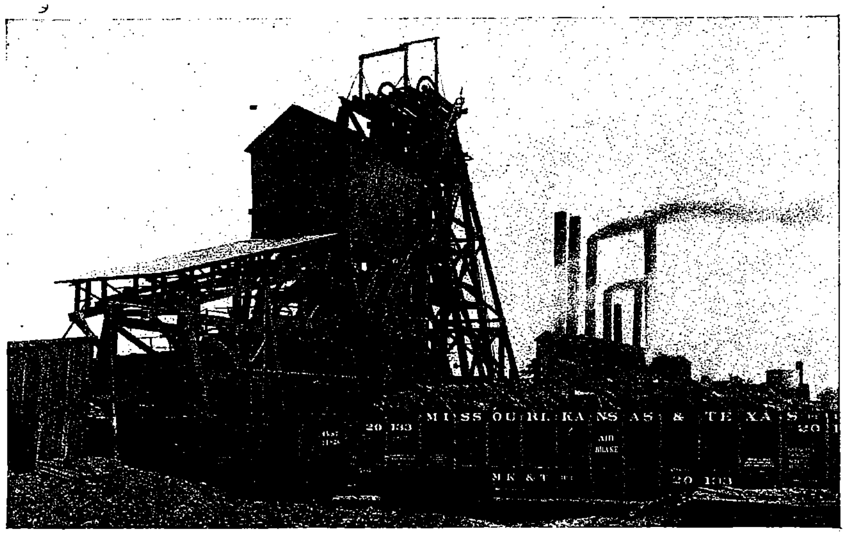
The uses to which a rock or mineral can be put depend in many instances upon the ingenuity and resourcefulness of man. A potentially valuable rock may



4. Iron ore. A stock pile of brown iron ore from the Arbuckle Mountains. This ore is used in the manufacture of special cement and by some Oklahoma foundries.

lie dormant for many years until sufficient field investigation and laboratory research have indicated its commercial possibilities. For example, impure siliceous limestones have long been known in Oklahoma, but they were not used until research by the Oklahoma Geological Survey in 1939 showed that several deposits were ideal raw materials for making rock wool, and inspired the erection of a plant.

It is easy to understand that many of Oklahoma's raw materials are not utilized at the present time. But, because technology changes and formerly useless materials become valuable through new processes, many of our rocks will be put to use in the future. It is well for the student to remember, when he examines the specimens in this collection, that each mineral and rock has or may have some commercial significance. He should,



5. Coal loading in eastern Oklahoma. The production of coal was at one time one of Oklahoma's leading industries, but has been considerably depressed during the past decade. Production fell from 3,818,054 tons in 1927 to 1,540,303 tons in 1936, with a drop in value of $8,000,000. The high point of 4,849,288 tons, worth $23,294,000 was reached in 1920. The decrease was due largely to competition from oil and gas.

therefore, investigate these specimens in the light of their present and potential usefulness and their geologic history.

MINERALS AND CRYSTALS

A mineral, according to scientific definition, is a natural inorganic substance with a definite chemical composition and usually with a definite internal structure. Most minerals occur in the solid state, but water and mercury are liquids. According to legal definition, however, a mineral need not be inorganic, for oil, gas, asphalt, and coal are legally minerals even though of organic origin. Nearly all minerals have a definite geometrical arrangement of component atoms, and because of this property may, under favorable conditions of growth, attain smooth planes called *crystal faces*. Such minerals are called *crystals*. Rock crystal, known as the mineral quartz, is an example. Crystals are often quite attractive in shape and show pleasing colors, leading many people to admire and collect them as a hobby. Furthermore, they are the source of all natural gem stones, including diamond, sapphire, ruby, and emerald.

PHYSICAL PROPERTIES OF MINERALS.

Because the physical properties of a given mineral are constant, it is possible in many instances to use these properties to identify an unknown mineral. Given below is a list of the important physical properties most commonly used.

Luster is the appearance of a mineral in reflected light. It may be either *metallic* or *non-metallic*. A mineral with a metallic luster has the appearance of a metal, like iron, lead, gold, etc. Examples are magnetite and galena. Minerals of this type do not transmit light, even in the thinnest pieces, whereas non-metallic minerals have an appearance like glass, diamond, flint, etc., and thin pieces always transmit light. The luster of a mineral is not entirely determined by its chemical composition, nor related to its economic use, for many non-metallic minerals are composed partly of a metal. For example, calcite contains the metal calcium; siderite contains iron; feldspar contains aluminum and potassium; sphalerite contains zinc; yet all these minerals have a non-metallic luster.

A glassy appearance is the common luster of non-metallic minerals. A glassy, or *vitreous*, luster is characteristic of such minerals as quartz, calcite, barite, etc.

Color in minerals depends upon the amount of light absorbed. In general, non-metallic minerals are light-colored or colorless. Such color as minerals of this luster possess is often produced by minute amounts of impurities. Thus quartz and calcite are colorless when pure; but impure specimens may be brown, black, green, blue, red, yellow, violet, etc. Because of its variability in many such minerals, color is not a reliable criterion for identification.

In metallic minerals, color is usually darker and more constant. Pyrite is nearly always brass-yellow; magnetite is iron-black; galena is lead-gray; and psilomelane is blue-black.

Streak is the color of the powdered mineral. It is usually obtained by rubbing a mineral across a piece of unglazed porcelain, called a streak plate; unglazed tile and porcelain electric insulators are satisfactory substitutes. The rough surface powders the mineral so that its streak may be obtained and inspected. Very hard minerals may be pulverized with a hammer or by other means, and the color of the powder can be examined on a piece of white paper.

Streak is more constant than color and therefore more emphasis is placed upon it by mineralogists. Calcite and quartz, as mentioned above, may have practically any color but the finely ground powder is always white. Most metallic minerals have nearly the same color and streak. For example, galena has a lead-gray color and a lead-gray streak.

Specific gravity of a mineral is its weight compared with an equal volume of distilled water at 4° Centigrade. All inorganic minerals are heavier than water, but some are much heavier than others. For example, gypsum has a specific gravity of 2.3; quartz, 2.6; calcite, 2.7; barite, 4.4; pyrite, 5.5; and galena, 7.5. As a general rule the mineralogist does not determine the exact specific gravity of each mineral specimen but estimates it from previous experience. Quartz and calcite are considered light minerals, whereas barite, pyrite, and galena are heavy.

Hardness is the resistance a mineral offers to abrasion. It is measured by comparison with a standard scale of hardness arbitrarily set up many years ago. This scale, known as the Mohs scale of hardness, is used at the present time.

1. talc	6. orthoclase feldspar
2. gypsum	7. quartz
3. calcite	8. topaz
4. fluorite	9. corundum or ruby
5. apatite	10. diamond

In this table, talc is the softest mineral and will not make a scratch on any other mineral. Diamond is the hardest and will make a scratch on all other minerals. One determines the hardness by testing. For example, if an unknown specimen will scratch feldspar but will not scratch quartz, then its hardness is intermediate between them, or 6.5. For practical purposes the following common articles may be used: finger nail, 2.5; copper coin, 3.0; window glass, 5.5; and steel knife blade, 5.5-6.0.

Cleavage is the tendency shown by some minerals to break along rather smooth planes, the direction and number of planes being controlled by the atomic structure of the mineral. Some minerals show perfect cleavage, in as many as six directions, whereas other minerals have no cleavage at all. For example, galena breaks into cubes and calcite breaks into rhombohedrons, which resemble distorted cubes, but quartz has no cleavage, and breaks into irregular fragments, like ice. Because cleavage is always constant for a given mineral, it is much used by mineralogists.

Fracture describes the manner in which a mineral breaks when it does not follow cleavage planes. This property is best used with minerals lacking good cleavage. Quartz has no cleavage but has a marked *conchoidal*, or shell-like, fracture. For quartz, therefore, fracture is a more important property than cleavage.

ORIGIN OF MINERALS

The majority of minerals are deposited from water solutions. The principle of deposition of minerals from solution is shown by the evaporation of salt water. After a certain amount of water has evaporated, some salt crystals will precipitate. This phenomenon occurs because there is more salt present than the remaining amount of solution can dissolve, so the excess salt is precipitated. In nature the same conditions occur. Mineral salts are contained in sea water, in streams, and in water stored within the earth. When any of these waters evaporate, the excess materials are deposited. It is known that in the geologic past vast amounts of halite (rock salt), gypsum, calcite, and dolomite were precipitated from seas which had invaded the continents. Materials deposited in this manner compose an important portion of the rocks known in Oklahoma.

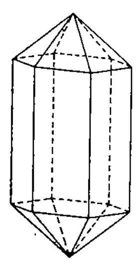
Mineral-bearing solutions may be very hot, having been heated at some depth below the surface of the earth. These solutions sometimes consist mainly of hot water with a small amount of dissolved minerals; or the hot solutions may consist of molten rock, or magma, like that of lava from volcanoes. The cooling of these solutions results in the precipitation of minerals. Minerals occurring in quartz veins and around hot springs were precipitated by the cooling of hot waters, and the minerals occurring in igneous rocks like granite were precipitated by the cooling of a magma.

Of approximately 1500 minerals known throughout the world, only about 25 are very common, and these 25 probably make up 95 per cent of the rocks seen at the surface of the earth. Perhaps one hundred minerals are known in Oklahoma, but many of these are rare or occur in microscopic grains. The 31 common rock-forming minerals and ore minerals included in the colletion are the most important in this state. These minerals are described in the following pages.

DESCRIPTION OF MINERALS AND CRYSTALS COMMON IN OKLAHOMA

QUARTZ

Quartz is crystalline silica, SiO_2. It has a non-metallic luster and may show nearly any color. The streak is white; hardness, 7.0. In all its varieties it has an excellent conchoidal fracture but there is no cleavage. Quartz is the most common mineral at the earth's sur-



6. Quartz crystal. Crystal form may often be used to assist in the identification of minerals. Both the shape of the crystal faces and the angles between them can be used. In quartz, for example, the six elongate side faces are rectangular in shape; and when viewed from above these faces form a regular hexagon with interior angles of 120°

face and it may occur in many different forms; it is an important constituent in certain common rocks, notably sandstone, quartzite, and granite. The following varieties are found in Oklahoma:

1.* *Crystal quartz*, known locally as "Arkansas diamond", "Hot Springs diamond", or "rock crystal", has variable colors, a vitreous luster, and shows good, six-sided crystal faces (Fig. 6). Crystals of special type are cut for use in radio transmitting and optical equipment, others are cut into semi-precious stones (rhinestones). In Oklahoma, crystal quartz is found chiefly in the Wichita and Ouachita Mountains, but none seems to be of commercial grade.

2. *Milky quartz* is white with a clouded or milky appearance. It is very abundant in veins in the Ouachita Mountains, and it is also known from the Wichita Mountains.

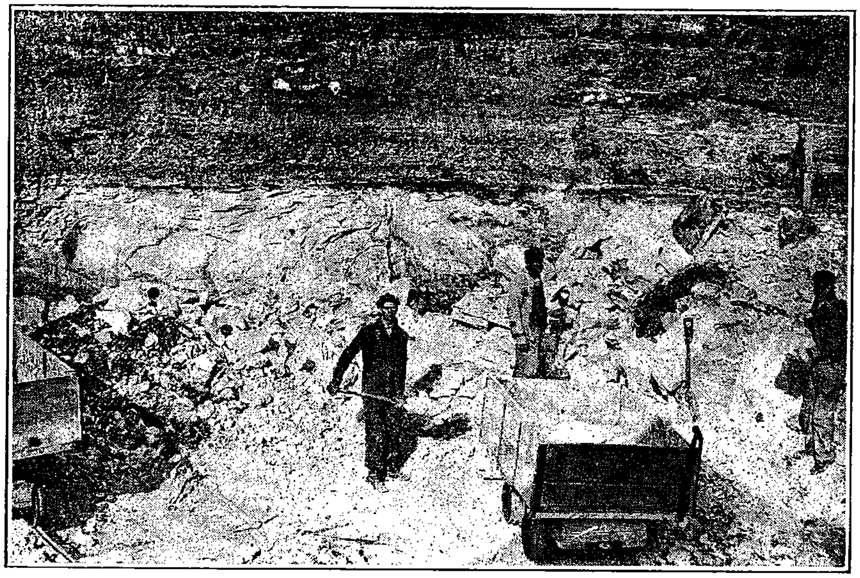
3. *Flint* is a dense, cryptocrystalline (hidden crystals) type of quartz. It may have nearly any color and will transmit light whereas chert appears opaque. Flint was much prized by Indians, who used it for making arrowheads, scrapers, etc.

4. *Chert* has a dull luster and usually is gray, brownish, greenish, or black in color. It it a fine-grained or cryptocrystalline variety of quartz, never showing crystal faces, and found chiefly in the form of nodules or beds associated with limestone or shale. It is the abundant gangue mineral in the zinc-lead ores of Oklahoma, where the crushed chert is recovered from the lead and zinc concentrates and sold for various construction purposes. Chert is very abundant in the Ouachita, Ozark, and Arbuckle Mountains. During 1937-1938, the value for chat sold averaged slightly more than $300,000 per year. *Novaculite*, found in the Ouachita Mountains of Oklahoma and Arkansas, is a rock closely

* Numbers correspond to the specimen numbers given in the table of contents and index, and to specimens included in the accompanying collection, and provide a cross-reference for the student.

resembling chert, and is mined for whetstones in the latter state.

5. *Tripoli* is a white, brownish, or pink, porous silica rock derived from the weathering of siliceous limestone. It occurs in northeastern Oklahoma where it is known as "cotton rock". The chief use of tripoli is as an abrasive, but it is also used as a filler in paints



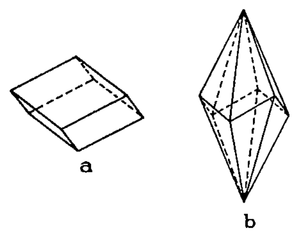
7. Tripoli quarry, Ottawa County.

and special cements, and as a filtering agent. It is mined in Ottawa County, Oklahoma, and has an annual value of about $40,000. Fig. 7 shows a tripoli quarry.

CALCITE

6. *Calcite*, calcium carbonate ($CaCO_3$), is found in many crystal forms. Calcite crystals found in the Tri-State district are known as "dog-tooth" or "nailhead" spar (Fig. 8b). Calcite has a vitreous, non-metallic luster; color is white or variously tinted; streak, white; per-

fect three-way cleavage which produces six-sided solids (rhombohedrons) resembling distorted cubes (Fig. 8a). A drop of dilute acid, applied to a specimen of calcite will produce a vigorous bubbling or effervescence. With other carbonates, except aragonite, the bubbling is not vigorous unless concentrated acid is used. Calcite is a very common mineral, and it is the most important



8. Forms of calcite. a, rhombohedron; b, scalenohedron, or "dog-tooth" spar. The rhombohedron represents both crystal habit and cleavage form of calcite.

constituent in limestone. Limestone has many uses, and occurs in many parts of Oklahoma; crystal calcite is found in the zinc-lead district of northeastern Oklahoma; and calcite veins are found locally in many places, especially in limestone areas, and in certain outcrops of igneous rocks in the Wichita Mountains.

Aragonite

7. *Aragonite* has the same chemical composition as calcite, $CaCO_3$, and is very much like that mineral, being distinguished from it by the crystal structure. The crystals may be six-sided, and flat, or they may be thin and needle-like. The six-sided crystals occur in western Oklahoma where they are known as "Indian money". The needle crystals are sometimes deposited from streams, and sometimes they are deposited by ground water in caves, forming drip-stones, or stalactites.

Dolomite Crystals

8. *Dolomite* is a carbonate of calcium and magnesium, $Ca,Mg(CO_3)_2$. It usually has a white, cream, or pink color and a white streak. Its hardness is 3.5; the

crystals are often small and curved in the shape of little saddles (Fig. 14). If the mineral is crushed and a little concentrated acid is applied, an effervescence will be produced. Beautiful crystals of dolomite are found associated with the lead and zinc ores of the Miami-Picher district.

Manganese Carbonate

9. *Manganese carbonate* is found in Johnston and Coal Counties near Bromide in association with psilomelane and other manganese minerals. It contains impurities of lime and iron, but is a valuable source of manganese for certain uses. The color is mottled gray, green, reddish, or brown. Similar minerals are now being mined near Batesville, Arkansas.

Siderite (Clay Ironstone)

10. *Siderite* is iron carbonate, $FeCO_3$. It has a vitreous luster, a gray or brown color, a light-colored streak, and with concentrated acid it effervesces like dolomite. Siderite is often mixed with clay and occurs in the form of rounded concretions of a reddish, yellow, or brown color. These colors are caused by the formation of various iron oxides which are alteration products of the original siderite. In some parts of the world, clay ironstone is used as an iron ore. The occurrence of siderite and clay ironstone is limited in Oklahoma largely to the Pennsylvanian formations of the eastern part of the state, and to the Ardmore district. One fairly large deposit crops out along Neosho River 5 miles northwest of Miami, Ottawa County.

Malachite (And Azurite)

11. *Malachite* is a carbonate of copper, usually with a bright green color and streak. The crystals are often needle-like or in seams and are somewhat heavy (specific gravity, 4.0). Malachite, like other carbonates, effervesces with concentrated acid. This mineral is an

ore of copper in some states, but it is found only in small quantities in the "red beds" of eastern and southern Oklahoma, and in some of the granites near Lugert, Kiowa County. Some attempts have been made to mine Oklahoma copper ores, but they were never profitable.

Azurite is the *blue* copper carbonate which is often associated with, but rarer than, malachite. The two minerals are practically the same except for color and streak.

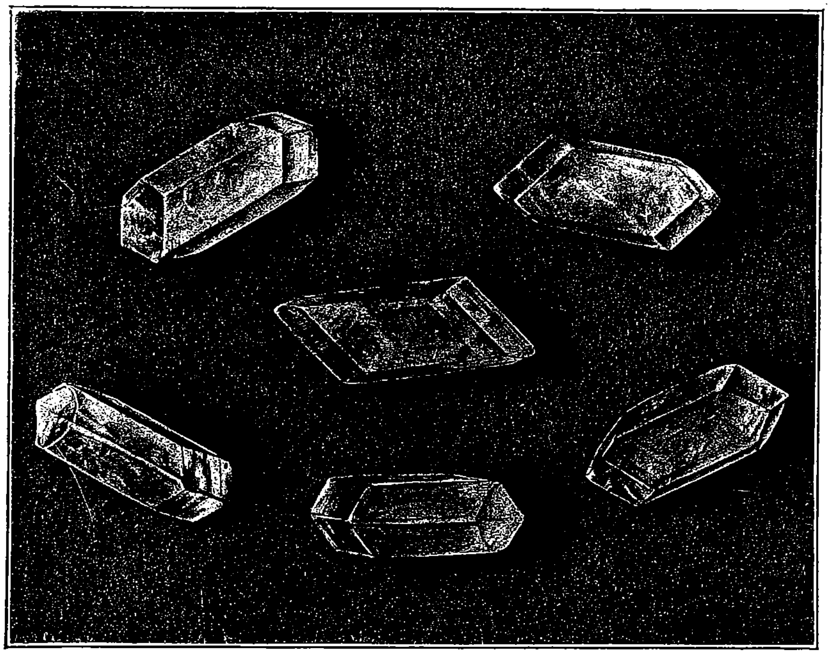
GYPSUM

Gypsum (12, 13, 14) is hydrous calcium sulfate, $CaSO_4.2H_2O$. It has a vitreous to dull luster; its streak and color are usually white, sometimes pink, greenish, etc. It is a soft mineral (hardness, 2.0) and can be scratched with the thumb nail. There are several common varieties of gypsum.

Gypsum occurs in great abundance in the Permian rocks throughout western Oklahoma, where it was deposited from the saline waters of ancient seas. The deposits are of considerable economic importance because gypsum is used in making plaster of paris, special cements, sheet rock, tile, etc. During the years 1937-1939, the value of rock gypsum produced in Oklahoma averaged approximately $250,000 per year.

12. *Selenite* (Fig. 9), or crystallized gypsum, is colorless and shows good cleavage in three directions. Although resembling some varieties of mica, for which selenite is often mistaken, a careful examination will quickly reveal several differences. Whereas mica can be bent, and will spring back upon release of pressure, selenite cannot be bent far without breaking. Furthermore, mica can be split only into thin leaves, but gypsum

will cleave along *three* different planes, yielding four-sided parallellograms. There is also a vast chemical difference, mica being a *silicate* whereas gypsum is a *sulfate*.



9. Selenite. Crystals of gypsum, found in clays in western Oklahoma.

13. *Satin spar* is fibrous gypsum composed of needle-shaped crystals which occurs in veins and seams (Fig. 10).

14. *Rock gypsum* is more or less compact and occurs in considerable masses, usually in beds (Fig. 11). It is the most abundant and the most useful type of gypsum. *Alabaster* is the dense, translucent, attractively colored variety of rock gypsum; it may be carved into ornaments such as vases, lamp bases, book ends, etc. Oklahoma has several deposits of alabaster, but the alabaster-carving industry in this state is still in its infancy.

10. Satin Spar. A fibrous variety of gypsum occurring as seams in clay. Western Oklahoma.

11. Gypsum bluff. Two beds of white, rock gypsum capping a hill of red shale. Western Oklahoma.

Barite

Barite (15, 16), or barytes, is sulfate of barium, $BaSO_4$. It has a vitreous luster; color is white, brown, or reddish; the streak is white. The hardness is about 3 and it is quite heavy; specific gravity, 4.4. It has good cleavage in three directions, but this property may not be observed in all specimens. Barite is used in the manufacture of paper, paint, and linoleum, and in making a heavy drilling mud for oil wells.

15. *Barite roses,* or sand barites, consist of sandstone with a barite cement. The barite, which encloses the sand grains, has been able to grow into flat crystals which interpenetrate. The resulting shape may resemble a rose. These are found in a narrow belt of sediments extending from Logan County to Garvin County, and similar forms are reported from a few other places in the world.

16. *Crystalline barite* is often quite pure, with a white color and pearly luster, showing three directions of cleavage. It is found in some mineral deposits in the Ouachita Mountains, in the eastern part of the Arbuckle Mountains, and in the lead-zinc ores of Ottawa County.

Some crystalline barite occurs in the form of nodules and has a radiating, needle-like structure. It has a brownish color and is present in Permian "red beds" south of the Wichita Mountains and in south-central Oklahoma.

Celestite

17. *Celestite,* strontium sulfate, $SrSO_4$, is very similar to barite. The most distinctive feature is the sky-blue color of celestite. This mineral occurs as long four-sided or six-sided crystals, or as granular masses. It is rather rare in occurrence, being found in Oklahoma

chiefly in "red beds" near Norman, south of Weatherford, and in northwestern Washita County. It is also reported from other localities. Celestite is used as a source of strontium, which produces the crimson color in flares and fireworks. No celestite is produced in Oklahoma.

HALITE (ROCK SALT)

18. *Halite* is the mineral name for common table salt. It is sodium chloride, NaCl. It has a vitreous luster; color and streak, white; hardness, 2.5. The mineral

12. Salt plain, Harmon County. Piles of salt in background.

occurs in cubic crystals or as incrusting masses; sometimes it occurs in extensive underground beds. Halite has cubic cleavage and is easily distinguished by its salty taste.

In Oklahoma, salt is found on salt plains (Fig. 12), chiefly in the western part of the state, in Alfalfa, Woods, Harper, Blaine, Beckham, and Harmon Counties. Commercial salt has been and still is produced from some of these plains. These salt deposits occur along stream valleys, having been deposited from brine springs. The brines have been produced by the leaching of salt from the underlying Permian "red beds" by ascending ground water. Salt springs also occur in eastern Oklahoma, chiefly in Mayes County and in an area southeast of Muskogee.

Another source of salt is from oil field brines. The saline waters which accompany oil and gas in subsurface reservoirs may be pumped to the surface where the salt can be extracted by evaporation. One plant, located near Sayre, Oklahoma, produces salt by evaporating brine from a deep well, using waste heat from a carbon black plant. Several years ago, considerable salt was produced from brine at West Tulsa.

Phosphate Nodules

19. *Phosphate nodules* are composed of calcium phosphate and occur in Oklahoma in shale and limestone formations. These nodules may be smooth and rounded, or disc-like, and gray to black in color; this type is found in black shales near Nowata, Muskogee. Stilwell, Eufaula, and Ada. A second type of nodule, found in "red beds" near Altus, Jackson County, has a red or brown color and often has a wrinkled surface or "skin". The principal uses for phosphate are as fertilizer, in baking powder, and in making smoke screens. It is not being produced in Oklahoma at the present time.

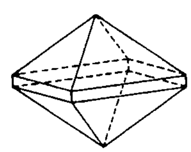
Grahamite

20. *Grahamite* is a variety of asphaltite which consists, when pure, of bitumen. It has a dull to bright luster, a shiny black color, and a black streak. Hardness varies from 2 to 3; fracture is conchoidal; specific grav-

ity, 1.2. When heated in a match flame, pieces fly off in all directions. Grahamite usually occurs in veins and seams; it may be used to manufacture certain varnishes, water-proofing, and mastic cements, etc. The Oklahoma deposits are rather pure and are located in the southeastern part of the state, chiefly in Atoka, Pushmataha, and Le Flore Counties. About 100,000 tons of grahamite were produced from these deposits in the past, but there is no production at present.

Zircon

21. *Zircon* is zirconium silicate, $ZrSiO_4$. It has a non-metallic luster; the color is often dark brown, sometimes colorless, yellow, green, etc.; hardness, 7.5; and it has a high specific gravity, 4.7. It may occur as granular masses or as crystals embedded in granite. Crystals may have beautifully developed pyramidal and prism faces



13. Zircon crystal. Zircon in minute grains is a very common constituent in many igneous rocks, but only rarely are the crystals sufficiently large or abundant to be observed in a hand specimen. In all the granite areas of Oklahoma, only one zircon locality is known, and this is a small area in the Wichita Mountains, northwestern Comanche County.

(Fig. 13). Zircon is used in making refractories, special enamels and glazes, and heat-resisting glass; transparent crystals are cut into semi-precious gems. Excellent crystals of zircon are found in the Wichita Mountains, but there are no gem varieties and no production from that area at the present time.

Orthoclase Feldspar

22. *Orthoclase* is a silicate of potassium and aluminum, $KAlSi_3O_8$. It has a vitreous luster, a pink or flesh-red color, and a white streak. The hardness is 6.0, which enables it to scratch glass; the specific gravity is low, 2.5. Crystals of this mineral may have numerous

crystal faces and are quite varied, but most commonly orthoclase occurs as grains in igneous rocks such as granite and rhyolite. It has perfect cleavage, in two directions, so that the mineral will break along two sets of parallel planes at right angles to each other. The principal use for orthoclase is in the manufacture of glass, but it is also used in making pottery glazes and enamels. Orthoclase is found as crystals in the pegmatite dikes of the Wichita Mountains; it is very abundant in the granites and rhyolites of the Wichita and Arbuckle Mountains; and is present to a lesser extent in certain feldspathic sandstones (arkoses or granite wash) of the state. It is not produced at the present time in Oklahoma.

HORNBLENDE

23. *Hornblende* is a silicate of calcium, magnesium, aluminum, and iron. It has a dark greenish or bluish color, a hardness of about 5.5, and cleavage in two directions. It is a common constituent of igneous rocks, but it is not abundant and no use has been found for it. Hornblende, the most common of the amphibole group of minerals, is found in Oklahoma in the granites of the Arbuckle and Wichita Mountains.

LIMONITE

24. *Limonite*, or brown iron ore, is a hydrous iron oxide, $Fe_2O_3.2H_2O$. The brown or yellowish color, and the yellowish-brown streak, are characteristic. Hardness, 5.0; specific gravity 4.0. Sometimes limonite is earthy, but it is often solid or cellular. It occurs in small quantities throughout the entire state, but it is particularly abundant in the eastern part of the Arbuckle Mountains in Johnston County. Here the deposits are being mined and the ore is used in cement manufacture at Ada, in making a special kind of cement used in massive concrete structures like dams. Also,

some ore has been shipped to Tulsa for foundry use. In some places in the world, limonite is used extensively as an iron ore, and limonite deposits of the Appalachian region, Missouri, and elsewhere supplied the American steel industry until extensive mining of the Lake Superior hematite deposits began in 1854.

MAGNETITE

25. *Magnetite* is iron oxide, Fe_3O_4. It has a metallic luster, and an iron-black color and streak. It has a hardness of 6.0, and will scratch glass. The specific gravity is about 5; the structure is usually massive or granular. Some types of magnetite (lodestones) are naturally magnetic, but all specimens are strongly attracted to a magnet. Magnetite is an important ore of iron; but the Oklahoma deposits, which occur in the Wichita Mountains, are very small in comparison to the size of the present-day workable deposits; furthermore, their titanium content is higher than that accepted by present blast furnace operations.

HEMATITE

26. *Hematite* is iron oxide, Fe_2O_3. It has a metallic to earthy luster; the color on some types of hematite is blackish-red but usually it is reddish-brown; the streak is always reddish-brown. Hardness is about 6.0; specific gravity is about 5.0. The largest hematite deposit in Oklahoma occurs north of the Wichita Mountains and northwest of Lawton in a sandstone bed. Here the hematite has an *oolitic*, or fish-egg, structure. The oolites surround the sand grains and cement them together. This deposit has been worked in the past, the hematite being used to make red paint.

PSILOMELANE

27. *Psilomelane* is an impure manganese oxide. It has a metallic luster and a bluish-black color and streak.

Its hardness is great enough to scratch glass, and it has a high specific gravity. In structure, psilomelane is usually solid or porous, with little "warts" or "billows" on the surface. This mineral is an important ore of manganese, a metal much in demand for making steel. The Oklahoma deposits occur in the Ouachita Mountains, in McCurtain County, associated with the chert or novaculite formations of that region, and in the Arbuckle Mountains, near Bromide, Johnston County. Some manganese has been produced from these deposits in the past. Manganese is now (1942) being mined from the Bromide area.

PYRITE

28. *Pyrite* is iron sulfide, FeS_2. It has a metallic luster, a brassy-yellow color, and a greenish-black streak. This mineral is often confused with metallic gold and hence is known as "fool's gold". Pyrite has a hardness of 6.0 to 6.5, and will scratch glass. It has a specific gravity of about 5. It is commonly found as cubes, but may be massive or granular. In some parts of the world this mineral is used as a source for sulfur, sulfuric acid, and to a limited extent as an iron ore. Pyrite is rather common in small amounts in black shales, coal, and some granites; a nine-foot bed of pyrite is reported in limestone near Spavinaw, Mayes County, to which a shaft was sunk and mining was attempted during World War I.

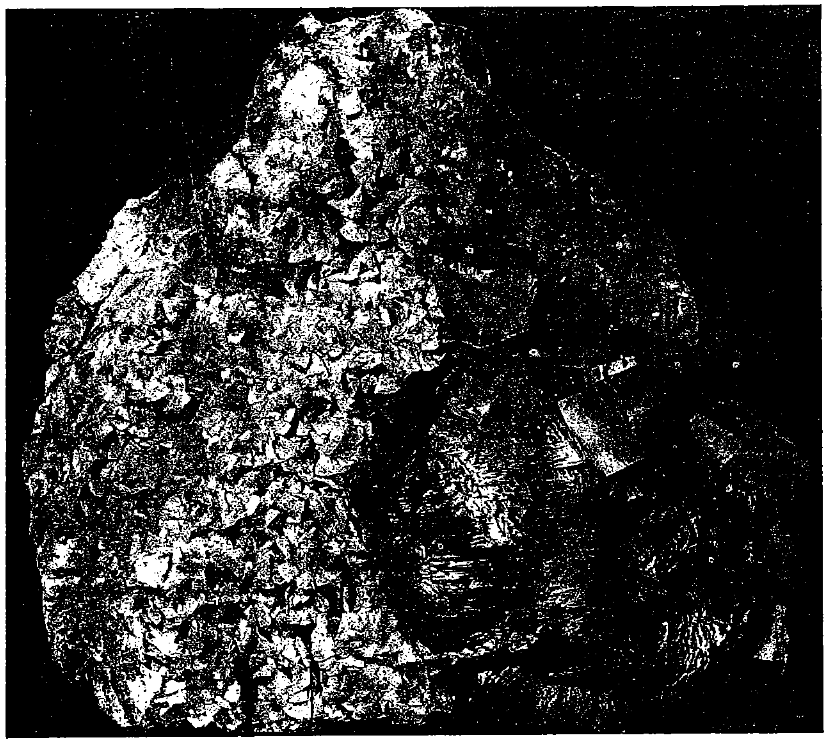
MARCASITE

29. *Marcasite* is iron sulfide, FeS_2. It has nearly the same physical properties as pyrite; the principal differences are that marcasite commonly has a crested or "coxcomb" structure, or consists of radiating needles. Marcasite alters by weathering more rapidly than pyrite, soon becoming coated with a bitter-tasting white powder of iron sulfate. Marcasite is found under the

same conditions and has the same uses as pyrite. Beautifully crystallized specimens of marcasite are found in the lead-zinc mines of Ottawa County. Nodules of marcasite, up to 3 inches in diameter, are abundant in some of the coal beds of Oklahoma.

GALENA

30. *Galena* is lead sulfide, PbS. It has a metallic luster, a lead-gray color and streak, a hardness of 2.5, and a high specific gravity, 7.5. The mineral often oc-



14. Sphalerite, Galena, and Dolomite crystals. Galena cubes resting on distorted crystals of sphalerite. Light gray saddle-shaped crystals are dolomite. Tri-State district, Ottawa County. Courtesy University of Oklahoma Press.

curs in cubic form (Fig. 14) and shows perfect cubic cleavage. Galena is the most important ore of lead. It occurs in Oklahoma as an ore in the lead-zinc district of Ottawa County. More than $2,800,000 worth of lead was produced in 1941. Small amounts are found in the limestones of northeastern Oklahoma and the Arbuckle Mountains, and in certain metalliferous veins of the Ouachita and Wichita Mountains.

SPHALERITE

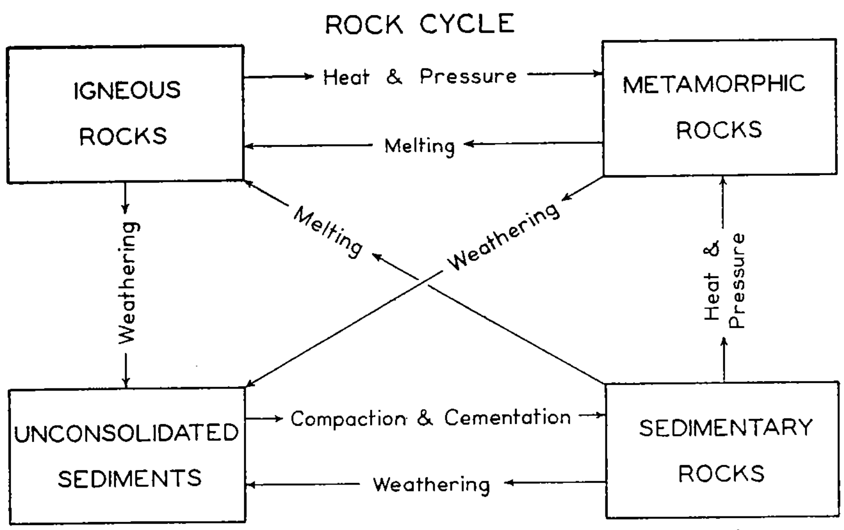
31. *Sphalerite* is zinc sulfide, ZnS. It has a resin-like luster, a dark reddish-brown color, and a yellowish to brownish streak. Hardness, 4.0; specific gravity, 4.0. Crystals are sometimes found, but they are usually complex and distorted (Fig. 14). The mineral has a highly perfect cleavage in six directions. Sphalerite is the most important ore of zinc. In Oklahoma, the leading zinc producer in the United States, the ores occur in the limestone and chert of the Boone formation near Miami, Ottawa County. Associated minerals are crystal calcite, dolomite, and marcasite. The value of zinc produced in Oklahoma in 1941 was more than $25,000,000.

Sphalerite is also found in small quantities in the Wichita and Ouachita Mountains, but to date it has not been found sufficiently abundant to be mined. It is also known in the Arbuckle Mountains, southwest of Davis, where it is associated with zinc carbonate and other minerals. In this area several mines and prospect pits were opened, and mills erected, shortly after statehood, but active operations were not continued long.

ROCKS

A rock is a compacted aggregate of minerals. Three great groupings of rocks are recognized on the basis of origin: igneous, sedimentary, and metamorphic. Under each group there are hundreds of types of rocks, each one being classified principally according to its mineral composition and texture.

Igneous rocks are formed from a molten magma and they were undoubtedly the first rocks formed on the earth. Sedimentary rocks have been derived from them through the ages, by weathering; and the metamorphic rocks have been formed from both types by heat and pressure.



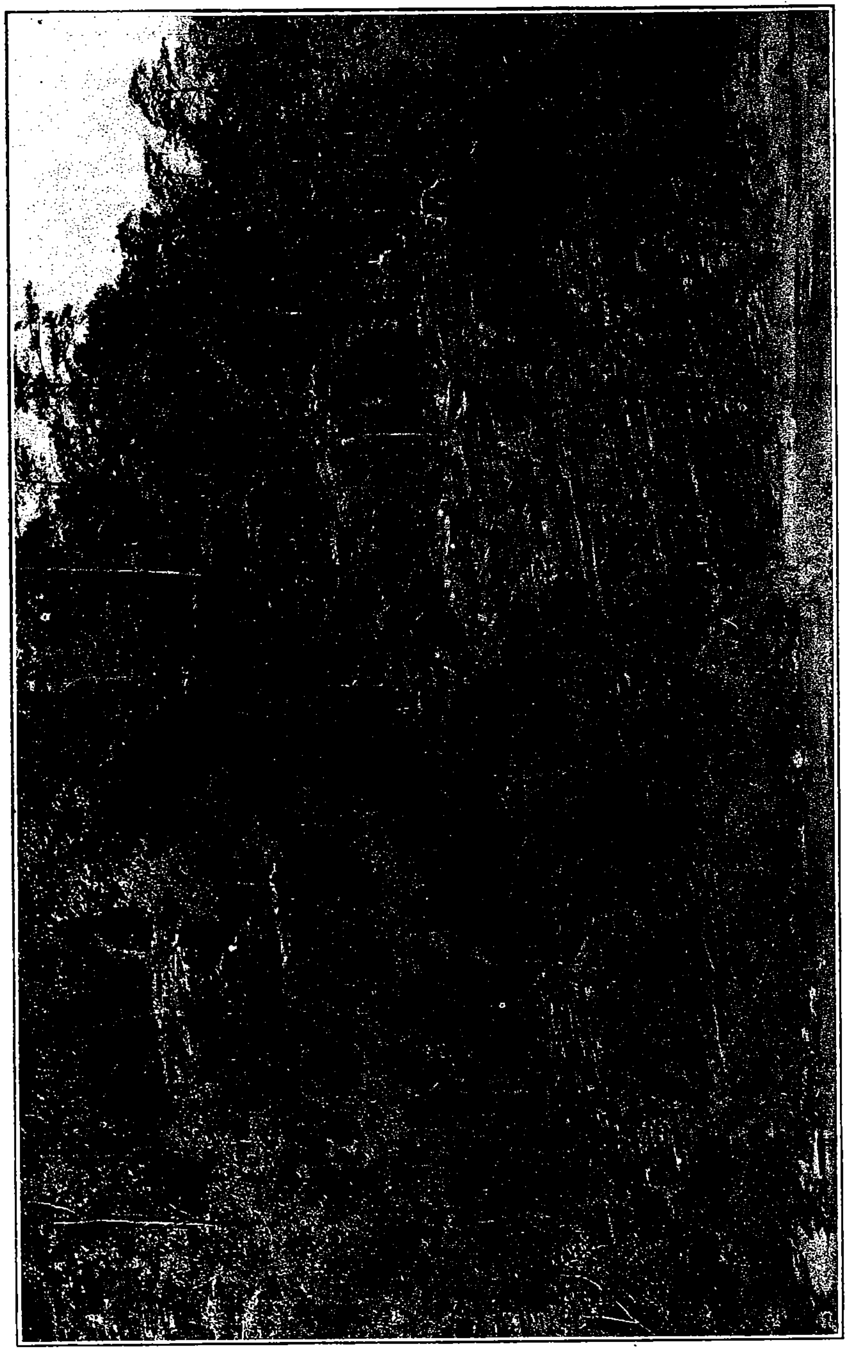
15. The Rock Cycle, showing processes in the origin of rock types.

The following points should be observed in the above diagram. (a) The primary igneous rocks are changed by weathering to sediments, or by heat and pressure to metamorphic rocks; (b) sedimentary rocks are formed by the compaction and cementation of unconsolidated sediments, which in turn have been derived from the weathering of all other rock types, including older sedimentary rocks; (c) metamorphic rocks are formed by the recrystallization of sedimentary and igneous rocks under high temperatures and pressures; and (d) any rock may be fused and remelted at considerable depths below the surface, giving rise to a hot magma from which new igneous rocks may form.

Sedimentary rocks cover about 75; igneous rocks about 23; and metamorphics, 2 per cent of the surface of the continents. Although sedimentary rocks are very abundant at the surface of the earth, they are everywhere underlain by igneous or metamorphic rocks. Taking the earth as a whole, sedimentary rocks are unimportant except in the outermost crust. Their average thickness is less than two miles, whereas the diameter of the earth is nearly 8,000 miles; the sediments are thus seen to be a thin veneer on the surface.

Rocks of some type are exposed everywhere at the surface of the earth, except where they are covered by soil, ice, or water. Mountains, plains, and plateaus are composed of rocks; rocks underlie the streams, lakes, and oceans. Rocks and the materials contained in them supply the major needs of our heavy industries.

Rocks are sometimes folded and broken by movements in the earth. Figure 16 shows tilted beds of sandstone in the Ouachita Mountains. Layers of rocks may be arched upward, like an inverted trough, into a structure called an *anticline*; layers of rock bent downward, like a bowl or trough, form a *syncline*. When subjected to shearing movements, rocks are sometimes broken and moved laterally or vertically, causing *faults*. If the compressive movements have been very great, huge slices of the earth are broken off and thrust or piled over each other. Such movements produced the Alps of Europe, and occurred in the Ouachita Mountains of Oklahoma and Arkansas.



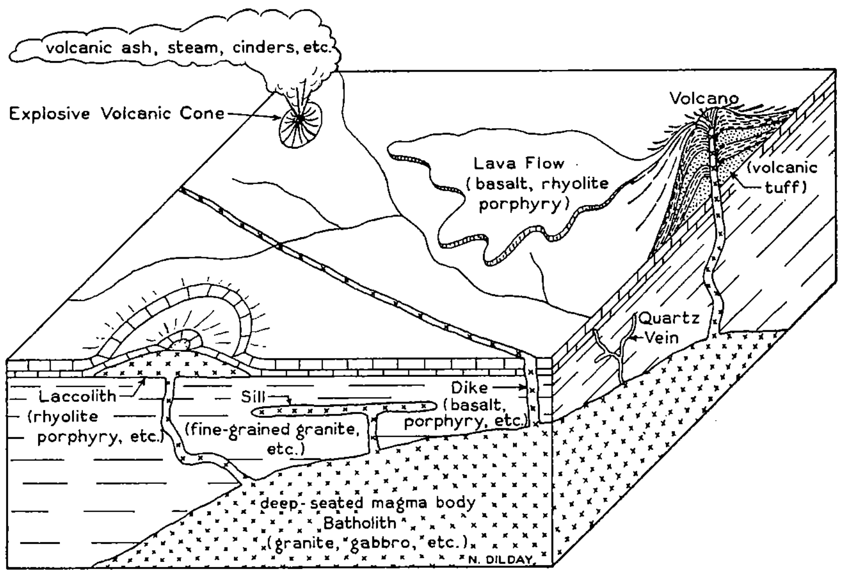
16. Sandstone bluff, Ouachita Mountains. Observe the thin sandstone beds dipping uniformly toward the left. These strata were originally flat and were folded when the Ouachita Mountains were formed.

IGNEOUS ROCKS

The word *igneous* means "of fire" or "born of fire"; and this term is applied to all rocks which have cooled from a hot, molten liquid called *magma.* When magma comes to the earth's surface from volcanoes or from other sources, it is known as *lava.* Magma apparently originates at some depth below the surface of the earth. Theories as to the origin of magma, and estimates of the depth at which it forms, are variable, but most magmas probably occur at depths ranging from ten to fifty miles. Many geologists believe it occupies large, irregular pockets, while others think there is a continuous belt or zone of magma somewhere at depth. In any event, magma sometimes rises through the overlying solid rock, either by eating its way upward or by occupying fissures. In some instances, magma reaches the surface through a pipe-like vent and may form a volcano; or, it may rise through an elongate fissure and flow quietly out upon the earth's surface, forming a lava field. Many times the magma does not reach the surface, but cools and becomes hardened below the surface. The igneous rocks thus formed may never be exposed at the surface. Indeed, the only rocks of deep-seated origin we now see at the surface are in areas where there have been uplifts and the over-lying rocks have been eroded off.

The geological classification of igneous rocks is based on two factors: mineral composition and texture. Texture is controlled largely by the rate of cooling. For example, if magma is extruded upon the surface of the earth, it will cool rapidly and the resulting rock will either be glassy or have a fine-grained (aphanitic) texture. If the magma cools slowly at depth, the resulting crystals will be comparatively large and the texture is said to be *phaneritic.* If the conditions of cooling are not stable, two or more sizes of crystals may be developed in the same rock, giving that rock a *porphyritic* texture. Figure 17 illustrates the relation of texture to depth of cooling.

Two rocks, having exactly the same mineral composition, have different names if their textures are different. Thus a rock containing principally orthoclase



17. Origin, forms, and relationships of igneous rocks. Note that all near-surface igneous rocks are genetically related to a deep-seated magma body, which occurs in the earth's crust, generally at depths of a few tens of miles. Nearness to the surface determines the rate of cooling and therefore the texture of the rocks. Volcanic ash and tuff, which are thrown from volcanoes, are often glassy; and lava flows, which cool less rapidly, crystallize to fine-grained rocks like basalt. Rocks occurring in sills, dikes, and laccoliths cool underground but near enough to the surface to crystallize to fine-grained or porphyritic rocks. Finally, rocks which form in a deep-seated batholith cool very slowly and produce coarse-textured rocks like granite and gabbro.

feldspar and quartz is called *granite* if the texture is phaneritic, and it is called *rhyolite* if the texture is aphanitic. Each of these rocks may show two generations of crystals and therefore each may be a porphyry, e.g., granite porphyry and rhyolite porphyry.

The mineral composition also determines the classification of an igneous rock. A rock composed chiefly of orthoclase feldspar is called *syenite*, but if appreciable amounts of quartz are present, it is called *granite*; if it contains mostly feldspar of the labradorite variety, the rock is called *gabbro*. It is therefore always necessary to determine what minerals are present in order to be assured of a proper classification.

The following diagram shows a simplified key to the classification of the common igneous rocks.

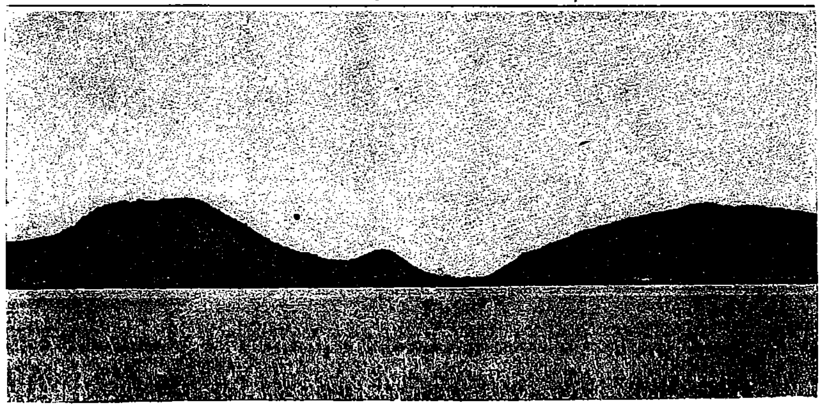
Texture	**Mineral Composition**			
	Orthoclase feldspar		Soda feldspar, hornblende	Soda-lime feldspar (labradorite) and hornblende
	Quartz	No quartz		
coarse or medium grained	granite	syenite	diorite	gabbro
fine-grained	rhyolite	trachyte	andesite	basalt

Only granite, rhyolite, gabbro, and basalt are common in Oklahoma: these are described on the following pages.

GRANITE

Granite (32, 33, 34) is the most abundant of all igneous rocks. It is composed chiefly of orthoclase feldspar and quartz, with minor amounts of hornblende and mica. The color is usually pink or flesh-red; but weathered granites may be white, gray, or brown. The texture may be fine-grained or coarse-grained, either type of which may be a *porphyry*; that is, show feldspar crystals of two different sizes. The rocks are often cracked by *joints, a feature which may aid in quarrying.*

There are three areas of granite outcrops in Oklahoma: Wichita Mountains, in Comanche, Kiowa, Greer,



18. Typical view of granite hills, Wichita Mountains. It shows how the granite hills rise from the red beds plains of shale.

and Jackson Counties; Arbuckle Mountains, Johnston and Atoka Counties; and near Spavinaw, Mayes County. The largest exposure of granite is in the Wichita Mountains, the area covering about 600 square miles (Fig. 18). The Arbuckle Mountains contain about 175 square miles, and at Spavinaw there are several small exposures about one-half mile long. These rocks are among the oldest known in Oklahoma and are of pre-Cambrian age (Fig. 1 and Geologic Time Chart). Quarrying operations are most extensive in the Wichitas; but some rock has been quarried near Tishomingo and Troy, stone from the latter locality having been used in the construction of the State Capitol building at Oklahoma City. (Fig. 19).

The following types of granite are included in the collection:

32. *Medium-grained, red granite* is the most common type of granite found in Oklahoma. Most of the

Wichita granites are of this type, as is that from Spavinaw. The principal minerals are pink orthoclase, quartz, hornblende, and a little black mica (biotite). This granite is used widely for monumental stone, bein~ quarried near Mountain Park and Granite, Oklahom.

19. Granite quarry. The principal granite producers in Oklahoma are located in the Wichita Mountains, where $280,000 worth of monumental and dimension stone was produced in 1938.

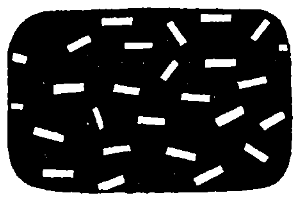
33. *Granite porphyry* is found in the Arbuckles near Troy and Tishomingo. It differs from the other granites of the state in being more coarsely crystalline, chiefly with crystals of pink-white orthoclase. The coarse texture renders it less desirable for monuments, but it makes an excellent building stone. The Tishomingo and Troy granite, used in the State Capitol building, is of this type.

34. *Gray granite* occurs in the vicinity of Cold Springs, Kiowa County, and is known as Cold Springs granite. The rock is composed chiefly of a white feld-

spar and hornblende, the blending effects of which give a blue-gray color. Cold Springs granite is quarried and sold for monuments under the name of "blue granite".

Rhyolite Porphyry

35. *Rhyolite* is a fine-grained rock of the same mineral composition as granite. It differs from granite only in its finer texture; granites cooled slowly at considerable depths, whereas rhyolite cooled near or



20. Rhyolite Porphyry. Lath-shaped crystals (phenocrysts) are pink feldspar; they are surrounded by a matrix of fine-grained feldspar and quartz. Wichita and Arbuckle Mountains.

upon the earth's surface. There are several rhyolite outcrops in Oklahoma. One of them is known as the *Colbert porphyry,* which occurs in the East and West Timbered Hills of the Arbuckle Mountains, near Turner Falls, south and west of Davis, Murray County. Here the rock is brick-red and strongly fractured, and contains medium-sized crystals (phenocrysts) of quartz and feldspar surrounded by a fine-grained *groundmass* (Fig. 20). Similar porphyries occur at Medicine Bluff and Saddle Mountain in the Wichita Mountains. These rocks have little economic value.

Volcanic Tuff

36. *Volcanic tuff* is composed of fine-grained rock and mineral fragments, ejected from a volcano, which have been consolidated into a rock. The shape of the fragments is commonly angular and their size varies from that of dust up to an inch in diameter. Frequently several different sizes are found in the same bed of tuff. Tuffs generally occur in beds that have been stratified by

wind and water. A thick bed of tuff occurs in the southern part of the Ouachita Mountains, in McCurtain County, and in this locality the tuff has a gray to bluish color.

Basalt (Lava)

37. *Basalt* is the geological name for dark-colored lava extruded upon the surface of the earth. Because of the quick cooling, basalt is always fine-grained. The minerals it contains are in general the same as those occurring in gabbro, but in basalts they are usually too small to be readily identified. Basalt occurs in Oklahoma in the extreme northwestern corner of the Panhandle, in Cimarron County, where it forms the caprock for Black Mesa. Here the basalt marks the present eastern extent of relatively recent lava flows which originated from the volcanoes in northeastern New Mexico. The top of Black Mesa, with an elevation of 4,978 feet, is the highest point in the state.

Basalt is tough and compact, breaking with a curved fracture, and has a dull greenish-gray or black color. It is 66 feet thick in Oklahoma, and the upper portion shows numerous round and elliptical holes which were formed by gas bubbles escaping while the rock was still molten.

Gabbro

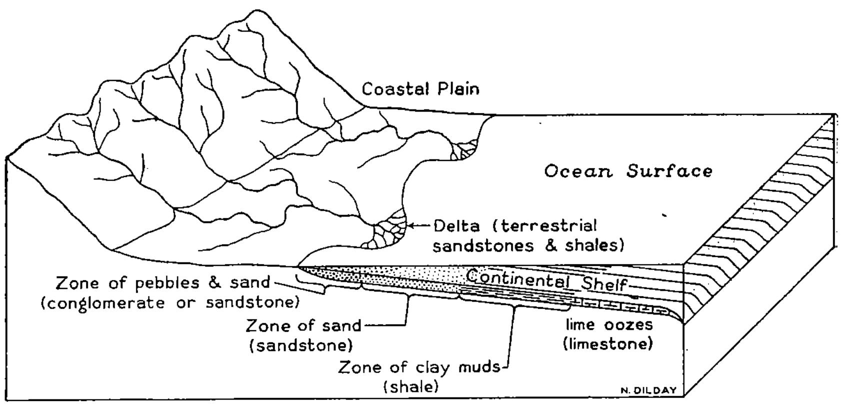
38. *Gabbro* is a medium-grained, dark-colored igneous rock. The constituent in this rock is principally a soda-lime feldspar called labradorite. One variety of gabbro, called anorthosite, consists almost entirely of labradorite. Most gabbros contain hornblende and magnetite, and in some areas of the Wichita Mountains there is a concentration of magnetite high enough to yield a potentially useful iron ore. Gabbro occurs in the central and northeastern part of the Wichitas; it has been quarried for monumental stone at Mount Sheridan.

Sedimentary Rocks

The sedimentary rocks are of secondary origin because their mineral components have been weathered and transported. Actually, they are formed of waste material derived from the erosion of the land. There are four essential phases in the formation of sedimentary rocks.

First, the sedimentary materials must be produced by the weathering of older rocks. This is accomplished both by mechanical and chemical processes. In the chemical process, soluble rocks are dissolved, the mineral material going into solution in ground water or streams. They are also decomposed by *bio-chemical* agencies; that is, by the action of animals and plants. Mechanical erosion consists of the fragmentation of rocks by the action of water, wind, frost, ice, plant roots, and gravity.

Second, the products of weathering are transported.



21. Environments of deposition of common sedimentary rocks. The diagram illustrates the deposition of marine sediments on the submerged continental shelf, with the coarsest sediments near shore, grading into finer sediments seaward. Most of the marine sedimentary rocks we see on land today were deposited in this manner. Sediments formed on land were mostly deposited in stream valleys, and at the edge of coastal plains in deltas. Such sediments may contain plant leaves, etc., but marine fossils are lacking.

Transportation is usually effected by running water, such as streams and shore currents, but some transportation is also done by the wind and by the force of gravity on mountain slopes. The ice of glaciers is also an agency of transportation.

Third, deposition of the sediments takes place in some suitable place or environment. Deposition usually takes place when the velocity of running water or wind is decreased; in the case of running water, the most important transporting medium, the current is generally diminished when a stream flows into a body of standing water like a lake, gulf, or bay. Thus lakes and seas are the most important sites of deposition for sediments. Deposition of chemical salts from solution, however, takes place by evaporation of water or by organisms. The sites of deposition of the common sedimentary rocks are shown in Figure 21.

The *fourth* and last step in this sequence is the transformation of the unconsolidated sediments into consolidated sedimentary rocks. For most rocks this is a more or less slow process, requiring thousands of years. Consolidation results from compaction or cementation, or both. Compaction is caused by the loading of other sediments on top of the strata, and this overlying load tends to squeeze out the contained water, which may be 75 per cent or more of the original deposit. Cementation takes place through the introduction of minerals which bind the particles together.

Most sedimentary rocks we see at the surface of the earth today are of ancient age. From the nature of their contained fossils and other evidence, it is clear that most of the sandstones, limestones, and shales were deposited in marine waters or in deltas. From this conclusion we may infer that the sediments from which these rocks were formed were deposited on an ocean floor or near an ocean beach. These sediments are now surface rocks because the sea floor was elevated and the sea withdrew. Further, it must be recognized from the distribution of marine sedimentary rocks in Oklahoma that all parts of the state at various times in the past have been covered by seas.

The classification of sedimentary rocks depends partly upon origin, upon mineral composition, and upon texture. A rock, precipitated by chemical or organic agencies, and consisting principally of one mineral, is usually given the name of that mineral. Thus we have rock gypsum, dolomite, chert, and rock salt. A rock which is composed of *clastic* or broken grains is classified according to the predominant particle size. Thus a fine-grained sedimentary rock, made up of clay particles, is called a *shale*; if the predominant grain size is that of sand, it is called *sandstone*; rocks composed of rounded pebbles are called *conglomerates*.

Sandstone

Sandstone is a sedimentary rock of mechanical origin. Its principal constituents are quartz sand grains which have been derived from older rocks and transported. The word *sand* is used for unconsolidated sand grains such as occur in a river bed or on a beach; but if the grains are cemented together, the rock is called a sandstone. Common cements are calcite, silica, and iron oxide; and in some rocks all three cements may be present together. In many areas sandstone is used extensively as a building stone (Fig. 22).

Sandstones are rarely pure silica, because at a given time streams may carry many different kinds of material and deposit it with the sand grains. Thus a sandstone may contain mica, feldspar, bits of chert or flint, etc. If one of these constituents is prominent, it is used to describe more completely the character of the rock. For example, a sandstone containing mica is called a mi-

22. Sandstone quarry. Near Coalgate, Coal County. Quarrying operations are greatly facilitated by the vertical cracks, or **joints,** and by the horizontal **bedding planes.**

caceous sandstone and one containing abundant feldspar is called arkose. Other varieties are based on color, giving red, brown, or gray varieties.

The following types are included in the collection:

39. *Glass sand* is a nearly pure silica sand used in making glass. Ordinary sands and sandstones are not suitable because they contain too much iron, which gives the glass an objectionable green color. A high grade glass sand must, therefore, be essentially free from iron; and it must also be low in alumina and other impurities. In Oklahoma, glass sands are found in the Simpson formation in the Arbuckle Mountains, near Sulphur and

Roff; in the Burgen sandstone of northeastern Oklahoma; and in the Trinity sandstone of the southern part of the state. Glass sand is one of Oklahoma's commercial minerals, and is quarried at Roff, Mill Creek, and Sulphur.

40. *Fossilferous sandstone* contains fossils, and these show the nature of the environment in which the rock was deposited. Generally the fossils are clams and snails which lived at or near an ancient beach. The fossils also indicate the geologic age and therefore their presence facilitates the correlation of beds. The Pawpaw sandstone (Cretaceous) of southeastern Oklahoma is a good example, but many other sandstones in the state are fossiliferous.

41. *Asphaltic sandstone*, or sand asphalt, consists of natural asphaltum contained in the spaces between sand grains. It is found where petroleum has migrated into sandstone beds and has lost its light, volatile constituents through evaporation and weathering. This type of material, which occurs in the Arbuckle Mountains and in southeastern Oklahoma, is produced as a valuable source of asphalt surfacing for street and highway construction. Oklahoma production of asphaltic sandstone and asphaltic limestone (see No. 74), collectively grouped as "rock asphalt", had a value of $121,830 in 1926.

42. *Arkose*, sometimes called "granite wash", is a sandstone containing appreciable amounts of feldspar. The feldspar grains are usually pink and more or less angular in shape. The abundance of feldspar indicates that its source rock was rich in feldspar, like granite. The arkoses of Oklahoma are found bordering granite outcrops, in the Arbuckle and Wichita Mountains.

43. *Micaceous sandstone* contains glistening flakes of white or silvery mica. This type of sandstone is very abundant in eastern Oklahoma, where the rocks are largely of Pennsylvanian age. The rocks are usually well bedded and of a brownish or gray color, and may be used for construction purposes.

44. *Glauconitic sandstone* contains the mineral glauconite, which has a green color and occurs in the form of small, rounded grains. In certain areas the glauconite may be so abundant that the rock appears green; if a rock is composed almost entirely of glauconite, it is called *greensand.* Glauconitic sandstone occurs in several formations of the state, chiefly in the Reagan sandstone of the Arbuckle and Wichita Mountains.

45. *Red sandstones* are colored by a cement containing red iron oxide, hematite. They are abundant throughout the central and western part of the state. Iron oxide rarely amounts to more than about 3 per cent, so this rock has no possibilities as an iron ore. If enough iron oxide is present to make the rock compact and durable, it may be used as a building stone; and it has been used for this purpose, locally, in parts of western Oklahoma.

46. *Gray sandstone* is usually cemented with silica or calcite, and there is present a comparatively small amount of iron. It occurs in many sections of the state and is used chiefly as a building stone.

47. *Brown sandstone* is usually cemented with brown iron oxide, limonite; or the sand grains may be only coated with this mineral. Rocks of this type are found in Cretaceous sediments near the Red River in southeastern Oklahoma, and in many Pennsylvanian formations of the eastern part of the state.

"Oil sands" (48, 49, 50), or petroleum-bearing sandstones, are natural reservoirs in the earth's crust in which petroleum is stored. Certain sandstones are more important than others because of their greater extent and greater productivity. Included in this collection are outcrop samples of three "oil sands" which are productive in some important oil fields of Oklahoma, Texas, and Kansas. Petroleum is Oklahoma's greatest mineral product, having a value of $283,500,000 in 1937.

48. The *Bartlesville* sand of northeastern Oklahoma oil-producing districts, and the Salt sand of the Okmulgee district, are equivalent to the Bluejacket sandstone, which crops out in Craig, Mayes, Rogers, Wagoner, and Muskogee Counties, and dips underground to the westward. Oil wells producing from this formation, therefore, are located west of the outcrop, mainly west of these counties. The oil fields of Washington and Nowata Counties, and the famous Glenn Pool of Creek and Tulsa Counties, produce from the Bartlesville sand.

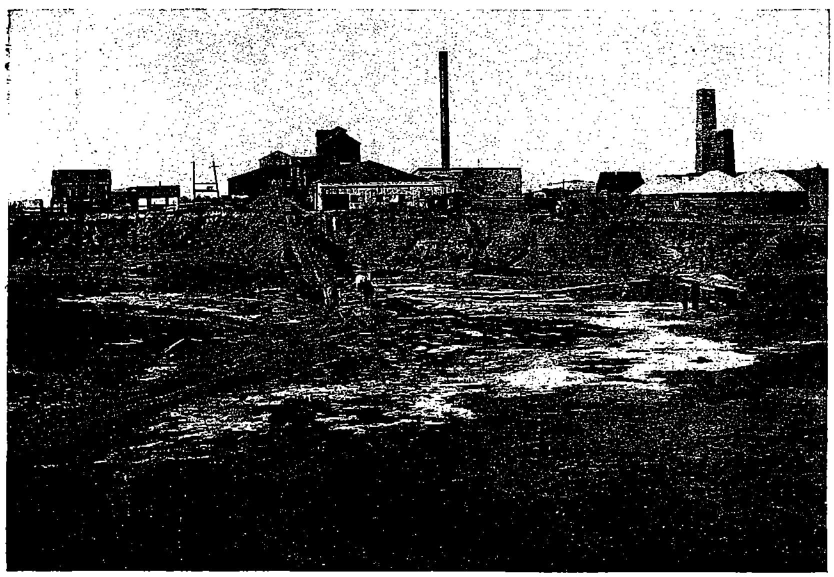
49. "*Wilcox*" or Simpson sand is a white, poorly cemented or friable sandstone containing rounded, pitted, and frosted sand grains. The rock crops out in the Arbuckle Mountains, and extends underground beneath a large part of Oklahoma. In the Oklahoma City field, for example, it is found at a depth of about 6,500 feet and is the most important producing sand in that field. Production from the "Wilcox" is often very large, single wells having yielded a million barrels of oil.

50. The *Woodbine sandstone* crops out in the southeastern corner of Oklahoma, immediately north of Red River. It dips southward and eastward, and forms the reservoir rock for the tremendous East Texas field. The rock is of Upper Cretaceous age.

SHALE

Shale is a fine-grained sedimentary rock of mechanical origin. Clay minerals and quartz are the most abundant constituents; they have been derived from the weathering of older rocks and carried in suspension by water. The particles were later deposited in seas or lakes, and on deltas, and still later they were compacted into rock.

Shales are characterized by being plastic when wet (due to the plasticity of clay minerals) and by being thinly bedded. They may have any color from white to black, but gray, green, red, and black are most common. When weathered at the surface of the earth, shales



23. Brick shale quarry. Mill and kilns in background. Ceramic clay is an important natural resource and is utilized in many parts of Oklahoma for making brick and tile. One plant makes high-grade pottery artware.

lose their bedded structure and become loosely compacted *clays*.

The raw material for brick, tile, and pottery is provided by shale; it is also a basic raw material for the manufacture of cement. In Oklahoma we have numerous brick and tile plants, a pottery at Sapulpa, and two cement-manufacturing plants, one each at Ada and Dewey. Clay products of Oklahoma were worth $720,000 in 1939 (Fig. 23).

51. *Brick Shale* must be relatively free from lime impurities and much sandy material, and it must burn to a pleasing color. It must be sufficiently plastic to allow moulding into desired shapes. Oklahoma has many deposits of clay shale suitable for making brick and tile, and some are suitable for making pottery. The clay now used for making pottery comes from a deposit near Ada.

52. *Red shale*, like red sandstone, is colored by minute particles of red iron oxide (hematite). It is an important ceramic clay in western and central Oklahoma. Gypsum, dolomite, and red sandstone are very often interbedded with red shale; sometimes satin spar is found as veins in this type of rock.

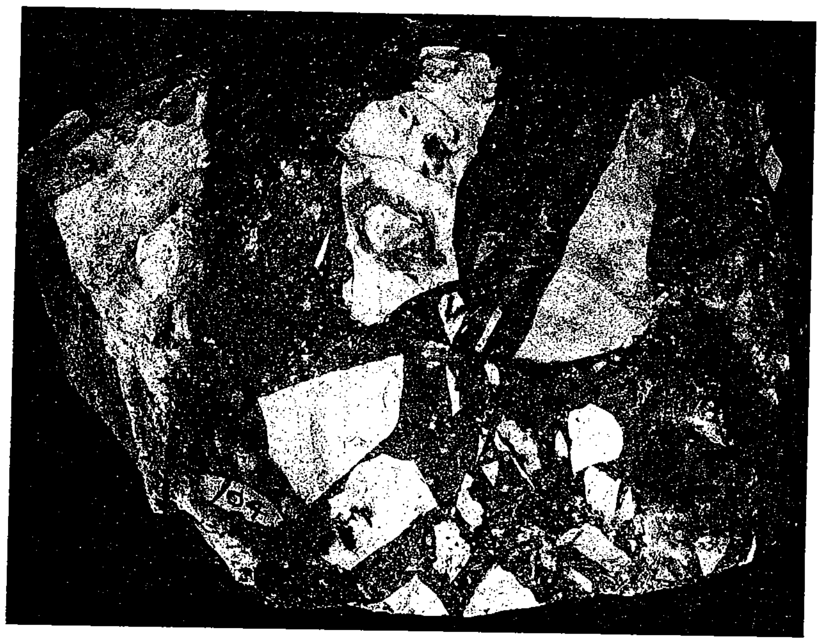
53. *Black shale* is very common throughout the eastern and southern parts of Oklahoma. The black color is due partly to finely disseminated organic matter and partly to the presence of iron sulfide. It is often *fissile*; that is, it is thin-bedded and breaks into thin leaves or sheets. Fossils are rare or lacking, but phosphate nodules (see Phosphate, number 18) are not uncommon.

54. *Green shales* do not contain dark organic matter like the black shales, nor do they often exhibit the property of fissility. They are generally well bedded and are interstratified with marine limestone and buff-colored sandstone. Green shale is common in eastern Oklahoma; it is also present in the Arbuckle Mountains

and in Cimarron County. The Ordovician Sylvan shale, which crops out in Murray, Johnston, and Pontotoc Counties, is used in large amounts for cement manufacture at Ada.

BRECCIA

55. *Breccia* is composed of broken, angular pieces of rock which have been cemented together by secondary minerals (Fig. 24). The *angular* character of the frag-



24. Breccia. The angular fragments are white chert and are cemented with black chert. Zinc mines, Ottawa County. Courtesy University of Oklahoma Press.

ments distinguishes a breccia from conglomerate. In general, breccias are not formed by normal sedimentary processes, because fragmental rock quickly becomes at least partly rounded by transportation. Breccias must therefore occur quite near the place at which the source rock becomes fragmented. Such a place is provided where a rock is fractured by faulting. The rock formed by the cementation of the fractured pieces is called a *fault-breccia* or *fracture-breccia.* Chert breccias of this type occur in the lead-zinc district of Ottawa County, and commonly contain lead and zinc minerals.

CONGLOMERATE

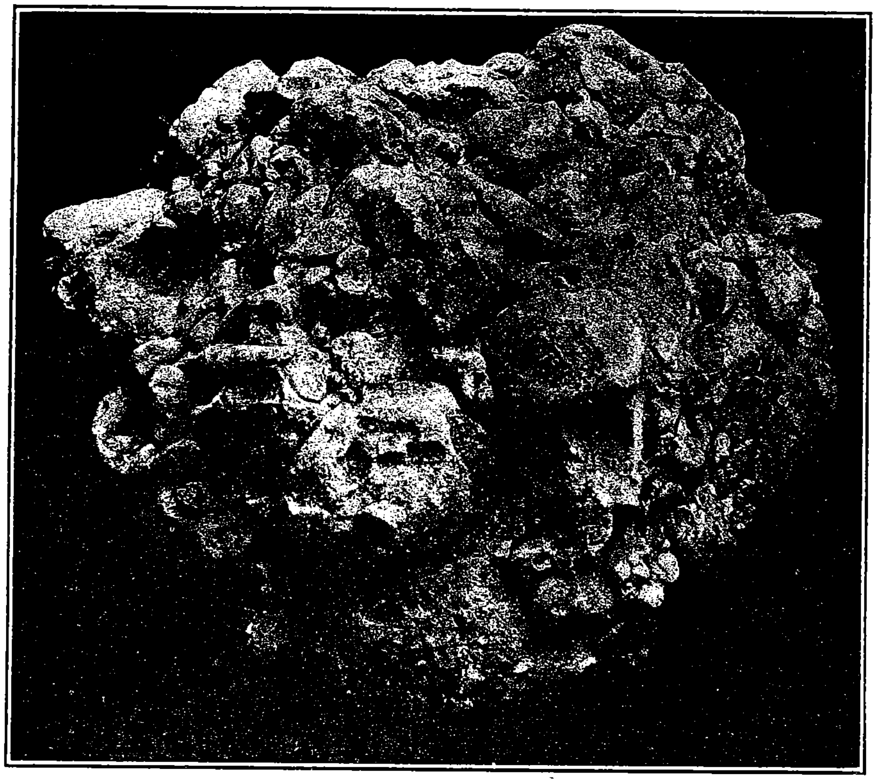
Conglomerate (56, 57, 58, 59) is a sedimentary rock composed of rounded rock pebbles cemented together. The pebbles became rounded during transportation by streams or by wave movement on marine beaches. At

25. Chert conglomerate. The rounded pebbles of chert are loosely cemented with sand and iron oxide. Trinity formation, southeastern Oklahoma.

the time of deposition, the pebbles were uncemented; that is, they were loose gravels. Later they were cemented together to form rock.

Conglomerates are composed chiefly of rocks and minerals which are able to withstand considerable transportation without decomposition. Thus the pebbles are relatively stable, such materials as quartz and chert being very common.

56. *Quartz conglomerate* contains rounded pebbles of the mineral quartz. The quartz pebbles are usually derived from a near-by granite, and they are cemented



26. Limestone conglomerate. The pebbles of limestone have been rounded by rolling along ancient river beds and sea shores, and later cemented by calcite. The rock closely resembles concrete. Pontotoc formation, Murray County.

together by quartz, calcite, or iron oxide. Quartz conglomerates are found in the Reagan formation (Cambrian) in the Arbuckle and Wichita Mountain regions.

57. *Chert conglomerate* is composed of chert or flint pebbles cemented together, usually by silica or iron oxide (Fig. 25). It is found in the Seminole, Vamoosa, and other Pennsylvanian formations in the eastern part of Oklahoma; in the Trinity formation of southeastern Oklahoma; and elsewhere in the state.

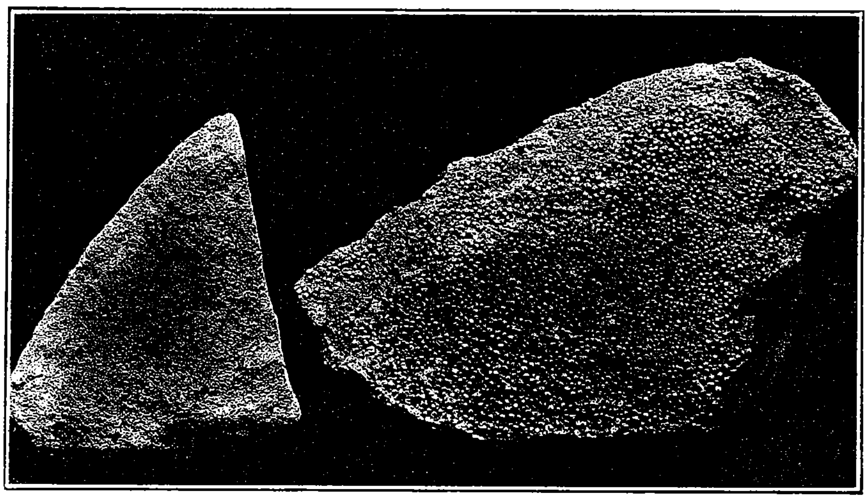
58. *Limestone conglomerate* contains limestone pebbles, usually cemented by calcite (Fig. 26). The pebbles have been derived from adjacent limestone areas. Rock of this type occur along the northern margin of the Arbuckle Mountains in the Pontotoc formation. They have been called "pudding stone" and look like concrete.

59. *Clay conglomerate* is made up of hardened, more or less rounded, balls of clay. The rock is often cemented by dolomite, and it has a pink or purplish color. In all probability this rock was deposited on an ancient delta. It occurs in the "red beds" of central Oklahoma, where it has been used to some extent as a building stone.

LIMESTONE

Limestone is a sedimentary rock made up chiefly of calcite, $CaCO_3$. The majority of limestones exposed at the earth's surface today were deposited in ancient seas, but a few have been deposited from ground water or from streams. Calcium carbonate may be deposited directly from solution, forming a chemical, or *non-clastic*, limestone; or it may be deposited by organisms, forming a limestone of *biochemical* origin; or limestone may consist of the fragmental, or *clastic*, remains of fossils.

Industrially, limestone is an extremely important rock. Not only is it the principal constituent in making cement, but it is also necessary in the smelting and purification of certain metals like iron; slab limestone, or dimensional stone, is used for buildings; and crushed limestone is used for concrete aggregate, road surface, and railroad ballast. Thus the entire construction industry, which uses enormous quantities of steel and concrete annually, depends to a large extent upon limestone. Limestone is burned to lime and slaked for use in plaster, treating water, and industrial processes; it is used to neutralize acid soils; it is a source of carbon dioxide, used in making dry ice; impure varieties are used in the manufacture of rock wool for insulating purposes; and limestone is a raw material for the manufacture of many chemicals. Oklahoma has two cement plants, at Ada and Dewey; there are three lime plants, at Oklahoma City, Ada, and Sallisaw; and carbon dioxide is produced as a by-product of the cement plant at Ada.



27. Oolitic and pisolitic structure. From the Hunton limestone, Arbuckle Mountains. The oolites (left) are about the size of small fish eggs, whereas pisolites are larger.

$1,820,000 worth of stone, mostly crushed limestone, were produced in the state in 1939.

There are many different types of limestones, the varieties being determined by impurities, structure, and mode of origin.

60. *Pisolitic limestone* is composed of small *pisolites,* which are rounded concretions resembling fish eggs and having the size of buckshot (Fig. 27). Each pisolite usually has a small grain in its core, and surrounding the core are alternate concentric layers of calcite. After their formation on a sea floor the pisolites were cemented together with calcite. Pisolitic limestone occurs in Oklahoma in the Hunton formation of the Arbuckle Mountains, and locally this rock has been *replaced,* by silica, but the replacement has not destroyed the shape of the pisolite.

61. *Oolitic limestone* is composed of *oolites,* which are like pisolites except that oolites are smaller, having the size of fine shot (Fig. 27). Oolitic limestone is known in Oklahoma from the Wapanucka and Hunton limestones of the Arbuckle Mountains, and from a few other localities in the state.

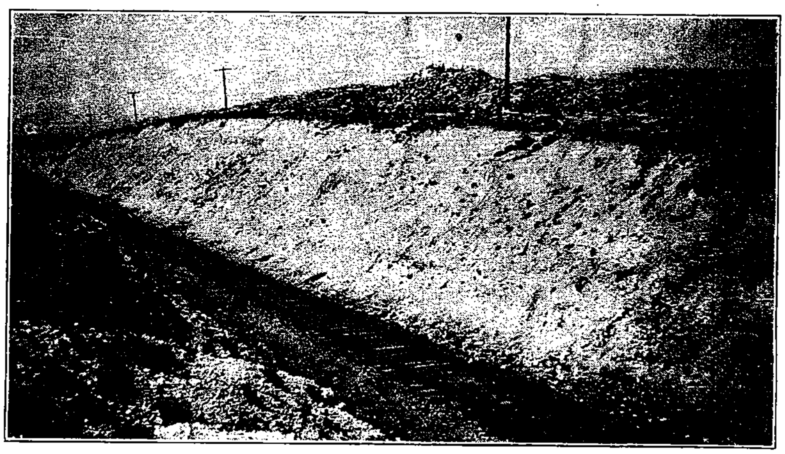
62. *Lithographic limestone,* which is composed of very fine-grained calcite crystals, breaks with a curved or conchoidal fracture. It may occur in thick beds or in more or less thin layers, interbedded with shale. The rock is so named because in past years special varieties were used by the printing trade for making lithographs. Lithographic limestones in Oklahoma are found principally in the eastern part of the state and in the Arbuckle Mountains.

63. *Crystalline limestone* refers to limestone with medium-sized or coarse crystals of calcite. The Pitkin, St. Clair, and Fernvale limestones are examples. The St. Clair limestone, which crops out at Marble City, Se-

quoyah County, is a high grade stone which is used to manufacture lime. To the stone trade coarsely crystalline limestone that will take a polish is called "marble".

64. *Chalky limestone* is more or less soft, light, and porous. It usually has a white or gray color and contains fossils. Part of the Goodland limestone (Lower Cretaceous), which crops out in southeastern Oklahoma, is an example of this type. It formerly was quarried at Ft. Towson, Choctaw County, to manufacture lime.

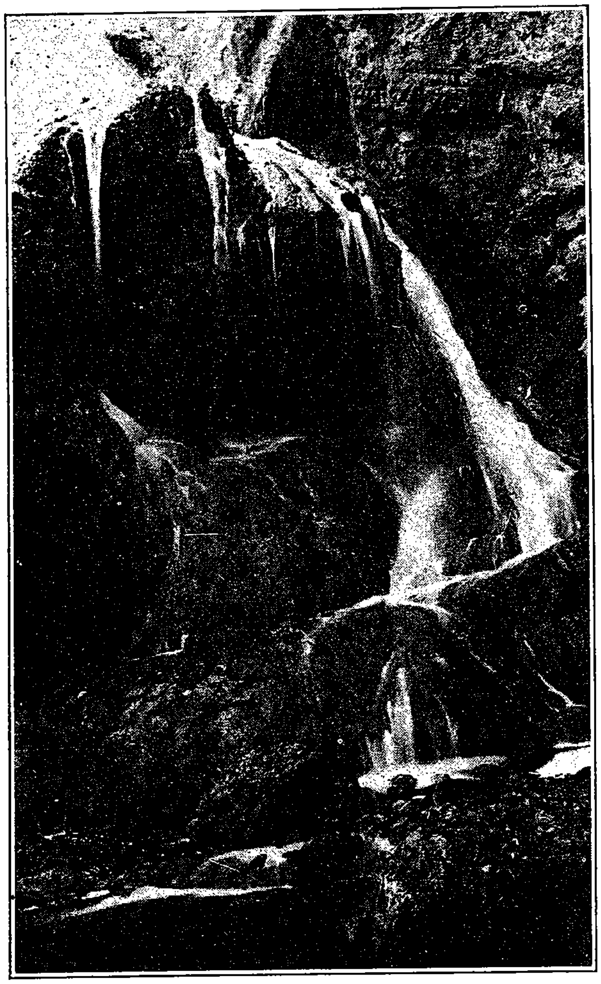
65. *Caliche* is a porous, gray limestone with impurities of sand and clay, and may resemble chalk. It has a wide distribution throughout northwestern Oklahoma and the Panhandle, as well as throughout the High



28. Caliche. This is the surface rock over most of the Panhandle of Oklahoma. It resembles limestone, but is deposited by evaporation of ground waters.

Plains area, where it forms the so-called "mortar beds" (Fig. 28). Caliche is deposited near the surface of the earth from evaporating ground water. Tests made by the Oklahoma Geological Survey indicate that rock wool can be made from some caliche deposits. It is used locally for road surfacing.

66. *Travertine,* or calcareous tufa, is an extremely porous type of limestone deposited by streams or springs (Fig. 29). The waters carry calcium bi-carbonate in solution, and this is especially abundant where ground waters and streams flow in limestone regions. Through the action of algae, which are small plants, or by mechanical agitation, the calcium carbonate is precipitated.



29. Turner Falls, Arbuckle Mountains. The rock over which the water flows is travertine. It is composed of $CaCO_3$ which was deposited from the water by mechanical agitation and through the action of small plants (algae).

Very commonly leaves, twigs, and roots are incorporated in the spongy travertine. In Oklahoma, this rock is found at Turner Falls and Price's Falls in the Arbuckle Mountains, and in Platt National Park at Sulphur.

67. *Lake-bed or lacustrine limestone* has been deposited in a fresh-water lake. It may not differ much from a marine limestone except for a more limited lateral extent and a different fossil assemblage. Geologically young beds of this type are known in Texas and Beaver Counties. The rock is very compact and fine grained, breaking with a curved fracture. Because of a lack of other building stone in this area, this rock has been used for constructing buildings.

68. *Fossilferous limestone* is the name applied to a great group of limestones which contain fossils. The fossils are important because they have helped to build the rock, because they give information about its geo-

30. Shell limestone. Limestone rock composed essentially of fossil oyster shells. Southeastern Oklahoma.

logic age, and because they may aid in determining the origin and environment of deposition of the rock. The fossil remains may be either of plants or animals. The majority of fossiliferous limestones, however, are of marine origin and contain the shells or other hard parts of such animals as pelecypods, brachiopods, crinoids, corals, sponges, bryozoa, etc. Some limestones consist almost entirely of one type of fossil.

69. *Shell limestone* is composed largely of the remains of fossil shells (Fig. 30). Commonly the shells are oysters, Spirifers, or Productids. If the rock is comprised *entirely* of the remains of shells, it is called a *coquina*; coquina-like limestones occur in the Cretaceous beds of southeastern and western Oklahoma, in Pennsylvanian limestones of eastern Oklahoma, and in the Arbuckle Mountains.

70. *Crinoidal limestone* contains abundant remains of fossil crinoids. Most abundant of these remains are the stems, which may make up 90 per cent of the rock. Many of the Mississippian and Pennsylvanian formations of the state are crinoidal, and they are often quite pure calcium carbonate.

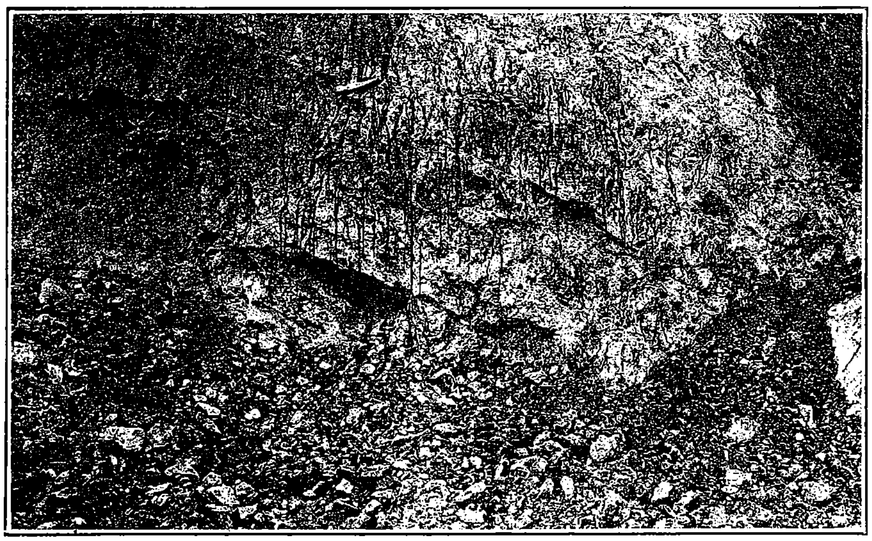
71. *Algal limestone* contains the fossil remains of minute plants known as algae. It is believed that these plants were able to extract calcium carbonate from the sea water and precipitate it. Locally, as in parts of the Arbuckle and Simpson limestones, fossil algae make up a considerable part of the rock. In the rock included here, the algal colonies are rounded and about the size of a marble. A microscopic examination is sometimes necessary to distinguish them from pebbles. Other algal colonies have quite different shapes and sizes.

72. *Glauconitic limestone* is a limestone containing rounded grains of the mineral glauconite. The grains of green glauconite were deposited on the sea floor with

the limestone. Glauconitic limestone occurs abundantly in the Honey Creek formation of the Arbuckle and Wichita Mountains and in the Hunton limestone of the Arbuckle Mountains.

73. *Sandy limestone* is a rock gradational between limestone and sandstone. The essential constituents are quartz sand grains cemented with calcite. Rocks of this type when of proper composition make excellent rock wool, and the Verden "sandstone" of Grady County is used for this purpose in the plant at Sand Springs.

74. *Asphaltic limestone* is limestone impregnated with asphalt (Fig. 31). It has an asphaltic smell and a



31. Asphaltic limestone. The asphalt contained in the limestone melts and flows over the quarry face during warm weather.

black color, and may be used for road surfacing. See "asphaltic sandstone" (No. 41) for commercial value of this material. The specimen of asphaltic limestone in this collection contains fossil cephalopods with what is thought to be the original color of the shell, beautifully preserved. (See cephalopods, No. 99).

75. *Marl* is a soft, incoherent rock composed of a mixture of shale and limestone. It is often called a shaly limestone. Marl may have the proper composition required for Portland cement, and it is used for this purpose in some states. It is found in the Haragan and Henryhouse formations of the Arbuckle Mountains, and in Pennsylvanian and Cretaceous formations.

76. *Red limestone* has been discolored by impurities of red iron oxide, hematite. Red is an uncommon color in limestone, for most of them are either white or gray. The Neva, Pawhuska, and Cushing limestones of northern and central Oklahoma are locally colored red.

Dolomite

77. *Dolomite* is a sedimentary rock deposited from solution. Its composition is $Ca,Mg(CO_3)_2$. Dolomite has been deposited in ancient inland seas as an original deposit, or as a replacement of limestone. The sedimentary layers of dolomite are interbedded with limestone or shale. The rock is often coarsely crystalline and may have a white, cream, or pink color. Dolomite beds are present in the red beds of western Oklahoma, in the Arbuckle formation of the Wichita and Arbuckle Mountains, in the Tyner and Cotter formations of Ordovician age in the Ozark area, and locally in the Wildhorse and Hogshooter limestones of Pennsylvanian age, in north-central Oklahoma.

Most dolomite is tough and compact and can be used for a building stone. It is also used as a flux in iron ore smelting, as a refractory, in the chemical industry, in paper manufacturing, etc.; and it is a potential source of metallic magnesium.

Rock Gypsum

Rock gypsum occurs in sedimentary beds which have been deposited in ancient seas under arid climates. There are billions of tons of gypsum in the Permian rocks of western Oklahoma, chiefly in the Cloud Chief and Blaine formations. This material is being mined and is used in making plaster of paris and other gypsum products in Blaine County. For further description and the specimen of rock gypsum, see number 14.

Chert

Chert is a fine-grained variety of quartz. It occurs principally in two forms: as massive strata, or as nodules and concretions. It is usually associated with limestone or shale. The beds are commonly jointed or otherwise broken into blocks, and these blocks make excellent road material because they are so hard and so resistent to weathering. Chert is very abundant in the Ouachita Mountains, the Ozarks, and in the Woodford formation of the Arbuckle Mountains. For further description and the specimen of chert, see number 4.

Coal

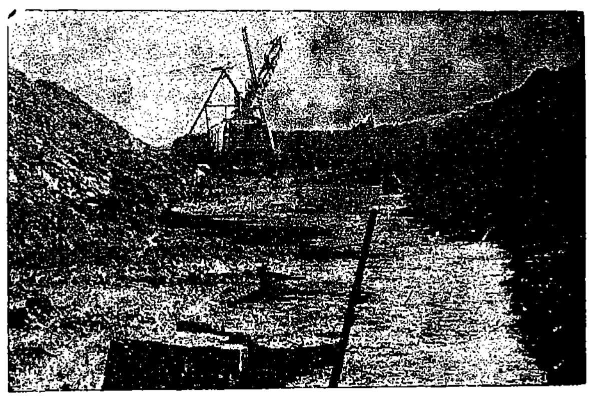
78. *Coal* is a natural hydrocarbon, derived from vegetable matter, which has undergone certain chemical and physical changes. Vegetable material is known to have contributed to the formation of coal because it often contains preserved leaves and stems of plants. It is also believed that this woody material accumulated under water in swamp-like areas, free from air, for a considerable period of time, to be covered later by sediments. If not thus covered and protected, the woody material would rot, and be decomposed and destroyed; and no coal would form. After its preservation, however, and with subsequent deeper burial, the vegetable

matter was further decomposed and carbonized by rock pressure until coal was formed.

The kind of coal formed depended upon the amount of pressure to which the rocks were subjected. Soft, or *bituminous*, coal has been only slightly metamorphosed, whereas hard coal, or *anthracite*, has been subjected to very high pressures, and has undergone resulting changes which drove off contained gases and other volatile matter, leaving almost pure carbon.

Oklahoma coals are mostly of the bituminous variety, but near the Arkansas line the folding of the rocks has been greater and the coal in that region is of a higher grade, namely, semi-bituminous, which contains higher percentage of carbon, and less volatile matter. The coal seams are mined either by surface stripping (Fig. 32) or by underground mining.

The principal use for coal is as fuel, and in the early

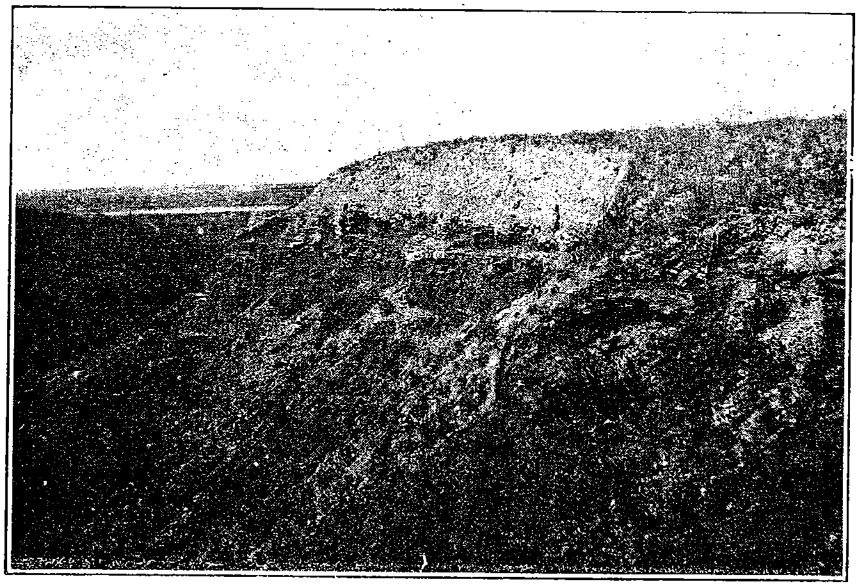


32. Coal seam. The horizontal seam of coal is being mined by stripping off the overburden of soil, sandstone. and shale with a steam shovel, thereby exposing the coal for direct mining.

days of Oklahoma coal was much sought after. With the discovery of large pools of oil and gas in the state, demand for coal decreased until at the present time we are producing only a fraction of our large reserves. Recently, however, there has been an increased demand for smokeless coal, and some of our coal is being shipped to St. Louis where it is used for this purpose. Some Oklahoma coals have coking properties, and coke was manufactured in the state in the early part of this century. At the present time there is a revival of interest in coke possibilities, in connection with the smelting of iron ores of this region.

Volcanic Ash

79. *Volcanic ash*, or *pumicite*, is composed of small, angular particles of volcanic glass. The fragments have been hurled violently from explosive volcanoes and car-



33. Volcanic ash. The white bed of ash lies on top of the hill. The ash was blown into Oklahoma from volcanoes probably located in New Mexico, and accumulated in local, thick deposits by the action of wind and water.

ried by wind, often hundreds or thousands of miles from their source. Volcanic ash may be deposited from the air and then later reworked and accumulated in thick beds by water (Fig. 33). Such a deposit is classified with the sedimentary rocks because of its transportation and sorting.

Volcanic ash occurs in many parts of Oklahoma, apparently having been derived from geologically young volcanoes in New Mexico. Large deposits in Woodward, Dewey, Hughes, Beaver, and Wagoner Counties have been quarried for use as abrasives, in oil refining, drilling mud, and topping for asphalt paving.

BENTONITE

80. *Bentonite* is a plastic material belonging to the clay family which may swell when placed in water. It was formed by the alteration of volcanic ash. Bentonite is used in drilling muds as a water-proofing material, and as a bleaching agency in refining oils. Oklahoma has some deposits of a type of bentonite, called *metabentonite,* or *subbentonite,* which have been used for drilling mud.

METAMORPHIC ROCKS

Metamorphic rocks are those which have undergone considerable change because of heat and high pressure. The principal change to take place is recrystallization, which causes the grains to become larger in size. There may also be some changes which result in the formation of new minerals. Fibrous or platy minerals become elongated in a common direction, generally at right angles to the direction of pressure, and give the rock a foliated appearance.

The causes of metamorphism—heat and pressure—operate to a certain extent on all rocks buried to depths of several miles, for there the heat is greater than it is above, and a considerable pressure is exerted by the load of overlying rocks. This does not mean that all buried rocks are metamorphosed, but it does mean that these rocks have a good chance to become metamorphosed.

Metamorphism is a common phenomenon in areas of strong folding and faulting caused by dynamic pressure. Rocks of the Ouachita Mountains have undergone such metamorphism. Another direct cause of metamorphism is the intrusion of igneous rocks, which causes the near-by rocks to become changed by the great heat of the intrusion. The Meers quartzite of the Wichita Mountains was formed in this manner.

Common metamorphic rocks are slate, marble, quartzite, gneiss, and schist. There are some schists, slates, and quartzites in Oklahoma; but there are no known examples of gneiss or metamorphic marbles. The St. Clair limestone, which crops out at Marble City, is coarsely crystalline, resembles a marble, and is known to the stone trade as marble; but it has not undergone the metamphoric changes resulting from high temperature and pressure.

QUARTZITE

81. *Quartzite* occurs only in the Wichita Mountains, near the town of Meers, Comanche County. It is usually of a dull gray color and is composed essentially of quartz grains thoroughly cemented together by silica. It can be determined that at one time the grains were rounded, indicating that the rock was formerly a sandstone. The explanation for its metamorphism is that the sandstone was intruded, at depth, by a hot, gabbro magma which recrystallized the rock to a quartzite.

In general, a quartzite is harder and more compact than a sandstone; a quartzite will break *through* the grains as well as its cement whereas a sandstone breaks through its cement, *around* the sand grains.

Quartzitic sandstones, which are not of metamorphic origin, have been formed by secondary cementation of sandstones by silica-bearing ground waters. Such rocks may have many of the properties of a true metamorphic quartzite.

Slate

82. *Slate* is familiar to everybody as a roofing material. It is a metamorphic rock derived from shale. Important changes in the metamorphism are the hardening of the rock and development of pronounced parting planes by which slate breaks into thin sheets. Oklahoma "slates" occur in the Ouachita Mountains. They have a black or greenish color and otherwise resemble commercial roofing slate except that they are softer and therefore are not suitable for roofing purposes.

Schist

83. *Schist* is a thin-leaved or foliated metamorphic rock, usually containing abundant mica. Parts of the Womble formation of the Ouachita Mountains are very much like a schist. The rock has a brownish-gray color and contains mica and sand grains. It probably was formed by the metamorphism of a sandy shale.

FOSSILS

THE NATURE OF FOSSILS

Paleontology deals with the identification, description, classification, and economic and scientific use of fossils. A *fossil* may consist of a skeleton, shell, or any other evidence of *prehistoric life*. There are two principal requirements in the definition of a fossil: it must be some form or evidence of the former existence of life, either plant or animal; and it must have lived and died before historical records were first kept by man. Thus the skeleton of a horse which died and was buried one hundreds years ago is not considered a fossil. A horse which lived 2,000,000 years ago, however, *would* be a fossil, for it lived before historical time.

A very important aspect in the formation of fossils is *preservation.* Perservation usually requires that the organism be buried quickly in some sedimentary material such as mud or calcareous ooze, free from air so that it is protected from immediate decay. Once buried and protected, the plant or animal may be preserved in the rock and thus become a part of the fossil record. If the organism is not protected or preserved, it will decompose completely, and proof of its existence will be forever lost. The hard parts of an animal, such as shells, are generally composed of calcium carbonate secreted by the animal, and may be preserved rather easily. Plants, however, have no hard parts, and exceptionally favorable conditions must prevail in order for them to be preserved.

A common method of preservation is by *replacement.* The shell or other hard part of an animal, if easily soluble, may be dissolved by ground water and all trace of it be lost. But if some slightly soluble material like quartz replaces a calcareous shell, then there is little chance for solution to destroy it. Pyrite, quartz, opal, and other minerals may preserve fossils in this way.

The preserved footprint of an animal, made in soft rock, is considered a fossil because it is an evidence of life. Likewise, the cast of a shell, or its mold, is also a fossil. Other methods of fossilization include: burial of insects in resin, which later hardens to amber; burial of animals in asphalt seeps; the freezing of animals in ice, in the manner that a mammoth was entrapped in ice during the Glacial Age and was recently discovered in Siberia; the preserved teeth and scales of fish; and the carbonized imprints of plants in coal or other rocks.

Many hundreds of fossil genera and species are known in Oklahoma, but only a few of the more common and more easily recognized types are included here.

DESCRIPTION OF COMMON FOSSILS FROM OKLAHOMA

FOSSIL WOOD

84. *Fossil wood* is found in Mississippian, Pennsylvanian, Cretaceous, and Tertiary formations in Oklahoma. In many specimens the woody structure can easily be seen, having been preserved by the replacement of silica. The giant fossil tree *Callixylon* from the Woodford formation may be seen in the restored state at the entrance of the campus of East Central State Teachers College at Ada. It is one of the oldest large fossil plants known. A miniature forest of fossilized trees has been erected near the Geology Building on the campus of the University of Oklahoma at Norman.

FOSSIL PLANTS

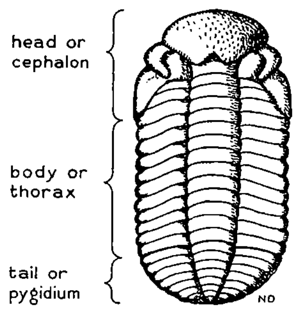
85. *Fossil plants* are found in Pennsylvanian, Permian, Cretaceous, and Tertiary rocks in Oklahoma. The plant remains, usually twigs or leaves, are actually only *imprints*, and are often composed of carbon. They occur principally in sandstone, shale, limestone, or clay ironstone.

FUSILINA

86. *Fusulina* is a small, one-celled or Protozoan animal which lived in ancient seas. The name fusulina means "spindle-shaped" and refers to the form of the tiny shells, which are often shaped like a grain of wheat. Some limestones in the state, especially those of Pennsylvanian age, contain abundant Fusulina.

TRILOBITES

87. *Trilobites* are extinct marine animals, somewhat similar to crayfish, which lived on ocean floors. In general, the body of a trilobite is divided into three parts or segments: the tail, the main body or thorax, and the head (Fig. 34). With death, these three parts were commonly detached, and perhaps only one of these parts was preserved as a fossil. The tail, or pygidium, is very often preserved, although heads and sometimes entire specimens may be found. Most trilobites lived in lime



34. Trilobite, about natural size. This type of fossil animal, now extinct, is related to modern crayfish. Note the three principal parts of the animal's anatomy.

oozes or mud on the sea floor, and therefore their fossil remains are found in limestone and shale. This type of fossil is found in rocks ranging in age from Cambrian to Permian. In Oklahoma, trilobites are found in the Cambrian, Ordovician, Silurian, and Devonian limestones in the Arbuckle and Wichita Mountains; and in eastern and northern Oklahoma in limestone and shale of Mississippian and Pennsylvanian age.

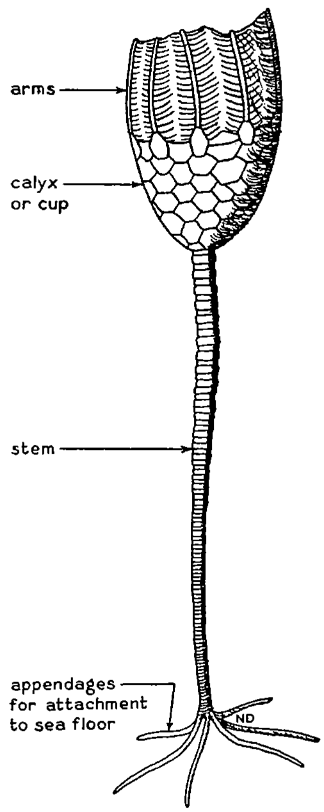
CORALS

88. *Corals* are lime-secreting animals of many different forms. They may be shaped like an organ pipe, they may be dome-shaped, or branching, or have the shape of a cow's horn. Horn corals are abundant in many Paleozoic limestones of Oklahoma.

BLASTOIDS

89. *Blastoids*, or sea-buds, were marine animals which lived from the Ordovician through to the Permian, at which time they died out completely. The head, or *calyx*, which resembles a rose bud, was attached to the sea floor by means of a slender stem. Blastoids are abundant in certain limestones in eastern Oklahoma. When weathered free from the rock, they may be thickly strewn along the surface of the ground. Locally they are sometimes known as "fossilized pecans" or "acorns."

CRINOIDS

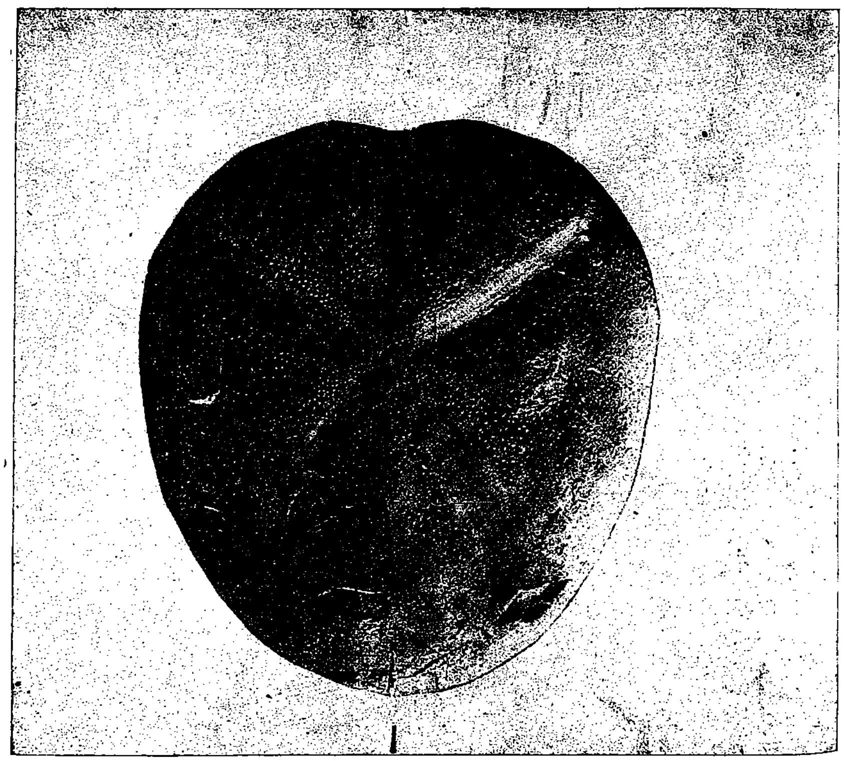


35. Crinoid. Reconstruction of the entire animal, reduced. Complete fossil specimens are rarely found, but stem fragments are abundant in many Mississippian and Pennsylvanian limestones.

90. *Crinoids* were marine animals similar to blastoids, with an attached base, a long, thin stem, and a

head or *calyx* (Fig. 35). Numerous food-gathering arms or tentacles grew from the calyx. Bases, calyces, and tentacles are rarely found; but the segmented stems are very abundant, often comprising the greater part of a limestone (see crinoidal limestone, number 70). Crinoids flourished during the Paleozoic era, especially during Mississippian and Pennsylvanian time, but they later died out. The sea lily from modern seas, however, is quite similar to the extinct crinoids.

ECHINOIDS



36. Echinoid. These ancient sea animals are found in many of the Cretaceous rocks of southeastern Oklahoma. They are characterized by a biscuit-like shape and the five grooves radiating from a central point. The small bumps on the surface represent the bases of spines, which have been broken off. Echinoids are related to the modern "sand dollars."

91. *Echinoids*, which are related to modern sea-urchins, were marine animals having the shape of a flattened egg or a biscuit, and having five grooves radiating from the center of the upper surface (Fig. 36). When alive, these animals were covered with many spines, hence the name echinoid, meaning "like a hedge hog". They are very abundant in some of the Cretaceous rocks of southeastern Oklahoma. The "sand dollar" is a modern representative of this kind of animal.

BRYOZOA

92. *Bryozoa* are sometimes called moss animals because, like moss, their colonies often grew on some foreign object. They sometimes encrust other fossils, have a lace-like or branched form, or occur in oval or irregular masses. The calcareous skeleton is composed of thousands of small pores, or cups, each of which sheltered a single living animal. They are known from the Ordovician to the present time, and are quite common in the Paleozoic rocks of Oklahoma.

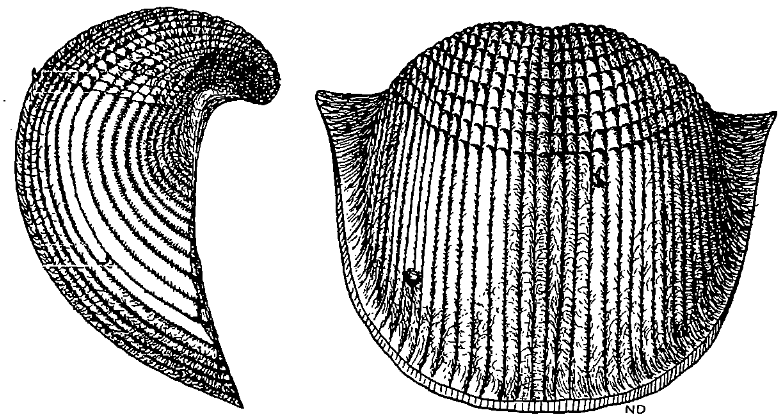
BRACHIOPODS

Brachiopods (93, 94, 95) are marine animals with two valves or shells enclosing the living organism. The shells are usually composed of calcium carbonate, which was secreted by the brachiopod and which grew in size each year. They have many different shapes, but all are characterized by having two valves of *unequal* shape, but each valve can be bisected into two *equal* parts (Fig. 38). Hundreds of different types are known from the Paleozoic rocks of Oklahoma, but only a relatively small number of forms are living today. Three common fossil types are included in this collection.

93. *Orthostrophia* is the name given to a group of brachiopods which was very abundant during Devonian

time. These fossils, which occur in great numbers in the Haragan marl of the Arbuckle Mountains, are flat, semicircular, deeply grooved, with radiating lines, and often perfectly preserved.

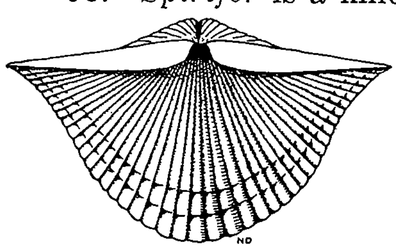
94. *Productids* are very common brachiopods in the Mississippian and Pennsylvanian rocks of the state. Entire specimens may be found in limestone and shale beds, but in sandstones only the imprint may be preserved.



37. Productid brachiopod, natural size. A very abundant type of fossil in many Mississippian and Pennsylvanian limestones in Oklahoma.

The shell is hemispheric in shape and is characterized by an overhanging beak (Fig. 37). The outer portion of the shell was grooved with parallel lines and covered with spines, but the spines are generally broken off.

95. *Spirifer* is a kind of brachiopod which is usu-



38. Spirifer brachiopod, showing typical characteristics of this group of fossils: two valves of unequal shape, and bilateral symmetry.

ally wider than it is long, and the ends taper to a point along a straight hinge line. The surface of the shell is often deeply grooved, and it also possesses a well-developed fold in the middle (Fig. 38). Spirifers are found, in Oklahoma, in Devonian limestone of the Arbuckle Mountain region and in the Mississippian and Pennsylvanian sediments of the eastern third of the state.

Pelecypods

Pelecypods (96, 97) are small animals which live in mud, sandy beaches, and lime oozes, in marine or fresh water. Clams and oysters are the most common representatives of this group. They have two shells, or valves, which are mirror images of each other; the animal lives inside and is protected by these valves.

Included in this collection are two important types of pelecypods.

96. *Oysters* are pelecypods of irregular shape and often with a rough, corrugated surface. In the Cretaceous rocks of southeastern and western Oklahoma, oyster shells are so abundant as to compose nearly the entire bulk of the rock, forming *coquinoid limestone* (see specimen 69 and Fig. 30.

97. *Fossil clams* show a wide range in size, varying from about one-quarter inch up to several feet in length. Most specimens, however, are not longer than a few inches. In Oklahoma, fossil clams are known from practically all of our sedimentary rocks, but they are particularly abundant in the Mississippian, Pennsylvanian, and Permian.

Gastropods

98. *Gastropods*, or snails, are known from the Paleozoic, Mesozoic, and Cenozoic rocks of Oklahoma. The coiled shell, in which the animal lives, is quite variable in shape: some have high spires, others are low-

spired; some are thick and fat, others are thin; some are one-quarter of an inch long, others may be eight inches, etc. Fossil gastropods usually lived in water, few of the land snails having been preserved as fossils.

CEPHALOPOD

99. *Cephalopod* means "head-footed" and refers to the presence of feet, or tentacles, which branch out from

39. Ammonite, a coiled cephalopod. Such fossils may attain a diameter of 18 inches. Common in the Cretaceous limestones of Love County. Related to modern chambered nautilus.

the head of the animal. The best example of a living cephalopod is the chambered nautilus. Fossil cephalopods are known from Cambrian time. The first cephalopods had a straight shell, and resembled a giant cigar. By Mississippian and Pennsylvanian times the shell had become coiled like the modern nautilus, and by Cretaceous time they had achieved great size. Some Cretaceous cephalopods, known as *ammonites*, were very specialized, having a diameter of two feet and showing many highly developed wavy lines or sutures (Fig. 39). Ammonites are very abundant in some of the Cretaceous rocks of southeastern Oklahoma. *Goniatites* are coiled cephalopods, generally not more than a few inches in diameter. They usually occur in limestone and in calcareous concretions in Mississippian and Pennsylvanian shale.

Horse Teeth

100. *Fossil horse teeth* are found in many places in Oklahoma in Tertiary and Quaternary sediments. Thousands of teeth have been excavated from a quarry near Optima, Cimarron County, by J. W. Stovall, professor of vertebrate paleontology at the University of Oklahoma, who donated these specimens. The teeth in the collection are from an extinct, primitive horse called *Pliohippus*, which lived during the Pliocene epoch of the Tertiary period. *Pliohippus* was about the size of a burro and roamed the plains of western Oklahoma several million years ago.

GLOSSARY

By

ELOISE TITTLE

Alteration — change by which one rock or mineral is converted into another, or new texture is developed.

Ammonite — fossil cephalopod shell with extremely complex sutures and usually ornamented on the outside with ribs, knobs, spines, etc. Related to the chambered nautilus from modern seas.

Amorphous — without crystal form.

Anorthosite — dark colored, medium-grained igneous rock composed essentially of labradorite. A variety of gabbro.

Anthracite — hard black lustrous coal with conchoidal fracture. Known as hard coal.

Anticline — a fold or arch of rock strata, dipping downward in opposite direction from an axis.

Arkose — sedimentary rock containing essentially quartz sand and feldspar fragments. Derived from granitic rocks.

Bituminous coal — compact, brittle coal of gray-black to velvet-black color with splintery or cubical fracture.

Bonanza — a rich body of valuable mineral which is profitably producing ore.

Brine — water saturated or strongly impregnated with salt.

Calyx — cuplike structure of invertebrate animals which encloses the body.

Cellular — porous, like a sponge, or consisting of numerous, small cells.

Ceramic — relating to the manufacture of any or all products made from earth by the agency of fire.

Clastic — made up of transported fragments of minerals and rocks. Refers to certain sedimentary rocks, e. g., sandstone, conglomerate, etc.

Clay — fine, soft, aluminous sediments that are plastic.

Clay ironstone — compact, impure variety of iron carbonate, mixed with clay, sand, and limonite, generally of dull brown color.

Cleavage — property of many crystalline substances of breaking or splitting in definite directions, yielding more or less smooth surfaces.

Conchoidal — curved, shell-like. Refers to the fracture of many minerals.

Concretion — rounded mass formed by accumulation about a center.

Consolidated — made solid or compact; solidified.

Coquina — fragile variety of limestone consisting of shells and their fragments somewhat compressed and cemented together as rock.

Cryptocrystalline — finely crystalline. Appears amorphous in hand specimen.

Crystal — substance bounded, entirely or partially, by natural plane surfaces arranged in a definite geometric system.

Crystal faces — natural plane surfaces which bound a crystal.

Delta — an alluvial deposit at the mouth of a river.

Dimension stone — stone that is cut or quarried in accordance with required dimensions, used for construction and ornamentation.

"Dogtooth" spar — a variety of calcite with sharp-pointed crystals.

Dormant — appearing or being in a state of suspended animation, as a dormant volcano.

Fault — a dislocation of a bed or vein attended by movement which breaks its continuity.

Fissile — capable of being split into thin leaves, as schist, slate, and shale.

Fissure — crack or crevice in rocks.

Flux — any substance or mixture used to promote fusion, especially the fusion of metals or minerals.

Foliated — in plates or leaves which separate easily.

Fossil — any remains, impression or trace of an animal or plant of past geological ages which have been preserved by natural means.

Fracture — the character or appearance of the surface of a rock or mineral freshly broken in a direction other than parallel to cleavage or parting. Also applied to breaks in rock strata. Similar to fissure.

Friable — easily crumbled or reduced to powder.

Frosted — etched, or pitted, as the surfaces of some sand grains.

Goniatites — a type of ammonite having a discoidal coiled shell with angular-lobed sutures.

Greensand — generally refers to sedimentary deposit consisting, when pure, of grains of glauconite which have a dark greenish color.

Groundmass — the fine-grained or glassy base of a porphyry in which the distinct crystals, or phenocrysts, are embedded.

Hardness — resistance a mineral offers to abrasion or scratching.

Hydrous — containing water chemically combined.

Igneous rock — one formed by the solidification of a molten magma coming from within the earth.

Imprint —image or figure of anything formed by pressure, or impress. Pertains to fossil imprints.

Joint — small fracture in a rock not accompanied by dislocation.

Labradorite — a dark-colored feldspar, with the composition $(Na,Ca)Al_2Si_2O_8$. Principal constituent of gabbros and anorthosite.

Lodestone — variety of magnetite which is magnetized like a magnetic needle.

Luster — manner in which a mineral or rock surface reflects light.

Magma — molten mass formed within the earth from which igneous rocks are formed or derived.

Metabentonite — clay-like material believed to have been formed by alteration of volcanic ash; also called subbentonite.

Metallic — kind of luster; term applied to minerals that are opaque and have the luster of a metal, as gold, copper, etc.

Metamorphic — rock that has been altered after solidification, by heat, pressure, liquids, or gases, so as to render its texture either crystalline or schistose.

Mineral — natural inorganic substance with a definite chemical composition and most commonly with a definite crystal structure.

Nodule — rounded mass of irregular shape.

Non-metallic — of, pertaining to, or of the nature of, a nonmetal. Luster of many minerals which appear glassy, resinous, diamond-like, etc. Opposed to metallic luster.

Novaculite — a variety of extremely fine-grained siliceous chert-like rock, conchoidal in fracture, generally white or pale gray, and semi-translucent. Used extensively in the manufacture of whetstones.

Opaque — will not transmit light even through thin layers or edges. Opposed to translucent and transparent.

Ore — a metal-bearing mineral deposit which may be mined with profit.

Pegmatite — very coarse grained igneous rock, consisting essentially of quartz, feldspar, and mica.

Phenocryst — one of the prominent embedded crystals of a porphyry.

Plastic — capable of being molded or shaped.

Prism — a form in which the faces are parallel, similar, and equal polygons, such as the side faces of quartz crystal.

Pumicite — synonymous term for volcanic ash. Material composed of fine, glassy, irregular particles from explosive type volcanoes.

Pyramid — a type of crystal form in which 4 or more triangular faces meet at a point.

Red beds —sedimentary strata, largely of Permian age, containing few fossils and prevailing red in color.

Refractory — a material or compound capable of enduring a high temperature without softening.

Replacement — the process by which one mineral takes the place of some other mineral.

Rhombohedron — a crystal form bounded by six faces intersecting at angles other than 90°. Characteristic form of calcite.

Rock — any naturally formed consolidated aggregate or mass of mineral matter.

Sedimentary — formed by deposition of grains or fragments of rock-making material by water or air, or by precipitation from solution.

Siliceous — containing silica, or having the properties of silica.

Specific gravity — the ratio of the weight of a material to the weight of an equal volume of water.

Stalactite — a deposit of crystalline calcium carbonate resembling an icicle.

Strata — layers of sedimentary rock.

Stratified — arranged in, or composed of, strata, or layers.

Streak — the color of powdered mineral obtained by rubbing on unglazed porcelain (streak plate).

Subbentonite — see metabentonite.

Syncline — Downfolded rock in which the dip of the strata is toward the center, or axis of the structure. May be elongated like a trough, or circular like a bowl.

Tentacles — arm-like appendages of certain invertebrate animals, used primarily for food-gathering.

Unconsolidated — not solid or compact.

Vein — crack or fissure, partially or completely filled with mineral matter.

Vitreous — glassy luster.

Weathering — result of physical or chemical processes by which surface rock is disrupted, decomposed, or in any way loosened.

Wool rock — rock from which rock wool (wool-like fibers), used for insulating material, can be manufactured. Generally impure, siliceous limestone or dolomite.

NUMBER INDEX TO SPECIMENS IN COLLECTION