Bulletin 6

MINERAL RESOURCES *of* ARKANSAS

ARKANSAS GEOLOGICAL & CONSERVATION COMMISSION

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STATE OF ARKANSAS

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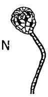
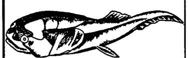
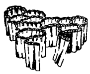
PREFACE

Since the founding of the Arkansas Geological Survey, there have been two general studies of Arkansas mineral resources published: Outlines of Arkansas Mineral Resources in 1929; and Bulletin 6, Mineral Resources of Arkansas, in 1942. This type of publication has proved to be very popular particularly in the schools and also with the general public. As a result, the supplies of Bulletin 6 have been exhausted in a relatively short period of time. In order to meet a continuing requirement for a current publication of this type, the present publication, a revised version of Bulletin 6, has been prepared.

In the process of revision most of the statistical data of the original Bulletin 6 have been eliminated because such figures are rapidly outdated. More important, however, has been the addition of new minerals to the list, the addition of new deposits of minerals already known, and the inclusion of new uses for known mineral deposits. It should not be inferred that all of the mineral occurrences described herein are economic deposits. The more marginal occurrences are included with the realization that rapid changes in technology, and development of new uses for minerals may someday make them economically valuable.

As Bulletin 6 is designed primarily for the layman, only generalized geological descriptions of the various mineral deposits are included. For the professional geologist, and other individuals desiring more detailed information, the Commission has available both published and open-file geologic reports and maps on these deposits.

TIME DIVISIONS: ERAS	TIME DIVISIONS: PERIODS	DURATION IN YEARS	ROCK TYPES IN ARKANSAS	MINERAL PRODUCTS
CENOZOIC	QUATERNARY 	1 MILLION	Sand, gravel, silt, and clay Thickness 0 - 200'	Clay Sand Gravel Ground water
	 TERTIARY	60 MILLION	Sand, gravel, and some limestone 0 - 4100'	Lignite Bauxite Iron Clay Sand Gravel Ocher Ground water Bentonite
MESOZOIC	 CRETACEOUS	70 MILLION	Sandstone, gravel, clay, marl, limestone, chalk, igneous intrusives, and volcanics 0 - 6600'	Asphalt Chalk Marl Clay Diamonds Thorium Natural gas Petroleum Iron Molybdenum Rare earths Titanium Gypsum Portland cement materials Barite Greensand Nepheline syenite Columbium Uranium
	JURASSIC	35 MILLION	Subsurface only - shale, siltstone, limestone, dolomite, gravel, anhydrite, and salt 0 - 4600'	Natural gas Petroleum Salt Bromine brines Sulfur
	TRIASSIC	30 MILLION	Formations of Triassic age are unknown in Arkansas.	
PALEOZOIC	PERMIAN	20 MILLION	Formations of Permian age are unknown in Arkansas.	
	 PENNSYLVANIAN	20 MILLION	Sandstone, siltstone, shale - some limestone, clay, and coal 0 - 18,000'	Lead Silver Coal Natural gas Sandstone Quartzite Mercury Clay Zinc
	MISSISSIPPIAN 	20 MILLION	Shale, limestone, sandstone, chert, siltstone, and novaculite 0 - 13,000'	Antimony Mercury Barite Novaculite Slate Natural gas Manganese Limestone Copper Zinc Lead Marble Tripoli Sandstone Phosphate rock
	DEVONIAN 	60 MILLION	Novaculite, chert, and some limestone 0 - 900'	Novaculite Tripoli Manganese
	SILURIAN 	40 MILLION	Sandstone, limestone, and shale 0 - 1800'	Slate Limestone Marble
	ORDOVICIAN 	70 MILLION	Shale, sandstone, dolomite, chert, and limestone 500 - 5000'	Manganese Slate Nickel Soapstone Quartz crystals Zinc Lead Iron Copper Limestone Dolomite Marble Phosphate rock Silica sand
	 CAMBRIAN	80 MILLION	Shale - some chert and limestone 300±	Limestone
PRECAMBRIAN ERAS		3 BILLION	Not exposed at the surface in Arkansas - probably igneous and metamorphic rocks	

GEOLOGIC TIMESCALE AND ARKANSAS ROCK CHART

MINERAL RESOURCES OF ARK

INTRODUCTION

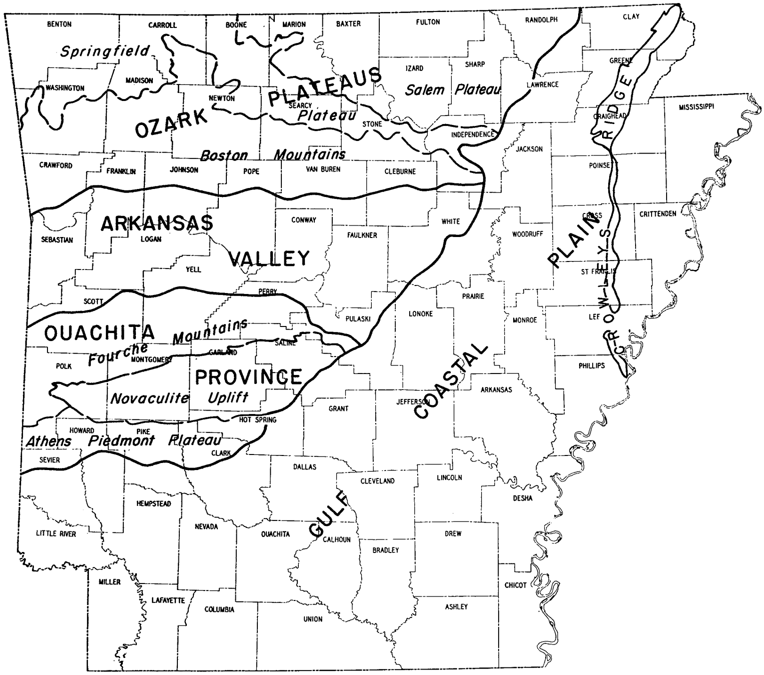
The importance of the mineral industry to th of the state can best be appreciated by a review of annual value of minerals produced. The trend in mineral production in Arkansas moved steadily upward from the latter part of the nineteenth century to 1925, when, due to oil discoveries, it reached a peak. The total value of mineral products in 1899 was $1,643,709 and the value in 1925 was $87,185,532. This peak was not exceeded until the early part of the postwar economic expansion of the state in 1947 when the value of minerals produced was $90,857,000. This value has increased annually almost without interruption, and by 1957 it amounted to $140,939,000.

It is reasonable to expect that the trend of mineral production will continue upward in order to furnish a firm base for the anticipated industrial expansion in Arkansas.

PHYSIOGRAPHY AND TOPOGRAPHY

Physiography is defined as the study of land forms and their classification according to the processes which formed them. In this sense Arkansas lies within two major physiographic divisions of the southern United States—the Gulf Coastal Plain and the Interior Highlands. The Gulf Coastal Plain (lowlands) in Arkansas falls within the southern and eastern portions of the state. The Interior Highlands in Arkansas include the northern and western portions of the state, and are divided into the Ozark Plateaus, the Arkansas Valley, and the Ouachita Province.

The eastern and northeastern portion of the Gulf Coastal Plain consists of a comparatively level south and southeast sloping plain with elevations in most areas of from 100 to 300 feet above sea level. The only unusual feature in this lowland is Crowley's Ridge, which extends north from Helena, Phillips County, Arkansas, to near the Missouri boundary. The southwestern part of the Gulf Coastal Plain is a rolling to hilly country eroded by south



Physiographic provinces of Arkansas.

and southeastward flowing streams, with elevations varying from 200 to 700 feet above sea level.

The Ozark Plateaus of northern Arkansas, southern Missouri and northeastern Oklahoma make an uplift more or less oval in shape with the longer axis trending northeast-southwest, and covering about 40,000 square miles.

In Arkansas the Ozark Plateaus may be subdivided into the Boston Mountains, the Springfield Plateau and the Salem Plateau. The southernmost subdivision, the Boston Mountains, forms an irregular east-west trending escarpment that bounds the Springfield Plateau on the south. Most of the mountain tops stand at about the same level and form a greatly eroded table land that rises about 1900-2200 feet above sea level. The Boston Mountains include the highest elevations and the most rugged terrain of the Ozark Plateaus in Arkansas. The Springfield Plateau lies just north of the Boston Mountains and is rather narrow except in the northwest part of Arkansas. It is for the most part gently rolling and has elevations in most areas of from 1250 to 1700 feet above sea level. The Salem Plateau, which is the largest as well as the lowest of the Ozark Plateaus, lies north of the Springfield Plateau, and is a rough to rolling country with elevations averaging about 1250 feet.

The Arkansas Valley lies between the Ozark Plateaus on the north and the Ouachita Province to the south. The Valley is a gently undulating plain or lowland 25 to 35 miles wide that extends generally from Searcy westward to Fort Smith. Many long, sharp ridges and several broad-topped hills such as Petit Jean Mountain rise above the general level of the valley.

The Ouachita province lies north of the Gulf Coast Plain and south of the Arkansas Valley. The Ouachita province is separable into three subprovinces, the Fourche Mountains to the north, the Novaculite Uplift in the center and the Athens Piedmont Plateau on the south.

The Fourche Mountains occupy a belt about 25 miles in width extending from near Little Rock westward to the Oklahoma line near Mena. Most of the mountains in the western part of the province are rugged and rise 1000 feet or more above the valleys but they decrease in height eastward. Pinnacle Mountain and Shinall Mountain near Little Rock lie in this province.

The Novaculite Uplift is a spindle-shaped area extending from near Little Rock westward to southern Polk County. The uplift consists of a series of broad basins with gently rolling topography almost completely encircled by high ridges of Arkansas novaculite. The center of the uplift exposes the oldest rock known in Arkansas, the Collier shale near Mount Ida.

The Athens Piedmont Plateau lies in a belt 8 to 18 miles wide extending from near the Ouachita River in Hot Spring County, westward into Oklahoma. Its surface slopes from an elevation of about 1100 feet near the novaculite ridges in northern Howard and Pike Counties to 400 feet along its southeastern border. Several eastward-trending parallel sandstone ridges project 150 to 250 feet above the adjacent valleys.

GEOLOGY

The rocks which make up the surface of the state belong to two great divisions: (1) sedimentary rocks, which consist almost entirely of either consolidated or unconsolidated particles of sand, clay or lime, or some combination of these; and (2) igneous rocks which are solid masses of the crystals of various minerals.

The sedimentary rocks, which were laid down as sediments in shallow seas or on land, extend over 99.9 percent of the surface of the state. They may be divided into two classes, those which make up the lowland area (Gulf Coastal Plain) in the southern and eastern parts of the state, and those which make up the highland area (Paleozoic) in the northern and western parts of the state. The rocks of the lowland area consist principally of unconsolidated clay, sand, marl, and chalk. Compared to the rocks in the highland area these are of relatively recent age. They cover approximately 27,610 square miles, or 52 per cent of the area of the state. The rocks of the highland area consist principally of consolidated and usually hard sandstone, shale, limestone and dolomite of relatively ancient origin. They cover about 25,710 square miles, or 48 percent of the area of the state.

The igneous rocks, which were formed by the cooling of molten masses, make up less than one-tenth of one per cent of the total area of the state, and are exposed in a total of about 15 square miles, principally in Pulaski, Saline, Hot Spring, Garland, and Pike Counties.

The formations which make up the surface of the Ozark Mountains of northern Arkansas and the Ouachita Mountains of central and western Arkansas have been raised by compressive forces. The Arkansas Valley is a deep structural trough lying between these two uplifts. The formations which make up the Ozark Mountains consist principally of stratified limestones, dolomites, shales and sandstones. These layers of rock have gentle slopes to the south into the Arkansas Valley. The Ozarks have been deeply carved by streams forming irregular drainage patterns in the relatively flat-lying rocks. The formations which make up the Ouachita Mountains consist principally of shales and sandstones, and have been intensely folded by great compressive forces originating in the south. Erosion has removed immense quantities of rock from the area and the fact that these rocks have been compressed into long east-west trending folds has resulted in their weathering into long east-west trending ridges and narrow valleys. The Gulf Coastal Plain overlaps the uneven eroded surfaces of the formations of the Ozark Mountains and Arkansas Valley on the east, and of the Ouachita Mountains on the south.

Much of the surface of the Gulf Coastal Plain is covered by beds of Quaternary age which form a thin surface mantle. Formations of Tertiary, Upper and Lower Cretaceous age are exposed in the southwest.

MINERAL DISTRIBUTION

The character of minerals found in a given region are often related to the geologic history of the region and, therefore, to the types of rocks in which the minerals are found. Geologic processes active in Arkansas have developed a wide range of rock types. This diversity is largely responsible for the variety of minerals found in the state.

The relatively flat-lying poorly-consolidated rocks of the Gulf Coastal Plain contain; asphalt, bauxite, clay, sand, gravel, lignite, fuller's earth, bentonite, iron, greensand, gypsum, chalk, marl, ocher, natural gas, petroleum, sulfur, and brines containing salt and bromine.

The limestones, shales, dolomites, and sandstones of the Ozark Mountains yield zinc, lead, iron, copper, manganese, marble, phosphate, tripoli, silica sand, portland cement raw material, and uranium.

In the Arkansas Valley region coal, natural gas, sandstone, quartzite and lightweight aggregate materials are obtained from folded sandstones and shales.

The intensely folded, faulted, and altered sandstones, shales, and cherts of the Ouachita Mountains yield iron, uranium, silver, antimony, mercury, manganese, fuller's earth, quartz crystals, barite, novaculite, tripoli, slate, zinc, and lead.

Associated with the igneous rocks of Arkansas are the deposits of diamonds, titanium, molybdenum, nickel, rare earths, soapstone, and columbium.

MINERAL FUELS

Mineral fuels have provided much of the energy which has made possible the industrial development of the nation. These minerals are being consumed at an ever increasing rate, and insofar as the present generation is concerned they are irreplaceable. Arkansas mineral fuels include coal, lignite, natural gas, natural gasoline, and petroleum. Since modern industry in Arkansas is so dependent on these minerals for productive energy, conservation programs have been adopted to insure the efficient production and wise use of these mineral fuels.

COAL

Coal is a combustible mineral substance consisting of carbonized vegetable matter formed over a long period of time. Millions of years ago swampy conditions existed over the regions where Arkansas coal is now found. The trees, ferns and other plants which grew in and near these swamps fell into the water and were covered with mud and sand before they were completely disintegrated. Pressure and heat slowly altered this buried vegetable matter. The complete series of products formed, in the order of their alteration from vegetable matter to nearly carbon are: (1) peat, (2) lignite, (3) high-volatile bituminous coal, (4) medium-volatile bituminous coal, (5) low-volatile bituminous coal (6) semi-anthracite, (7) anthracite, and (8) graphite.

Composition and properties. Analyses of coals are commonly given by grouping the elements in the coal as follows: (1) water, (2) volatile gases, (3) fixed carbon, (4) ash, and (5) sulfur. Volatile gases and fixed carbon are the fuel elements, and water, ash and sulfur are the waste. The higher rank (harder) coals are commonly classified according to the fixed carbon they contain, and the lower rank (softer) coals according to their heat value.

Arkansas coals are all of high rank and vary from low-volatile bituminous coal in the western part of the field to semi-anthracite in the eastern part.

The following table summarizes proximate analyses on 157 samples of Arkansas coal and shows the average analyses of coal that has been produced from various fields in the state. The B. t. u. (British thermal unit) is the heat required to raise the temperature of one pound of water at its maximum density one degree Fahrenheit.

TABLE OF ANALYSES

	Dry Coal				Combustible		
	Volatiles	Fixed Carbon	Ash	Btu/#	Volatiles	Fixed Carbon	Btu/#
Sebastian County (71 samples)	17.35	73.61	9.04	14,150	19.13	80.87	15,550
Charleston (8 samples)	19.26	74.86	5.88	14,760	20.46	79.54	15,680
Denning (31 samples)	14.89	77.87	7.24	14,440	16.08	83.92	15,560
Paris (13 samples)	18.10	75.56	6.34	14,530	19.33	80.67	15,520
Philpot (5 samples)	16.66	80.05	3.29	15,150	17.22	82.78	15,660
Russellville (11 samples)	12.32	78.99	8.69	14,130	13.49	86.51	15,470
Spadra (18 samples)	12.85	78.43	8.72	14,100	14.09	85.91	15,450

Specific gravity of the coal is high, averaging about 1.35 with a maximum of 1.49 and a minimum of 1.29.

BASIC CLASSIFICATION OF COALS

CLASSIFICATION	Fixed carbon	British thermal Units
	Range	Range
ANTHRACITE:	**Percent**	**Number**
Meta-anthracite	98 or more	
Anthracite	92 - 98	
Semi-anthracite	86 - 92	
BITUMINOUS:		
Low-volatile bituminous	78 - 86	
Medium-volatile bituminous	69 - 78	
High-volatile A bituminous	Less than 69	
High-volatile B bituminous		13,000 - 14,000
High-volatile C bituminous		11,000 - 13,000
SUB-BITUMINOUS:		
Sub-bituminous A		11,000 - 13,000
Sub-bituminous B		9,500 - 11,000
Sub-bituminous C		8,300 - 9,500
LIGNITIC:		
Lignite		Less than 8,300
Brown coal		Less than 8,300

Most of the Arkansas coals are brittle or friable, and yield from 10 to 40 percent fine material or slack. One of the principal advantages of Arkansas coal is that it gives off little smoke when burned.

Uses. The principal use of coal is to produce heat for conversion into electrical or steam energy. The chemical and physical properties of a coal determine the use to which it is best suited. For example, the hard coals, even though they may produce less heat, are better adapted to domestic use than the soft because they give out less smoke. Soft coals or those high in volatile matter are usually suitable for the manufacture of coke and the by-products of its manufacture, such as tar, ammonium sulfate, gas, benzol, toluol, naptha, and napthaline.

Almost all of the Arkansas coals are relatively low in volatile matter and are therefore non-coking. However, some of them in the western part of the coal field have been found to produce a satisfactory coke when blended with high-volatile bituminous coal. A blend containing 10 to 20 percent low-volatile coal and 80 to 90 percent high-volatile bituminous coal yields a strong coke that is desirable for metallurgical use. The coal produced in the western part of Johnson County and the majority of Sebastian County is sold for use in steel mills because of its coking qualities. Some of the Arkansas slack coal is used as a powdered coal to generate steam. Franklin County produces an excellent grade of coal for this purpose as does Sebastian County. A small amount of coal has been used in the zinc smelters of Western Arkansas and eastern Oklahoma.

Occurrence. The Arkansas coal field lies within the area known as the Western Interior Coal Field of the United States. This includes parts of Iowa, Missouri, Kansas, Oklahoma, Texas, and that part of Arkansas lying in the Arkansas Valley west of Russellville. A small amount of coal, sometimes used locally, als ococurs in central, northern, and northwestern Arkansas. Commercial production of coal in Arkansas has been limited to Johnson, Sebastian, Logan, Franklin, Pope, and Scott Counties. During 1958 a total of 44 mines were operated among the first five counties named. Scott County had no operations during the year.

The Arkansas coal field occupies the valley of the Arkansas River between the western border of the state and Russellville, and is about 33 miles wide and 60 miles long. Its shape is something like that of a capital "L" with its base along the Oklahoma line. The thickness of the coal beds in some places exceeds 9 feet. The coal-bearing areas are often of small extent because the coal-bearing beds have been folded, faulted, and eroded in many places. The various Arkansas fields that have produced coal have been grouped conveniently into western and eastern districts as shown below.

ARKANSAS COAL DISTRICTS

District and Field	County
WESTERN DISTRICT (south of Arkansas River):	
Bonanza-Jenny Lind	Sebastian
Excelsior-Greenwood	Sebastian
Hartford-Huntington	Sebastian
Bates	Scott
Charleston	Franklin
Paris	Logan
Scranton	Logan
EASTERN DISTRICT (north of Arkansas River):	
Philpott	Franklin-Johnson
Denning-Coal Hill	Franklin-Johnson
Spadra	Johnson
Ouita and Shinn Basins	Pope

History of development. Arkansas coal was referred to in publications as early as 1818. The first recorded coal production in Arkansas was 220 tons in 1848. At the Old Spadra Mine at the mouth of Spadra Creek in Johnson County a steam plant was installed in 1873. Soon after the extension of the Little Rock and Fort Smith Railroad, about 1873, coal from the Coal Hill mines in Johnson County was put on the market.

Interest in coal mining in the Arkansas Valley began to increase in 1887 when the St. Louis and San Francisco Railway was extended south of Fort Smith. Rumors of other railroads to be built caused speculation, leasing of land, prospecting, and drilling during that and succeeding years. Extensive mining operations were started in 1888 at Huntington, Hackett, Jenny Lind, Paris, Charleston, Scranton, and other localities in the Arkansas Valley and eventually resulted in the present development.

Mining Methods. Three methods of mining coal have been used in Arkansas. These are the room and pillar method, the long-wall method, and the stripping method. The first two methods apply to underground workings and the third to surface operations. In the room and pillar method, coal is moved to form rooms, and pillars of coal and rock are left to support the roof. In the long-wall method, the coal is mined from a continuous face and, as work proceeds, the roof is allowed to cave, haulageways being kept open by packwalls of waste material. Stripping is used when the coal beds are near the surface and considerable tonnage exists. The soil, clay, shale, and sandstone overlying the coal are removed by large power shovels or drag lines. Coal was first mined in Arkansas by stripping but as the mining expanded most of the coal was produced from deeper workings reached either by slopes or shafts. A majority of the Arkansas mines are now slope openings which are generally driven directly down the dip of the beds, with lifts turned to the right and left across the dip, about every 300 feet. The rooms are driven either directly up the dip or at an angle to decrease the grade. Mining in much of the Arkansas coal area is done exclusively by mining machines with conveyors or scows being used to convey the coal from the face to the mine cars. All of the mines in Arkansas are relatively shallow owing to the comparatively flat dips of the strata in the coal basins.

Production and reserves. From 1880 to 1920 coal ranked first in the value of Arkansas mineral products, but since 1922 the value of oil has exceeded that of coal and all other minerals. The annual net tonnage of coal produced in Arkansas from 1880 to 1959 reached its peak in 1909 with a production near 2,400,000 tons. Production during 1958 was 415,081 net tons. Sebastian County had been the leading coal producer in the state since the beginning of coal mining operations; however, during five of the last ten years it was displaced by Johnson County.

Coal is one of the most important mineral resources of Arkansas. The state has great coal reserves lying in the western Arkansas Valley. Approximately 300 to 320 square miles within the valley contain coal which occurs in beds thick enough to be mined, but much of it is deeply buried and cannot be profitably mined at present prices. Seams as thin as 14 inches are being worked. In Johnson County the average thickness of the coal is about 3 feet. The thickness in Sebastian County varies from 2 to 6 feet. Logan County coal beds average from 1½ to 2 feet in thickness. The seam of coal worked in Franklin County ranges in thickness from 14 to 24 inches. All of the coal produced in the Arkansas field is from strata of Pennsylvanian age. The Lower Hartshorne coal underlies a larger area than any other coal in Arkansas and is the most productive coal in the state. It averages about 3 feet in thickness. The Lower Hartshorne coal occurs near the base of the McAlester shale. The coal reserve in Arkansas is estimated at 1,400,000,000 tons. Assuming a loss of 50 percent in mining, the recoverable reserve would be approximately 700 million tons of coal.

LIGNITE

Lignite or brown coal is young coal in which the alteration of vegetable material has proceeded farther than in peat, but not as far as in high-volatile bituminous coal. The heating value of Arkansas lignite is about 6,360 B.t.u. per pound. One of the most important products of lignite is char, which is used as an industrial fuel. Important byproducts, such as tar, oil, and montanwax have been developed by lignite processing.

Most of the lignite in Arkansas occurs in the Wilcox formation of Eocene age in the Gulf Coastal Plain. It is known to be present in beds of this age in Ouachita, Cleveland, Dallas, Hot Spring, Grant, Saline, and Pulaski Counties, and is also present in these beds in Crowley's Ridge in eastern Arkansas.

The most extensive lignite area now known in the state is an area of about 60 square miles lying immediately northwest of Camden, Ouachita County. Lignite is exposed there along the banks of the Ouachita River and tributary streams. The deposit is usually 2 to 3½ feet thick, has a maximum thickness of 6 feet, and is estimated to contain 75 million tons. A deposit of lignite which covers an area of 60 acres and is 8 feet thick occurs 2 miles east of Manning, Dallas County. Shipments from this deposit have been used in the manufacture of brown pigment.

Some local use of Arkansas lignite as a fuel has been made. Recently a plant in Hot Spring County, near Malvern, operated an open pit lignite mine from which about 50 tons of lignite daily were milled for montanwax and resin extraction.

NATURAL GAS

Natural gas consists of combustible hydrocarbons which are gaseous at ordinary temperatures and pressures, and which have essentially the same origin as the fluid hydrocarbons which make up crude petroleum. Methane (marsh gas) and ethane are commonly the chief constituents. Most natural gases contain small and variable quantities of carbon dioxide, carbon monoxide, sulfur dioxide, hydrogen sulfide, nitrogen, hydrogen and oxygen.

Composition and properties. Natural gas is known commonly as either "wet" or "dry" gas. Wet gas contains some of the heavier fluid hydrocarbons as vapor, is commonly associated with petroleum, and is particularly valuable because of the gasoline and other extractable liquids it carries. Most of the gas from the Arkansas oil fields is of this type. Dry gas differs from the wet variety in that it does not carry appreciable quantities of the heavier fluid hydrocarbons as vapor. The gas of the Arkansas Valley is of this type.

Natural gas is colorless and most of it is nearly odorless. An odorant is added before the gas is sold to the public in order to insure the detection of gas leaks. When mixed with air in certain proportions gas is highly explosive. Its heating value varies from about 700 to 1,200 B.t.u. per cubic foot. The dry natural gas of commerce from the Arkansas Valley fields has a heating value of from 986 to 1,016 B.t.u. per cubic foot. Dry natural gas is used principally as fuel. It is estimated that of the gas consumed in Arkansas, 75 percent is utilized for industrial and commercial purposes with the remainder being about equally divided between domestic service and miscellaneous purposes.

Occurrence. Natural gas is intimately associated with petroleum in practically all of the oil fields of the world. It also occurs in dry gas fields unaccompanied by any appreciable amount of condensible hydrocarbons. Natural gas is present in commercial quantities in two areas in Arkansas—the Arkansas Valley, and the southern Arkansas oil fields. There were 39 gas fields in the Arkansas Valley as of June, 1959. These fields contained 338 gas wells, considering multiple producing zones in each well as separate wells. The gas fields extend from the Arkansas-Oklahoma boundary eastward into Conway County.

The Atoka formation of Pennsylvanian age contains the principal gas-producing horizons in the Arkansas Valley. It consists mainly of a series of sandstone and shale beds with a maximum thickness of over 12,000 feet. The Morrow group, also of Pennsylvanian age, underlies the Atoka formation and is the only other current source of gas in the Arkansas Valley. Both the Atoka and Morrow beds have been folded into numerous east-west trending folds or anticlines which serve to entrap the gas within porous beds. The gas from these beds is dry, no oil having been produced from them in commercial amounts. Natural gas has been produced commonly with oil in the southern Arkansas oil and gas fields in Bradley, Calhoun, Columbia, Lafayette, Miller, Nevada, Ouachita, and Union Counties. Drilling and production methods for natural gas are very similar to those used for oil.

History of development and conservation methods. Natural gas was first discovered in the Arkansas Valley in 1887 in Fort Smith, but there was no commercial production until 1902 when two wells were brought in near Mansfield, Sebastian County. Gas was first discovered in southern Arkansas on April 22, 1920, when the Constantin Oil Company completed a gas well near El Dorado, Union County. Almost all of the gas produced in southern Arkansas is wet gas.

The effectiveness of the conservation of natural gas is dependent on the control measures which are taken during the drilling of a gas well and during its productive life. Waste may occur during drilling and excessive amounts of gas may be lost if a well is permitted to "run wild." The amount of gas wasted or "vented" with the production of oil in Arkansas at present is held to a minimum by careful conservation practices. The Arkansas Oil and Gas Commission exercises close supervision in both of these instances, requiring economic spacing of wells, safe drilling procedures, and the granting of "allowables." An allowable refers to the quantity of oil or gas a well is permitted to produce in accordance with efficient engineering practices.

Production and reserves. The annual production of natural gas in Arkansas for 1958 was more than 54 billion cubic feet. South Arkansas fields accounted for approximately 55 percent of the production and the Arkansas Valley for the remainder. The peak period of gas production for the state was in 1948 when the combined fields in the entire state produced nearly 74 billion cubic feet of gas. Reserves of natural gas in South Arkansas and the Arkansas Valley, as of January 1, 1959, have been estimated as being some 683 billion cubic feet and 804 billion cubic feet, respectively. Arkansas is considered to have about 0.5 per cent of the estimated proved recoverable reserves of natural gas in the United States. The state ranked eleventh out of twenty-nine gas producing states in 1957 both on the basis of gross withdrawals and estimated proven reserves.

NATURAL GASOLINE

Many wet natural gases contain, in vapor form, considerable amounts of natural gasoline. The wet gas, also known as casinghead gas, is chiefly a mixture of methane, ethane, and the volatile hydrocarbons propane, butane, pentane, hexane, and heptane. The latter five form the constituents of the natural gasoline, which is recovered in liquid form mainly by absorption or compression processes. Pentane, hexane, and heptane are liquids under normal atmospheric conditions and are the chief components of ordinary refinery gasoline. In some cases propane and butane are liquefied under high presure and blended with lower gravity gasolines. The propane and butane are also used, under the names bottled gas, liquefied petroleum gas, LPG, or LP-gas, for domestic heating and for tractor or bus fuel.

The wet gas produced from the oil and gas fields of South Arkansas has a natural gasoline content ranging between about 1.6 and 5.5 gallons per thousand cubic feet of gas. Arkansas has 10 natural gasoline plants located in Columbia, Lafayette, Union, Miller and Hempstead Counties. These include noncycling, cycling and vacuum plants. Noncycling plants, after the recovery of liquids, sell most of the resulting dry, or residue, gas for fuel use. Cycling plants return most of the dry gas to the reservoir to maintain field pressure and force additional wet gas from the reservoir. Vacuum plants use a vacuum to draw rich gasoline vapors from the petroleum trapped in the reservoir. The liquids and gases extracted by gasoline plants today are being used in increasing amounts as raw materials for the rapidly expanding petrochemical industry. For example, the butanes are used for aviation gasoline and synthetic rubber; natural gasolines help make aviation gas, nylon, plastics, explosives, and cosmetics; ethane-methane mixtures are used for fuel, carbon black, ink, rubber, antifreeze, plastics, drugs, and dyes; ethane-propane mixtures are used for rubber, plastics, and commercial chemicals. The heavier hydrocarbons are used to make jet fuel, diesel fuel, gasoline, and kerosene.

Production and reserves. Natural gasoline is removed chiefly from natural gas by one of two processes—absorption or compression. In the first, natural gas is passed through "low test" gasoline or a mineral seal oil, which absorbs the wet fractions from the gas. This process is generally used with gas containing only small quantities of extractable hydrocarbons. In the compression process the natural gas is compressed and cooled and the wet fractions condensed. This method is generally used with gas having a relatively high gasoline content. Often it is used in conjunction with the vacuum pumping process by which vapor pressure on the oil sands is reduced in order to increase the gasoline content of the natural gas.

The annual production of gasoline in Arkansas varied from about 4 million gallons in 1922 to more than 41 million gallons in 1958. Also during 1958 more than 45 million gallons of LP-gases were produced. The reserves of natural gasoline in southern Arkansas are naturally dependent upon the amount of the wet gas reserves. Using the estimated reserve of 683 billion cubic feet and an average recovery of 2.8 gallons per thousand cubic feet, the natural gasoline reserve estimate would approximate 2 billion gallons.

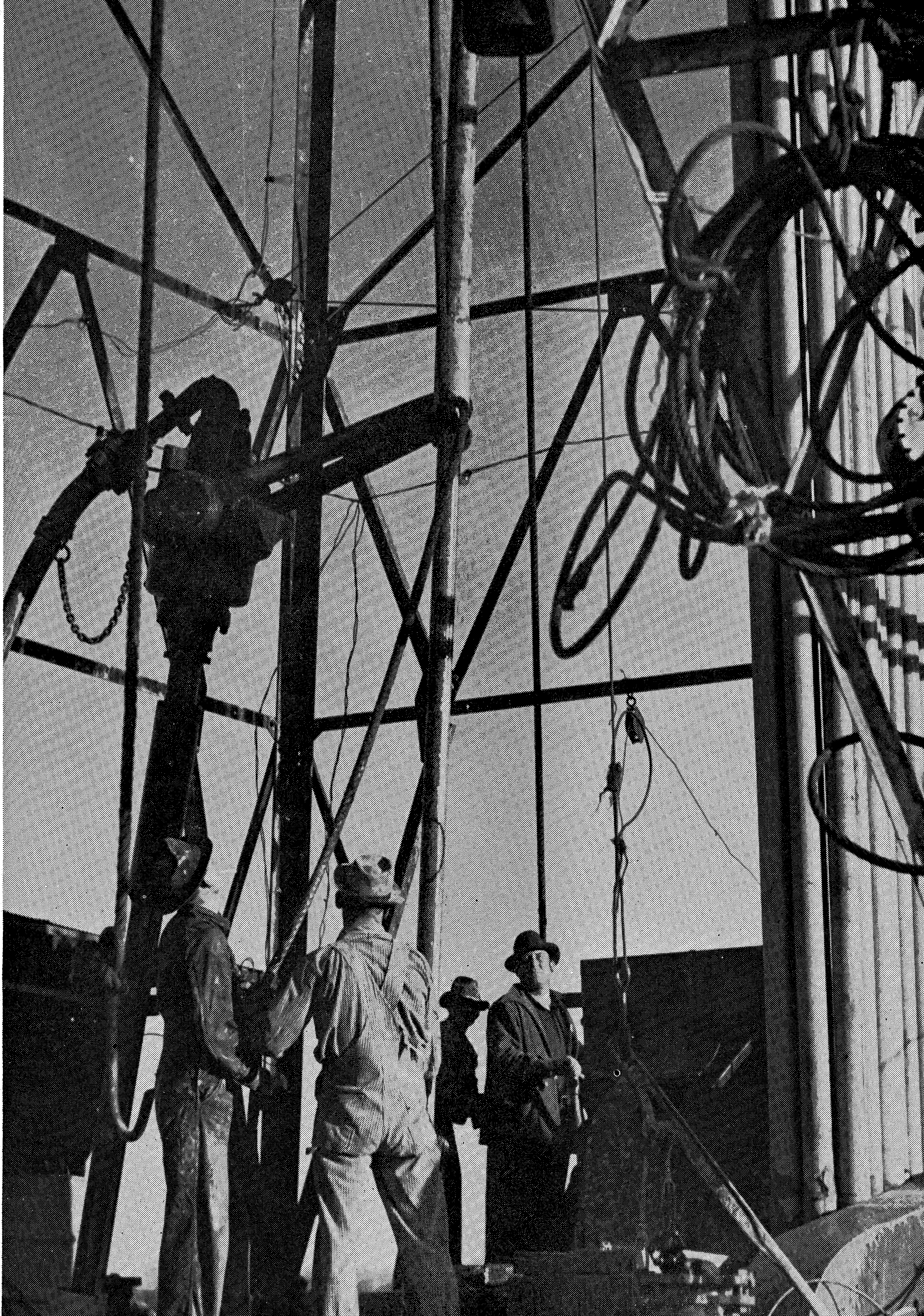
PETROLEUM

Crude petroleum is a greasy liquid which is found in certain localities in porous rocks beneath the surface of the earth. It is formed by the slow alteration of organic remains through long periods of time. Petroleum consists of a mixture of hydrocarbon compounds and varies widely in composition, color, density, and viscosity. It is usually classified according to the predominance of paraffin or asphaltic compounds and, accordingly, is said to have a paraffin base, an intermediate base, or an asphalt base.

Petroleum finds its principal uses as a source of fuel and in lubricating oils. Compounds and mixtures of compounds are separated from crude petroleum by distillation and include gasoline, benzine, heavy naphthas, different grades of lubricating oils, and residuum. South Arkansas has 6 refineries in current operation, processing about 75,000 barrels of crude oil daily. Between 80 and 90 per cent of the crude petroleum produced in Arkansas is refined in the state. Many hydrocarbons extracted from the petroleum are used by the petrochemical industry.

Occurrence. The southern part of the Gulf Coastal Plain of Arkansas contains all of the oil producing fields of the state. These are in Union, Ouachita, Columbia, Nevada, Lafayette, Miller, Calhoun, and Bradley Counties. Ashley County produced a small quantity of oil from one field discovered in 1948 and abandoned in 1953. By the end of 1958, a total of 149 oil, condensate, and gas fields had been found in South Arkansas; although only 122 are producing currently.

Drilling for oil in South Arkansas.



The first oil discovered in Arkansas was found in Ouachita County in April, 1920, about 3 miles east of the Stephens field, with the drilling of the S. S. Hunter et al. well in sec. 13, T. 15 S., R. 19 W. In the same month, gas was discovered in the north portion of the El Dorado field in Union County by the Constantin Oil and Refining Company and on January 10, 1921, oil was discovered in the S. T. Busey well also in this field. This marked the beginning of crude oil production in Arkansas.

During the early development of the Arkansas oil fields, prospecting and locating structures favorable for the accumulation of oil and gas was accomplished almost entirely through information gained by the correlation of the records of wells already drilled.

Prospecting and Production Methods. In recent years marked advances have been made in prospecting for oil structures, and geophysical methods have largely replaced the earlier methods in the southern Arkansas area. The most widely used geophysical instrument is the reflection seismograph. In using this instrument, waves are directed into the earth by means of explosives discharged near the surface and the seismograph records the reflected or refracted waves. By identifying the waves at several stations, the approximate depth to the reflecting or refracting bed can be calculated. Also used to a considerable extent are the magnetometer and gravimeter, which indicate variations in the earth's magnetic and gravitational fields, respectively.

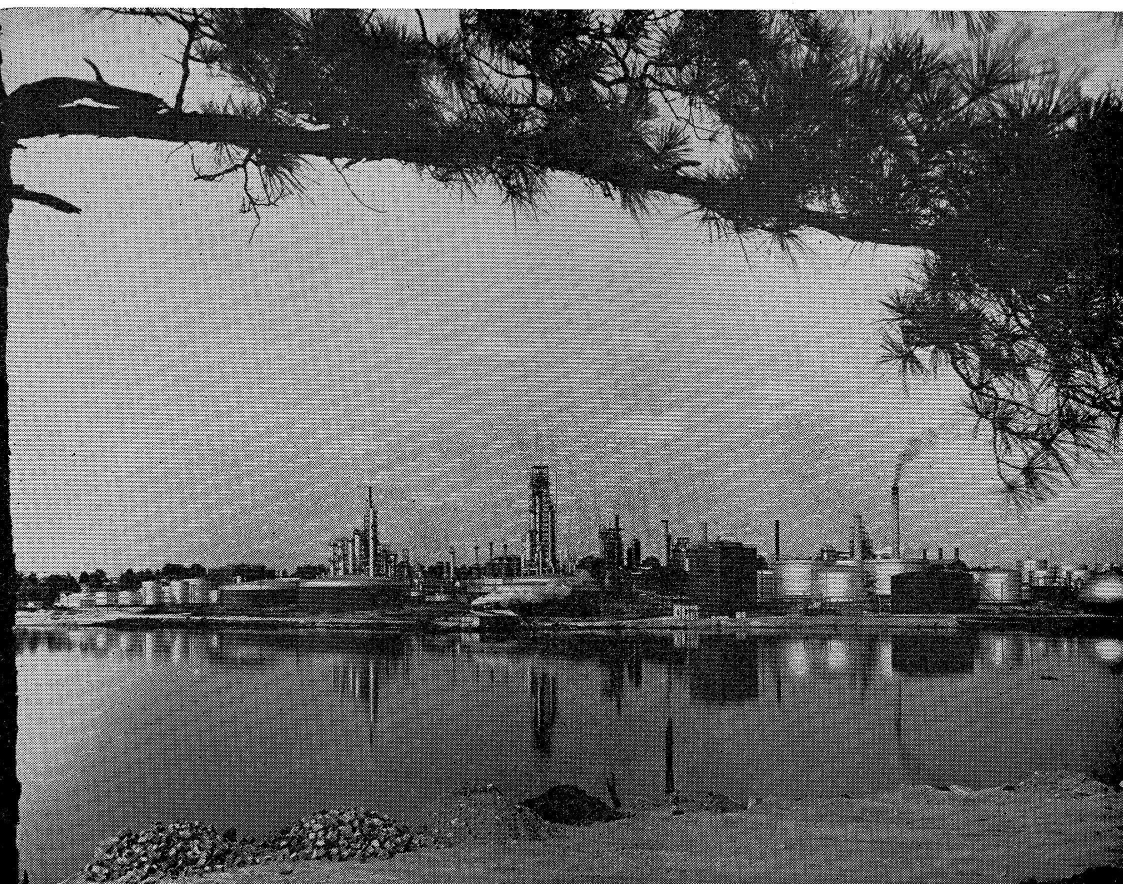
About 15 percent of the oil production in Arkansas during the years 1921-36 originated in rocks of Lower Cretaceous and Jurassic age, with the remainder coming from Upper Cretaceous rocks. This trend was reversed during 1936-41 by an increase in deep drilling, which resulted in Lower Cretaceous and Jurassic beds furnishing about 60 percent of the oil produced in the state. Since 1937 oil in southern Arkansas has been obtained from depths exceeding 9,000 feet. The producing depth record in Arkansas, approximately 9,300 feet, has been established for some time in the Tubal Field, near the boundary between Colum-

Petroleum refinery, El Dorado.

bia and Union Counties. The oil produced is from beds of Jurassic age.

Present day production methods, based on advanced technical knowledge and the principles of conservation, have greatly increased the amount of oil and gas that can be recovered from an oil pool. Better equipment makes it possible to pump oil profitably from depths exceeding 9,000 feet. Improved handling and storage facilities at wells have eliminated much of the waste that was present in the early fields, where earthen pits or wooden storage tanks were used. Present production methods are much more efficient and include the utilization of natural underground forces of gas pressure and water pressure in obtaining the largest recovery of oil over the longest possible period.

Drilling Costs and Methods. Oil and gas production involves relatively high fixed costs and a major item in the



total investment is the cost of drilling. This cost varies with such factors as the depth of the well, the formation penetrated, the diameter of the hole, and the sources of supply. Drilling may be contracted for either on a footage or a daily basis, the latter being independent of the footage drilled. A well may be found to cost from a few dollars a foot to fifty dollars or more per foot after all expenses are computed. The decrease in prices permitted by competition, increased skills, and better equipment has in many cases been offset by the increasing depth of current drilling. The deepest well drilled to date in Arkansas is the Hunt Oil Company R. B. McDonald No. 1, sec. 1, T. 20 S., R. 21 W., Columbia County. This 12,925 foot dry hole was drilled in 1957.

Drilling in Arkansas is either by cable tools (percussion), rotary tools (rotating drill pipe and bit), or by a combination of the two. With conventional rotary tools drilling mud is used to cool the bit, condition the hole, and help recover well cuttings. In the Arkansas Valley numerous rotary holes have been drilled using compressed air or air and engine exhaust gas mixed, instead of mud, to speed-up drilling and reduce costs.

Production and Reserves. Arkansas currently produces an average of 30 million barrels of oil and gas condensate annually. The maximum production of petroleum in Arkansas occurred in 1925 when 77,398,000 barrels were taken from the fields, and the minimum production was in 1936 when approximately 10,400,000 barrels were produced. The average annual price of petroleum in Arkansas in 1939 was 79 cents per barrel. The present prices for 36.0-36.9 API gravity oil range between $2.77 and $3.02 per barrel with a 2 cent differential per degree of gravity.

Arkansas oil exploration was encouraged during 1957 by the passage of an important new law. The Act provides a reduction in the State Severance Tax of 75 percent for 5 years if the newly discovered oil pool is above the base of the deepest producing oil formation in the county of discovery. Additional incentive offers a reduction for 10 years if the pool is in a county where there is no oil production, or if the new production is below the base of the deepest oil producing formation in the county.

Estimates of petroleum reserves in Arkansas, prepared by the American Petroleum Institute for 1935 were 75 million barrels; for 1937, 84 million barrels; and for 1938, 192,101,000 barrels. Almost entirely as a result of the expansion of the Magnolia field in Columbia County, the petroleum reserves increased approximately 75 percent during the first six months of 1939. The reserves of oil and gas condensate for Arkansas as of January 1, 1959, are approximately 420,000,000 barrels. Arkansas produced its billionth barrel of oil during March, 1957. Arkansas is ranked twelfth among the 32 producing states in estimated proved reserves of crude oil, natural gas liquids, and total liquid hydrocarbons, and is considered to have about one percent of the United States total.

OIL AND GAS CONSERVATION

Arkansas is recognized today as one of the leaders among petroleum producing states that have enacted into law comprehensive conservation programs concerning their irreplaceable oil and gas resources. The conservation program of Arkansas became a law with the passage of Act 105 of the 1939 (Fifty-Second) General Assembly, as amended by Act 305 of the Fifty-Third General Assembly. Prior to this time the program was carried on under a voluntary agreement among oil producers, dating from January 1, 1938. This grew into the Interstate Oil Compact Commission, which is today a voluntary organization of 31 producing states, among them Arkansas, dedicated to waste prevention. The sole purpose of the Oil Compact Commission is to encourage oil and gas conservation through established state agencies.

Need for conservation measures. During the first 16 years representing the time of discovery and development of the old or settled pools in Arkansas, lack of knowledge about efficient production methods resulted in the recovery of only about 20 percent of the oil in the reservoirs. Science, as applied by the petroleum production engineer, the geologist, the geophysicist, the chemist, as well as the lessons of experience, has transformed the production methods in newly discovered pools, and in some old ones, to a point where more than 50 percent of the actual oil in the reservoirs can be recovered.

One of the world's most intensively engineered waterflood projects has been underway for some time in the prolific Magnolia Field of South Arkansas. It is anticipated that the current phase of this secondary recovery program will yield an extra 31 million barrels of oil, or an estimated 60 percent recovery of the oil in place. The Magnolia Field, a 19-year-old Smackover limestone pool of about 4,000 acres, had already produced about 85 million barrels of oil.

Since 1917 the state has had rules and regulations concerning the drilling, casing, and plugging of wells to prevent the surface escape of oil or gas into the streams with the resulting pollution of fresh water supplies. However, little or no attention was paid to production practices prior to 1938. The present law not only takes into consideration proper production practices and the prevention of stream pollution, but provides that the oil pools of the state must be developed and exploited so as to obtain the maximum scientific recovery of oil.

Factors affecting conservation practices. Generally speaking, an oil pool may be found in any subsurface sedimentary formation with connected pore spaces. In addition to having porosity, however, the formations must be so disposed structurally that the accumulation of oil and gas in volume is made possible. An overlying impervious layer of rock must also be present to prevent the escape of the hydrocarbons.

Most of the production in Arkansas is from limestone or sandstone reservoirs. The porosity of sandstone can be pictured as analogous to the open spaces between oranges when they are symmetrically grouped, and that of limestone as similar to the various openings in a sponge. Porosity is expressed as the percentage of void space in a rock. For example, a 25 percent porosity means that for each 100 cubic feet of reservoir rock, one-fourth, or 25 cubic feet, is void or pore space. Should the grains be perfectly round, the total pore space is the same regardless of the size of the spheres, the group of larger spheres simply having fewer but larger openings.

Permeability is a measure of the ease with which fluids flow through porous media. Since the resistance to flow is less through larger openings, a rock composed of large grains would have the greater permeability. The contents of an oil pool are always found to exist under pressure—usually the greater the depth, the greater the pressure. This pool or reservoir pressure is a result, in most instances, of the hydrostatic head of water which is connected with oil or gas. Contributory effects are vapor pressure of the liquids, chemical reactions, earth movements, geological folding and the internal heat of the earth.

Gas and water are usually found in association with oil. Gas, if present, will be found dissolved in the oil, and, in a few cases, as free gas above the oil. As the amount of gas dissolved is proportionate to the pressure and temperature, the deep pools of Arkansas are found to have oil that is fully saturated with gas and, with any reduction of reservoir pressure, the gas comes out of solution and either occupies the space above the oil or is produced with the oil.

Gas in solution in oil has desirable effects; the two most important of these are the lowering of the viscosity of the oil, rendering it more fluid or mobile, and the reduction of the surface tension which makes it slick or less sticky. Both of these effects prevent unnecessary retention of oil in the reservoir rock; therefore, an oil pool should be so operated as to maintain the maximum amount of gas in solution.

Oil and gas pressure. The Arkansas Oil and Gas Commission believes that the source of energy by which oil is procured is of vital importance in every pool in the State of Arkanas. Oil wells do not produce oil; oil is produced by oil pools, and the well itself is merely a means of transporting the oil from the pool to the surface. Many oil pools are abandoned not because the oil has been exhausted, but because the gas has been exhausted, thereby leaving the "dead" oil underground without sufficient energy to bring it into the well bore.

Oil movement through a rock formation to a bore-hole is caused by the pressure on the fluids and gases in the oil-bearing formation. This pressure differential between the various parts of the reservoir and the well bore is a result of one of the following three forces or a combination of them:

Gravitation, or that force which tends to attract objects to the center of the earth: This force causes oil to trickle out of a saturated formation into the well bore to the bottom of the hole. From a practical standpoint, it is negligible so far as moving an appreciable quantity of oil from a formation into the bore of a well.

The force of water drive: Water contained in the same strata or zone which is adjacent to an oil or gas deposit is called edge water. It exerts a pressure known as water drive, varying in some pools of the state from a few pounds to more than 4,200 pounds per square inch. Where the withdrawals of oil from a reservoir are greater than the encroachment of the edge water, the pressure of the reservoir decreases proportionately. Unless the edge water pressure or water drive is substantially controlled by uniform spacing of wells and uniform withdrawals from a common reservoir, water channeling and water coning result in the trapping of oil and gas deposits which may never be recovered, thereby causing underground waste.

The force of expanding gas, either in solution or in contact with oil: This is one of the principal causes of oil movement through the formation. The Arkansas General Assembly took cognizance of this fact and enacted laws requiring the Arkansas Oil and Gas Commission to establish an efficient gas-oil ratio for the oil fields of the state. These laws define waste as being, among other things, "the operation of any oil well, or wells, with an inefficient gas-oil ratio," the gas-oil ratio being the volume of gas, expressed in cubic feet, produced with each barrel of oil.

In the absence of an active water drive, when the gas pressure in a formation has decreased to approximately atmospheric pressure, little differential pressure exists between the sand and the well bore, and production ceases even though 50 percent to 80 percent of the oil may remain in the reservoir. Hence, where gas is permitted to escape without doing useful work, underground waste will result. An efficient gas-oil ratio will tend to conserve this source of energy for bringing the oil to the bore of a well, where it may be recovered in greater amounts.

Spacing of oil and gas wells. The correct spacing of wells in the pool is an important factor in controlling the operating efficiency of the entire pool. With the advent of restricted withdrawals and the resultant curtailment of production, the industry has come to realize that the close spacing of wells as practiced in the past is unnecessary. In fact, many petroleum engineers today are convinced that with the proper control of production, even with wells more widely spaced, it will be possible to recover a larger amount of oil than has been the case in the past.

In those fields producing only dry gas, as in the Arkansas Valley, the spacing allocation is usually 640 acres (one section) to each well.

Summary of Conservation Practices. In the foregoing discussion, it was pointed out that the gas held in solution at high pressure is released from solution upon reduction of pressure. This procedure increases the viscosity and surface tension of the oil, a result which obviously should be avoided if possible. In summary, it can be said that the reservoir pressure decline can and should be curtailed by the application of the following factors: correct well spacing, controlling rates of withdrawal, control of gas production, control of water production, and injection of gas or water to the reservoirs. Under the optimum or efficient rate of production concept, it is intended that no reservoir pressure need be spent other than the flush pressure and that the greatest practical recovery be obtained from each reservoir.

METALS

Metals provide the structural needs and precision tools so necessary for the improvement of man's standard of living. The United States is especially fortunate in possessing some of the richest mineral deposits known to man. These have made possible the extensive industrial development of the nation.

Metals found in Arkansas include antimony, aluminum, columbium, copper, gold, iron, lead, maganese, mercury, molybdenum, nickel, rare earths, silver, titanium, uranium, and zinc. Unlike mineral fuels most metals are recoverable and may be used again and again in the improvement of standards of living. Conservation practices should include the wise use and reuse of these metals.

ALUMINUM

Because of the lightness of aluminum, its great strength, its resistence to atmospheric corrosion, and its electrical conductivity it has become an essential modern metal. The principal ore of aluminum is bauxite. Bauxite is an earth or rock consisting principally of hydrated aluminum oxides with which small amounts of silica and iron and titanium oxides usually occur. Bauxite is usually white to gray or brown in color and, in Arkansas, occurs in three forms: (1) the "pisolitic" or oolitic form (like a cluster of peas); (2) the "sponge" form in which the original crystal forms of nepheline syenite or "granite" from which it is derived, are preserved; and (3) the "earthy" form which resembles earth or clay. Of the bauxite ore mined, approximately 65 to 80 percent is used in the manufacture of metallic aluminum, about 7 percent for chemicals, and about 10 percent for abrasives, refractories, and alumina cements.

Arkansas produces over 90 percent of the bauxite mined in the United States. Some bauxite is mined in Georgia and Alabama and small deposits are known in Tennessee, Virginia, Mississippi, and New Mexico. The commercial bauxite deposits of Arkansas are confined to Saline and Pulaski Counties and are closely associated with nepheline syenite, the so-called blue and gray granite from which the deposits were derived by prolonged weathering. The oolitic type usually makes up the upper part, and the sponge or granitic type the lower portion of the ore bodies. Most of the ore bodies are of blanket or sheet type and are of irregular outline, lying above the nepheline syenite masses. The bauxite usually grades into kaolin and this, in turn, into syenite. A small percentage of the bodies are lens-like layers that are of the transported type and are interbedded with Tertiary beds of sedimentary origin.

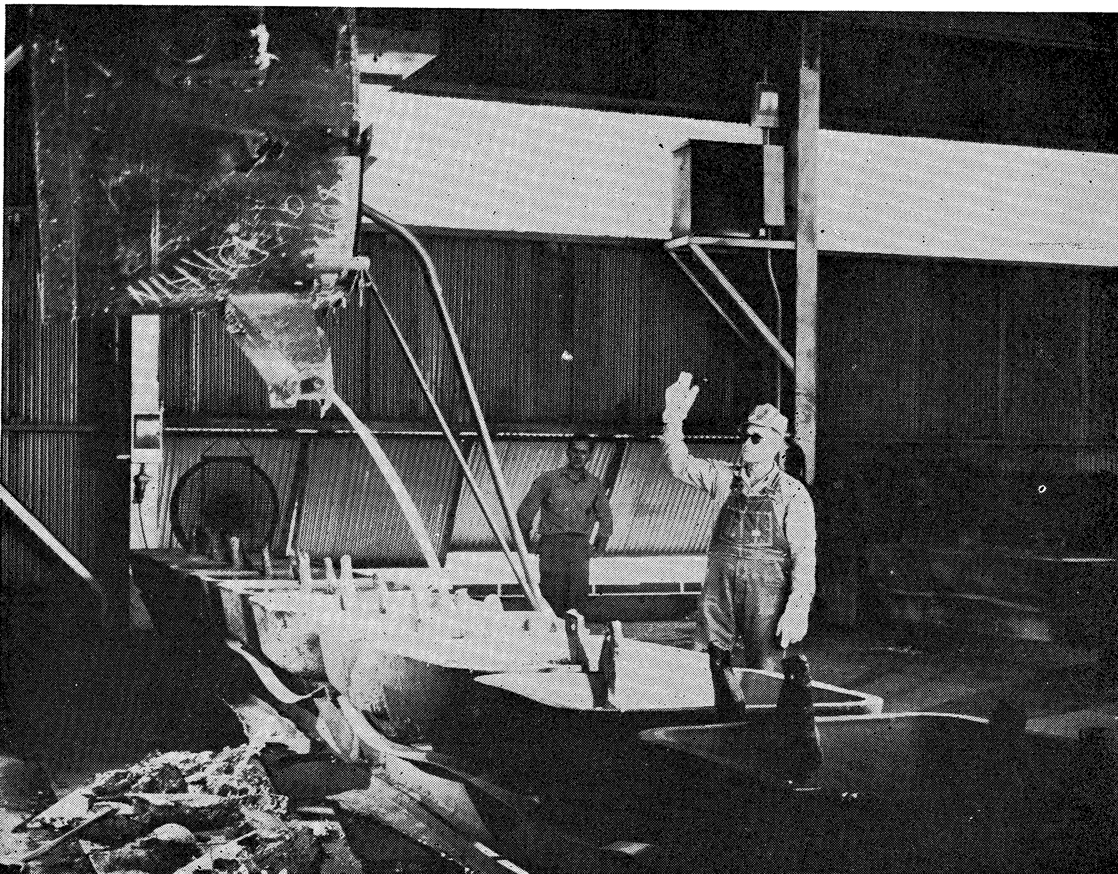
Bauxite was first identified in Arkansas by John C. Branner, state geologist, in June, 1887, in a deposit in Pu-

Pouring molten aluminum at Jones Mill near Hot Springs.

laski County on the Little Rock-Pine Bluff highway, where it was being used for road surfacing. This was the same year in which bauxite was found in Georgia, and 66 years after the mineral had been originally discovered in the village of Baux in southern France, the town from which bauxite takes its name. Three years prior to 1887 the Pittsburgh Reduction Company had been organized to commercialize the Hall electrical process for the reduction of aluminum.

Soon after the discovery of bauxite in Pulaski County, other deposits were found in Saline County. Commercial mining began in 1899 when 5,045 long tons, valued at $18,000 were shipped.

The bauxite deposits of Arkansas in some places crop out on the surface, but more commonly are buried beneath



Tertiary sands and clays. Formerly all of the bauxite was mined by stripping and open pit methods, but a large tonnage is now mined underground.

In the manufacture of aluminum from bauxite the bauxite is crushed and dissolved in caustic soda. From this solution, a white powdery substance known as alumina is extracted. The powdered alumina is dissolved in molten cryolite and aluminum metal is extracted from the alumina-cryolite melt by electrolysis.

Arkansas now has two alumina plants; one at Hurricane Creek, near Bauxite, and one at Bauxite. Aluminum metal is produced at two plants in the state; the Jones Mill Reduction Plant on Lake Catherine, and the Gum Springs plant at Arkadelphia.

ANTIMONY

There are many minerals containing antimony, however, stibnite and antimonial lead ores are the chief sources of the metal. Stibnite, practically the only mineral mined for its antimony alone, occurs in Arkansas. Stibnite is an antimony sulfide and contains 71.4 percent antimony and 28.6 percent sulfur. The mineral is heavy, steel-gray, has a metallic luster and is often in slender prismatic crystals which are sometimes curved or bent.

Antimony is a constituent in various alloys. The presence of antimony not only hardens the alloys, but lowers their melting points and decreases their contraction during solidification. Its main use is to impart stiffness and hardness to lead alloys. Antimony compounds are used in medicine, in the rubber and patent leather industries, for pigments, glazing enamelware and in paints.

Stibnite occurs in the southwestern part of Arkansas in northern Sevier County. Small amounts of it are also found associated with cinnabar in Pike County. The deposits in Sevier County occur as lenses or pockets of stibnite associated with quartz in veins which cut the steeply folded shale and sandstone beds. Sulfides of copper, zinc, iron and bismuth locally are associated with the antimony sulfide.

Antimony has been mined intermittently in Arkansas since 1873. Presently there are no antimony mines in operation. Mining has been carried on by sinking shafts into the ore bodies and drifting into adjacent ore bodies.

COLUMBIUM

Columbium (niobium) is a rare element, steel-gray in color, hard, fusible with difficulty, and resistant to acids. It is used principally as a carbide stabilizer in stainless steel and for creep resistance and fatigue strength in light high-temperature alloys.

Arkansas has two known areas of columbium concentration: Wilson Springs in Garland County and Magnet Cove in Hot Spring County. In the Magnet Cove area there are substantial deposits of titanium ore in which the rutile and brookite crystals contain an average of 1.25 percent and a maximum of 9 percent columbium. The columbium of the Wilson Springs area is found in the mineral pyrochlore. Soil samples taken in this area ranged up to 0.9 percent columbium. Another possible source of columbium lies in the waste material produced in the processing of bauxite.

Columbium-bearing materials have been known to exist in the Magnet Cove area since 1890; however, there has been no commercial production of columbium in the state to date.

COPPER

Copper is obtained commercially from a large number of minerals, but only 4 of these; chalcopyrite, malachite, azurite, and native copper are known to occur in Arkansas. Copper minerals have been found at many places in the Ouachita Mountains and in one area in the Ozark Plateaus. Although these occurrences are small it is possible that larger deposits may be found in the future.

Chalcopyrite (copper iron sulfide) is found in the west-central Arkansas mineral belt and in the north Arkansas district. A few carloads of malachite (basic copper carbonate) have been mined at the Tomahawk Mine, in Sec.

6, T. 16N., R. 16W., east of St. Joe, in Searcy County. A small quantity of the same mineral was shipped from Ferndale, Pulaski County.

GOLD

Small quantities of gold are sometimes found in common pyrite in the rocks in the highland area of Arkansas. Some of these specimens contain as much as a few hundredths of an ounce of gold per ton, but the cost of concentrating the pyrite has been estimated in each case to be considerably greater than the value of the gold which could be recovered.

Interest in gold mining in Arkansas recurs from time to time, but the greatest activity took place between 1885 and 1888 when it is estimated that gold-mining companies capitalized at more than 11 million dollars were engaged in prospecting in western Arkansas. In 1888 the chemist of the Arkansas Geological Survey assayed 183 samples reported to contain gold from Pulaski, Saline, Garland, Hot Spring, Yell, Montgomery, Pike, Sevier, Polk, Scott, and Logan Counties. Of these, 129 contained no gold, 51 contained traces, and three from Garland County contained 0.04, 0.06, and 0.08 of an ounce per ton. With gold at $35 per ounce, these amounts are equivalent to $1.40, $2.10, and $2.80 per ton, respectively.

Selected specimens from Booneville and Magazine Mountain in Logan County have assayed 0.07 of an ounce of gold per ton, and one specimen from a mine on Statehouse Mountain in Montgomery County showed 0.40 of an ounce of gold per ton. It should be remembered, however, that all of these samples were carefully selected and do not represent in any way what might be termed average recoveries from any given quantity of rock.

IRON

The iron minerals which occur in Arkansas are the oxides, limonite, hematite and magnetite; and the carbonate, siderite. Pyrite and marcasite (sulphides of iron) are also found in the state.

Limonite or hydrated iron oxide is a brown, blackish or yellow rusty-colored mineral. Hematite or ferric oxide or "red iron ore", varies in color from a brilliant black to blackish-red or brick-red. Siderite or iron carbonate is a gray-yellow, brown, green, white or brownish-red mineral. Magnetite, which is a black mineral, can often be recognized by the fact that it is magnetic. Pyrite, also known as fool's gold, is a brassy-yellow mineral with a metallic luster. Marcasite is known as white iron pyrite.

Iron minerals are common throughout many parts of Arkansas, but only in a few places are they found in sufficient quantity to be of possible commercial importance in the iron and steel industry. Nearly all of the iron minerals are confined to the highland portions of the state. The largest deposits are limonite and are located in the northern part of the state in Carroll, Lawrence, Sharp, Fulton, and Randolph Counties. Deposits of less size and importance are found in Washington, Marion, Garland, Hot Spring, Pulaski, Saline, and other highland counties.

The iron minerals of northeastern Arkansas occur in sandstones, cherts, and limestones, while those of the Ouachita Mountains occur mostly with shale and novaculite. Iron minerals, principally limonite and siderite, occur in significant quantities in southern Arkansas and are assocated with sands and clays.

Magnetite occurs in several deposits at Magnet Cove, an igneous area of about five square miles in Hot Spring County. Pyrite is usually found in small quantities associated with the vein minerals of western and northern Arkansas. The largest known deposit occurs in dolomite north of Berryville, Carroll County. Other deposits of some size are at Yellville, Marion County, and at Magnet Cove, Hot Spring County. None of these has been commercially developed.

Two small pig iron furnaces were operated in Arkansas prior to 1860. One was erected in Carroll County on the east side of Osage Creek in 1850 and abandoned before 1860. The other was built in 1857 on Big Creek in Sharp County. These furnaces were established to supply a local demand due to the high cost of transportation at that time.

More recently small tonnages of limonite from northeastern Arkansas and magnetite from Magnet Cove have been shipped to steel plants in East St. Louis, Illinois and Birmingham, Alabama. Approximately 250 tons have also been shipped from deposits near Rosston in Nevada County.

MANGANESE

Manganese is a metallic element with a specific gravity very near that of iron. The manganese minerals of Arkansas consist of the oxides, psilomelane, braunite, hausmannite, manganite, pyrolusite, and wad; and the carbonate rhodochrosite.

All but a small quantity of the manganese consumed in the United States is in the form of an alloy known as ferromanganese which is used in the manufacture of steel. Relatively small amounts of oxide are utilized in the manufacture of glass, paint and dry cell batteries, and as coloring material in pottery, tile and brick.

Manganese is found in two principal localities in Arkansas—the Batesville district and the western Arkansas district. A third, recently discovered district is located in northern Searcy County. The most important producer of these is the Batesville district, which includes about 100 square miles and is located in northwestern Independence County, southeastern Izard County, and northeastern Stone County. The western Arkansas district includes Pulaski, Saline, Garland, Hot Spring, Montgomery, Pike, and Polk Counties.

The manganese ores in the Batesville district are found in irregular lumps and nodules which were concentrated as residual products of the decomposition of the Cason shale and the Fernvale limestone of Ordovician age. These masses are found mainly in pockets of residual clay lying in depressions in the Fernvale limestone which lies below the Cason shale, or in succeeding limestones below the Fernvale.

Open pit maganese mine in the Batesville district.

At least one massive, bedded deposit of manganese also is known in this district.

The western Arkansas manganese deposits are oxides which occur in veins and pockets in a hard rock known as the Arkansas novaculite. These veins and pockets range in thickness from a fraction of an inch to an occasional four feet. Recently manganese has also been found occurring in the shales of the district. Although containing a large amount of manganese in the aggregate, these deposits are individually usually small and discontinuous. On account of the cost of mining, little manganese has been shipped from the western Arkansas district.

The manganese deposits of northern Searcy County are oxides which occur in irregular lumps and nodules in the St. Joe limestone and lower part of the Boone chert.

The manganese ore deposits of the Batesville district have been worked at times ever since 1849 and almost continuously since 1881. Peaks of production were reached in both World Wars, but the best year to date has been 1956, when manganese ore valued at $2,066,000 was produced in Arkansas, largely from the Batesville district.

MERCURY

Cinnabar is the most important ore mineral of mercury. It contains 86.2 percent mercury and 13.8 percent sulphur. The mineral is crystalline and can be recognized by its weight, its red color, and by the fact that it makes a vermilion streak when rubbed on unglazed porcelain.

Mercury is one of two metals that is liquid under ordinary temperatures, and for this property along with other physical and chemical properties it has become an important element. Mercury is used in thermometers and barometers, and in the manufacture of electrical appliances, medicines, rubber, dyes, and explosive caps. It is also used for silvering mirrors, for the recovery of gold and silver from their ores, and in mercury boilers for the generation of electricity.

Cinnabar is found in the steeply folded sandstones and shales belonging to the Jackfork sandstone and Stanley shale formations of Pennsylvanian age in the Athens Plateau portions of Pike, Clark, and Howard Counties. The mineral occurs as fracture and vein fillings, as disseminated crystals in sandstone, and associated with vein quartz. The cinnabar deposits seem to be closely related to the geologic structure. The sandstone and shales in the area have been intensely folded and broken.

Cinnabar was discovered in Arkansas in 1931, and although mining operations have taken place intermittently since that time, Lake Greeson now covers a large portion of the district. Mining is carried on by shafts and tunnels. The ore is hand-sorted, crushed and retorted in furnaces. Mercury is recovered by condensing the mercury vapor.

MOLYBDENUM

Molybdenum is a metal that is obtained from the mineral molybdenite, a sulfid ceontaining 59.9 percent molybdenum and 40.1 percent sulfur. The mineral is soft, lead-gray, has a metallic luster, a greasy feel, and gives a greenish streak when rubbed on glazed porcelain.

Molybdenum is used primarily as an alloy in hardening iron and steel. Recent investigations by the U. S. Bureau of Mines indicate that molybdenum shows promise as a primary metal.

The only known occurrence of molybdenite in Arkansas is at Magnet Cove in Hot Spring County. Here molybdenite occurs in veins in a fractured pyroxenite country rock. These veins are composed mainly of orthoclase and pyrite with minor amounts of quartz, apatite, plagioclase, molybdenite, and brookite. The veins range in thickness from less than a half inch to five feet.

Molybdenite was first recognized at Magnet Cove in 1939 and since that time the prospect has been explored by geophysical methods, trenching and drilling. No molybdenum ore has been produced from this deposit to date.

NICKEL

The only recognized nickel mineral found in Arkansas is millerite. Millerite is a nickel sulfide containing 64.7 percent nickel and 35.3 percent sulfur. It has a metallic luster and a pale brass-yellow color with a greenish tinge when in fine, hairlike masses.

The chief use of nickel is as an alloy in nickel steels and nickel cast irons. It is also used in nonferrous alloys, heat and electric-resistant alloys, an din plating. Nickel imparts to its alloys toughness, strength, corrosion resistance, and special electrical, thermal, and magnetic qualities.

The first known occurrence of nickel in Arkansas is at the long abandoned Rabbit Foot mine located approximately three miles north of Benton in Saline County. The nickel-bearing mineral is millerite which occurs in cavities and crevices in a quartz vein enclosed by black shale. In 1887 1,991 pounds of ore were sampled and assayed, showing 1.46 percent nickel and cobalt. This mine was opened in 1887 and closed a short time later and was never reopened.

Rocks showing a measurable amount of nickel occur elsewhere in Saline County; however, no nickel development or mining operations have taken place in Arkansas since the closing of the Rabbit Foot mine.

RARE EARTHS

The rare earth group includes a number of metallic elements that are similar in their chemical properties to aluminum. Among this group are some of the scarcest elements known but several are relatively common. Perhaps the best known of the group are cerium and yttrium. Monazite sand is the most important mineral source of the rare earth group. Until recently the rare earths were scientific curiosities, but new methods of separating them from their ores and new applications for them, particularly in the atomic energy and metallurgical fields, have made them commercially valuable. The familiar lighter flint contains a cerium compound.

Rare earths were first detected by the Commission's chemist in samples from the Magnet Cove area, Hot Spring County. Subsequent investigations of auger drill samples from the center of Magnet Cove revealed up to 4.3 percent combined rare earths. However, to date there has been no commercial production of rare earths in the state.

SILVER

Silver is found in nature in a great variety of minerals, many of which are complex in their composition. A very common ore of silver is argentiferous galena (lead sulfide containing silver). The conditions under which silver-bearing minerals occur in nature are more varied than those controlling the distribution of gold. Silver-bearing minerals are present at several points in the Ouachita Mountains. The silver in these deposits usually is associated with lead sulfide.

In 1888 the chemist of the Arkansas Geological Survey assayed 181 samples for silver from Pulaski, Saline, Garland, Hot Spring, Yell, Montgomery, Pike, and Sevier Counties. Of these, 152 contained no silver, 12 contained traces and the remaining 17 from Pulaski, Saline, Montgomery, and Sevier Counties showed measurable amounts of silver. The greatest amount found in any of these was equivalent to 788 ounces per ton, while six contained less than two ounces per ton each.

Some of the lead-bearing shales of the Arkansas Valley contain from 0.5 to one ounce of silver per ton. Localities in Pulaski, Garland, Hot Spring, Montgomery, Pike, Howard, Sevier, Polk, Scott, and Logan Counties have been mined for silver at various times in the past. Up to the present time no deposits of commercial importance have been discovered. The Kellogg Mine, located in sec. 30, T. 3N., R. 11W., Pulaski County, which has been worked intermittently since about 1840, had an estimated yield up to December, 1926, of 70 short tons of silver-bearing lead concentrates, valued at about $6,000. The only reported production was 3,118 troy ounces in 1925, valued at $2,164. One selected sample of silver-bearing tetrahedrite from the Kellogg mine contained 1112 ounces of silver to the ton.

THORIUM

Thorium is a metallic element that, until recently, was not very well known to the general public. It is not an abundant element, but large supplies are available in monazite sand, a complicated mixture of the rare earth elements. Thorium is mainly used in making mantles for gasoline lanterns. It is now used also in the preparation of tungsten filaments for electric lamps. The metal thorium has recently been suggested as a possible substitute for uranium in nuclear reactors.

Since thorium minerals are generally radioactive many thorium occurrences were located as a result of uranium prospecting. Such was the case in the discovery of the thorium occurrences in the Magnet Cove area of Hot Spring County. Samples from several radioactive anomalies in this area proved to contain thorium rather than uranium as the radioactive element.

Another thorium occurrence that was located during uranium prospecting was the Uebergang deposit in secs. 3 and 4, T. 1N., R. 15W., Saline County. Thorium and uranium both occur in a quartz-feldspar rock at this locality. A selected sample of the rock analyzed 0.019 percent uranium and 1.5 percent thorium.

To date there has been no production of thorium in Arkansas.

TITANIUM

The principal ore minerals of titanium in Arkansas are rutile, brookite and ilmenite. Rutile and brookite are chemically identical, differing only in crystalline form. They both consist of forms of titanium dioxide, contain 60 per cent titanium and frequently carry iron as an impurity. Rutile and brookite are black and are both found as grains and crystals, as water worn pebbles, or in massive form. Ilmenite is a ferrous titanate containing 36.8 percent iron, 31.6 percent titanium and 31.6 percent oxygen. It is iron black, has a metallic luster, and becomes magnetic after heating.

Titanium compounds are used in the manufacture of chemicals, in tanning leather and dyeing cloth, and in making smoke screens. Titanium white pigments have replaced to a large extent white lead and zinc oxide. Ferro-titanium is an alloy used for the removal of oxygen and nitrogen from steel melts. Titanium oxide is also used in the manufacture of welding rod coatings. Titanium is now being used as a primary metal because of its unique combination of properties: light weight, strength, and corrosion resistance.

Rutile and brookite are found in Arkansas at Magnet Cove, Hot Spring County. Two general types of deposits have been recognized: (1) feldspar-carbonate-rutile veins in igneous rock in the center of Magnet Cove, and (2) brookite-quartz veins in altered Arkansas novaculite in the rim of the Cove. The rutile veins were mined by open pit methods during the period 1932-1944.

Ilmenite associated with river sands was mined during the period 1939-1940 from the Arkansas River in Yell County.

Ilmenite sand concentrations have been known since 1938 in southern Howard County near Mineral Springs. As yet there has been no ilmenite production from this area.

URANIUM

The uranium minerals are usually classified as primary, or those which are in the same physical state as when originally deposited, and secondary, those which are formed by the chemical alteration (weathering) of the primary minerals. The most important primary mineral is pitchblende which is dark gray to black in color and very heavy. The secondary minerals are normally brightly-colored and may occur in any type of rock. Carnotite, a canary yellow mineral, is the most common secondary uranium mineral. Both primary and secondary uranium minerals can be detected by their universal property of radiation. In other words, they emit certain rays that can be detected by special instruments, the Geiger Counter and the Scintillometer. Both of these counters will detect radioactivity in rocks, but they will not distinguish between radiation from uranium and radiation from other materials of no commercial value. Therefore, a chemical assay of the radioactive rock is necessary for a positive determination of its uranium content.

With the advent of the "atomic age" in July, 1945, the search for uranium in the United States began. Prospecting was stimulated by exploration and discovery bonuses provided for in subsequent Atomic Energy Acts. In Arkansas, although the state has not been thoroughly prospected to date, several radioactive localities have been found, and several yielded samples containing 0.1 percent or greater uranium oxide.

The Rankin prospect in sec. 25 T. 8S., R. 26 W., Pike County, consists of radioactive carbonized wood fragments scattered through a silt of the Trinity formation. The wood fragments vary greatly in size, the smallest fragment containing the most uranium. The highest assay obtained from one of these small fragments was 0.24 percent uranium oxide.

At the Chandler prospect in sec. 16 T. 2S., R. 18W., Garland County, uranium occurs in a rare mineral that coats the surface of narrow fractures in the Arkansas novaculite. Samples of this mineral ran as high as 0.35 percent uranium oxide.

The radioactive material at the Bear Hill prospect in the SE¼, sec. 11, T. 19 N., R. 17W., Marion County is a bitumen sparsely scattered through an outcrop of black shale. Samples of the bitumen containing up to 2.0 percent uranium oxide have been collected at this prospect.

At the Runyan prospect in NW¼ sec. 8, T. 3S., R. 17W, radioactive material occurs in narrow brookite-quartz veins that cut the Arkansas novaculite. Samples assaying as much as 0.14 percent uranium oxide were tested from this deposit.

The Wilson Springs prospect is probably the best known and perhaps the first uranium occurrence found in Arkansas. The uranium mineralization occurs at the contact of a nepheline syenite intrusive with folded novaculite and shale beds. Geochemical and X-ray determinations by the U. S. Geological Survey indicated the uranium-bearing mineral was pyrochlore, a complex columbium-uranium mineral. Soil samples assaying up to 0.4 percent uranium were collected by Atomic Energy Commission geologists at this prospect.

Although samples from Wilson Springs and other prospects have indicated a commercial grade of uranium ore, there has been no production of uranium in Arkansas to date because of insufficient proven ore tonnages.

ZINC AND LEAD

The zinc minerals of commercial importance in Arkansas are sphalerite (also known as blende, rosin jack or black jack), smithsonite, and calamine. Sphalerite is zinc sulfide (67.1 percent zinc). Small percentages of iron, manganese or cadmium are sometimes present. In color it is usually brownish-yellow to yellow-green and has a resinous luster.

Smithsonite is zinc carbonate (48 percent zinc). It is harder than sphalerite, has a glossy to pearly luster, and usually has a white to light-brown color. A small amount contains cadmium sulfide which imparts a yellow color and is known as "turkey fat." Calamine is zinc silicate (67.6 percent zinc) and occurs in colorless, flesh-colored, brown or black crystals.

Galena is the only lead mineral of commercial importance. Galena is lead sulfide (88.6 percent lead) and is soft, very heavy, and gray in color with a metallic luster. It will make a dull gray mark on hard paper or unglazed porcelain.

The chief uses for metallic zinc or "spelter" are for galvanizing iron, in making brass (66.83 percent copper and 27.34 percent zinc), for battery electrodes, and for sheet zinc. In addition to brass, zinc is a constituent of other alloys such as "white metals", and German silver. Zinc oxide, or zinc white, is employed extensively as a white paint pigment. Zinc sulfide with barium sulfate is known as lithopone, another white pigment. Zinc chloride is used to preserve wood, and zinc sulfate is utilized in the dyeing industry.

Metallic lead is used in making lead pipe, sheet lead and shot. It is alloyed with antimony, copper and bismuth to make type metal, and with other metals it forms alloys used in electric lighting, in storage batteries and in organ pipes. White lead (basic lead carbonate) and litharge (red lead oxide) are used as paint pigments. Litharge and red lead (lead tetraoxide) are used in the manufacture of glass. Other compounds of lead, such as the carbonate and acetate, are used in drugs.

There are two regions in Arkansas where zinc and lead ores are known to occur. These are the north Arkansas district, which includes Boone, Marion, Newton, Searcy, and parts of Baxter, Stone, Independence, Sharp, and Lawrence Counties, and the mineral belt of west-central Arkansas extending through and including parts or all of Pulaski, Saline, Garland, Hot Spring, Montgomery, Polk, Howard, Pike, and Sevier Counties. The zinc and lead minerals in north Arkansas occur in irregular bodies in limestone, dolomite or chert beds. Smithsonite or zinc carbonate usually occurs above or in those parts of the sulfide bodies which have been subjected to weathering. In west central Arkansas the zinc and lead minerals occur as veins in folded sandstones and shales.

Although zinc is of much commoner occurrence than lead in the north Arkansas district, lead ore was recognized and developed first. The occurrence of lead in this district was mentioned by writers as early as 1818. Lead was mined locally years before the Civil War, and three lead smelters were in operation at Lead Hill in Boone County during this period. Since the Civil War lead deposits have been worked intermittently, and their history closely parallels that of zinc.

The earliest attempts to work north Arkansas zinc deposits were made at Calamine, in Sharp County, in 1857 when a zinc smelter was in operation. Active zinc mining began in the counties farther west in 1899 and reached its peak in the early years of World War I from 1914 to 1917. Since 1918 there has been only intermittent mining activity in the district.

In the mineral belt of west-central Arkansas a few zinc and lead mines were worked at Petty, six miles west of Gillham, Sevier County, in the early 1860's by the Confederate States Government. Between 1,000 and 1,500 tons were mined and three lead furnaces were in operation. In 1899 the North American Ore and Metal Company reopened, and for several years operated the same mines in Sevier County. During the first two years 1,140 tons of ore were removed. The district has been practically inactive ever since.

NONMETALLIC MINERALS

Many kinds of nonmetallic minerals are found in Arkansas. Among these are asphalt, barite, bromine, chalk and marl, clay, diamonds, fuller's earth and bentonite, greensand, gypsum, limestone and dolomite, marble, nepheline syenite, novaculite, ocher, phosphate rock, Portland cement materials, quartz crystals, salt, sand and gravel, sandstone and quartzite, silica sand, slate, soapstone, sulfur, tripoli, and water.

Nonmetallic minerals are used in the manufacture and construction of many articles and devices, from modern highways and skyscrapers to cosmetics and fragile pottery. Water is important to industry and agriculture as well as being directly consumed by man. Many minerals are present in Arkansas in substantial quantities but known reserves of others are definitely limited and conservation measures are needed to insure the best use of these minerals.

ASPHALT

Asphalt is the "heavy end" of asphalt base petroleum. It is a mixture of heavy hydrocarbon compounds that can be separated from the "light ends" of asphalt base petroleum by heating or evaporation. Asphalt has a low specific gravity, melts easily, and burns with a bright and hot flame. Asphalt is used for road building as "black top" pavement, as a filler for joints in concrete, as a dust preventive, for roofing and water proofing, in the rubber industry and in asphalt paints, and in the manufacture of asphalt flooring tile.

It is probable that the Arkansas deposits were once oil saturated sands which became asphalt as a result of the evaporation of the more volatile elements of the petroleum. There are eight known deposits of sand of this character in southwestern Arkansas. These are located in Pike and Sevier Counties near the border of the Gulf Coastal Plain, and range in thickness from a feather edge to five feet.

One of the asphaltic sand deposits located about 2½ miles southeast of Pike, Pike County, was worked from 1900 to 1906. Asphalt from this deposit was used for street paving in Little Rock. None of the asphaltic sand deposits in the state are now being worked. At the present time the asphalt used in Arkansas essentially is that derived from crude oil residues.

BARITE

Barite, a sulfate of barium, sometimes called barytes or heavy spar, is a heavy mineral, ordinarily white, but when impure may be of any color. It usually occurs as a granular or crystalline material, and is easily identified by its relative softness and high specific gravity. The principal use for Arkansas barite is in the manufacture of a weighting agent for drilling muds used in the oil industry. Barite can also be used for the manufacture of lithopone, a white paint pigment, and as a filler in paint, paper, rubber, linoleum and cloth. A new technique has been developed that utilizes barite in combination with rubber for road building, roofing paint and vehicle undercoatng.

Most of the barite deposits in Arkansas are in the Ouachita province, specifically in Hot Spring, Montgomery and Polk Counties. The Dierks district, however, is located in Sevier County in the Gulf Coastal Plain. These deposits result from three modes of emplacement: capillary replacement, cementation and fracture filling.

The Magnet Cove deposit, located just east of Magnet Cove in Hot Spring County, is the largest known deposit and has been the source of practically all the commercial barite production in the state. This deposit is the replacement type with the barite ore replacing a portion of the clay minerals in the lower-most beds of the Stanley shale formation in a synclinal or trough-like structure. The deposits in the Fancy Hill area of Montgomery County are similar to the Magnet Cove deposits.

Open pit barite mine near Magnet Cove, Hot Spring County.

The occurrences in Polk County are chiefly of the vein or fracture filling variety. In the Dierks district the barite occurs as a cementing material in the sandstone and gravels of the Trinity formation. Associated with these deposits is the occurrence of barite "roses" in the weathered residual zone along the edges of the deposits.

The occurrence of barite in the state is first mentioned in the annual report of the Arkansas Geological Survey for 1888, where it is suggested that the deposits might someday prove profitable. Barite was first found in Hot Spring County much later, about 1900, when a water well was dug at a spot two miles east of Magnet Cove, in the valley of Chamberlain Creek. However, it was nearly 15 years before the material was identified as barite and another 15 years before exploration was begun and the first descrip-

tion of the deposit published by the Arkansas Geological Survey. Production began in 1939 and within ten years this deposit was yielding as many tons each year as all of the other deposits in the United States combined. Arkansas has been the largest producer of barite since 1944. One plant at Malvern and one at the mine process the ore into a finished material ready to be used.

BROMINE

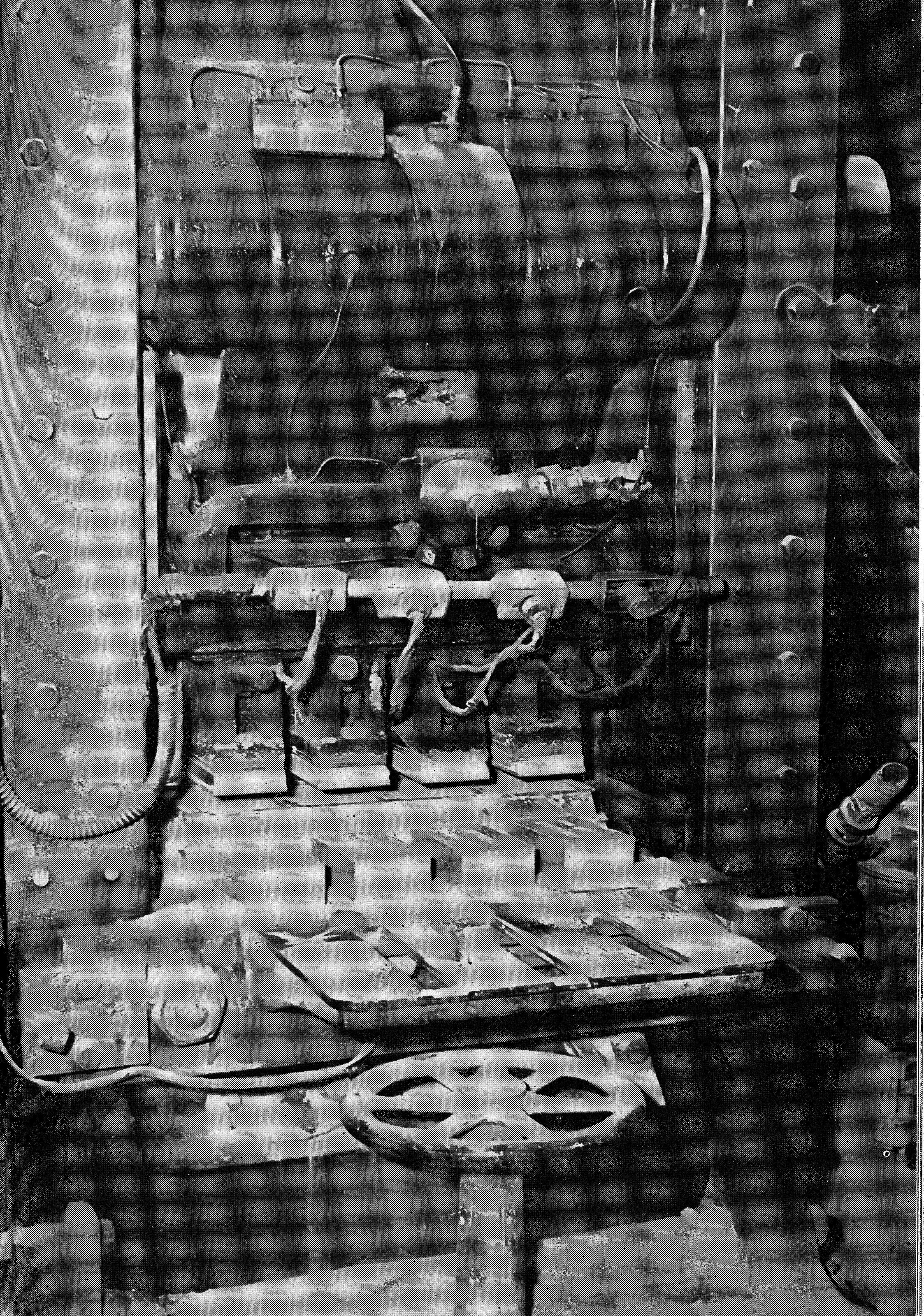
Bromine is a caustic brownish liquid which, along with fluorine, chlorine and iodine, forms a closely related family of chemical elements known as the halogens. It is recovered principally from sea water, well brines, and saline lake brines.

Over 90 percent of the total consumption of bromine is in the form of ethylene dibromide and other compounds. Ethylene dibromide is added to tetraethyl lead for use as an anti-knock mixture in gasoline. Other uses are as an intermediate in the synthesis of dyes and pharmaceuticals, as a nonflammable solvent for celluloid, resins, gums and waxes, and as an anesthetic, sedative and antispasmodic agent. It is also utilized in fumigation mixtures. Five percent of the total consumption is in the form of elemental bromine which is used as a laboratory reagent and as a bleach and disinfectant. It is also used in medical and photographic preparations.

Bromine occurs in abnormally high concentration in the salt brines of the Smackover formation in south central Arkansas. In analyses of brines taken from four oil fields the bromine concentration is from 4000 to 4600 parts per million.

Arkansas has one bromine recovery plant in operation. This plant, located at El Dorado and having a rated capacity of five million pounds per year, is processing brine from the Smackover Field.

Brick press in operation near Malvern.



CHALK AND MARL

Chalk is essentially an earthy calcium carbonate and therefore belongs to the limestone class of rocks. It is composed chiefly of the skeletons of microscopic limy organisms, and its distinguishing characteristics are its soft, friable qualities and its light color.

Chalk intermixed with clay results in an earth known as marl. The location of marl in southwestern Arkansas in an area removed from other limestone beds makes the deposits valuable to that part of the state. Arkansas chalk is used in the manufacture of Portland cement, and locally in the treatment of acid soils. It has been utilized also as whiting and asphalt filler. Marls are used in the preparation of fertilizers.

The principal chalk and marl beds of Arkansas are known as the Annona chalk, the Saratoga chalk, and the Marlbrook marl. These formations are of Upper Cretaceous age and are overlapped by younger formations west of Arkadelphia, Clark County. These formations include chalks and marls of variable composition, and extend in an eastward direction across Nevada, Pike, Hempstead, Howard, Sevier and Little River Counties. Of these deposits only three outcrops of any size may be classed as true chalk. (See section on "Portland Cement Materials")

CLAY

The term clay as used by most of us may mean a particular type of soil which becomes plastic when wet. The technical definition is much the same with a few additions. It is described as a naturally occurring earthy aggregate made up essentially of alumina, silica and water Further, it is usually plastic when sufficiently pulverized and wetted, rigid when dry, and becomes steel-hard when fired at a sufficiently high temperature.

Many types and kinds of clays exist, and they are classified in various ways, according to origin, physical properties, chemical composition and chief clay mineral constituent. A convenient way of classifying clays is according to their use, since the properties of a clay limit its use to a more or less definite field.

Heavy Clay Products. These may be made from a great variety of clays, ranging from low-grade red-burning to high-grade buff-burning clay. Familiar items included in this group of products are: common and face brick, hollow tile, sewer pipe, stoneware, and flower pots. Suitable clay for these uses are found in many parts of Arkansas and a large industry is already prospering in the state.

Pottery and Whiteware. Pottery may be made from either light or dark firing clays and shales. Included in this group are domestic and chemical stoneware, electrical insulating ware, and art pottery. Whiteware is made from mixtures of ball clay, kaolin, feldspar, and flint, as well as other minor constituents. China and porcelain, floor tile, wall tile, and artware are all considered whiteware. Some grade of all of the constituents are produced in Arkansas and plants making several of the products exist in the state.

Refractories. Fire bricks for lining furnaces and kilns are made from clay capable of withstanding high temperatures. Much of the light colored clay such as that in Hot Spring County near Malvern is suitable for usual refractory purposes. In the bauxite region of Saline and Pulaski Counties super duty fire clays are now produced.

Kaolin. Kaolin is the most common useful clay mineral for manufacture. All of the products mentioned above use clays in which kaolin is the principal clay mineral, possibly making up half of the clay. There are natural occurrences of nearly pure kaolin, however, and several such occurrences are known in Arkansas. Minor amounts of kaolin have been produced from Pike County and the refractory clay from the bauxite region is essentially this mineral. In addition to its ceramic applications this material has many other applications such as a filler in rubber and paper and in cosmetics.

DIAMONDS

One of the few places in the world and the only place in North America where diamonds are found in the rocks in which they were formed is in Arkansas. The Prairie Creek peridotite area is roughly triangular in shape, containing approximately 73 acres, and is situated 2½ miles southeast of Murfreesboro, the county seat of Pike County. The area has been known to geologists since 1842. It is the site of an old volcano, a volcanic neck, of the same type that yields diamonds in South Africa.

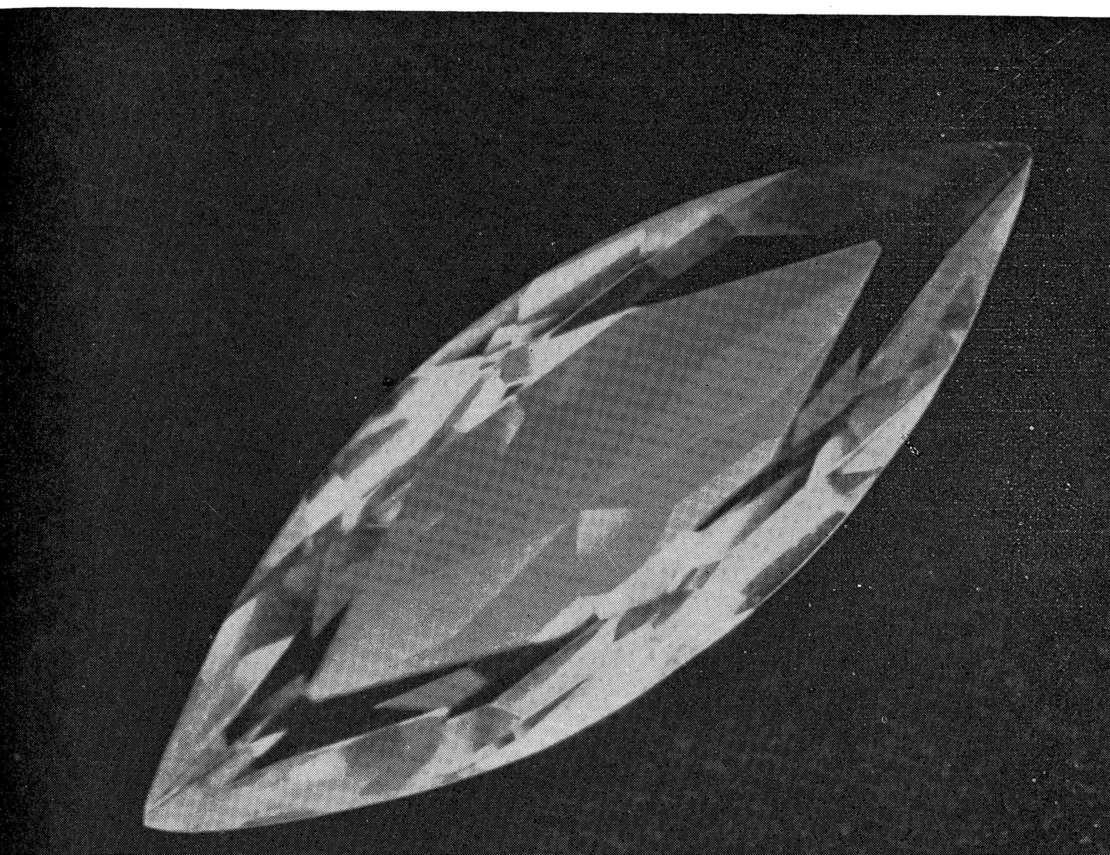
The peridotite is a dark rock which is fairly coarse grained. Some of it was broken up into smaller pieces as it was moved up into the volcano and this broken material is called peridotite breccia. Some diamonds have been found in the peridotite, but most of them have been taken from the peridotite breccia or from the thin soil overlying this type of rock.

History of Development. Diamonds were first discovered in Arkansas in 1906 when two stones were found by John M. Huddleston near the mouth of Prairie Creek, 2½ miles southeast of Murfreesboro, Pike County. Following this discovery, diamonds were reported to have been found in two areas of small size about 2 miles to the northeast. Several efforts were made to place the recovery of diamonds on a commercial basis, but without sustained success. In 1919, the Arkansas Diamond Corporation was organized with a capital of 10 million dollars. A washing plant was erected which in 1920 washed 18,000 loads of peridotite. The corporation discontinued operations after 9 months. Early in 1940 the property was taken over by The Diamond Corporation of Arkansas. A 2000 ton washing and concentrating plant began operation in 1948 and was shut down a year later.

"The Star of Arkansas" one of the largest diamonds found at the deposit near Murfreesboro. About five times natural size.

At the present time Mr. Howard A. Millar operates the "Crater of Diamonds" on part of the area as a tourist attraction. Diamonds as large as the "Star of Arkansas" which weighed 15.22 carats uncut have been found by visitors.

Production. Production figures are incomplete, but it is estimated that approximately 48,000 stones, with an average weight of one-fourth carat, have been produced since the discovery of diamonds in the area. The largest diamond reported was the "Uncle Sam" which was discovered in 1924, and weighed 40.23 carats. It was cut as a gem with a weight of 24.3 carats, and the color is faintly rose.



FULLER'S EARTH AND BENTONITE

Fuller's earth is any earth, usually a clay, which has a high adsorbing power. It may vary widely in color, chemical composition and physical appearance, and can be identified only by actual tests with the liquid to be clarified. The material is commonly "short" or non-plastic. Bentonite is a clay which has adsorbent ability and may also have the ability to take up as much as 7 times its volume of water.

Fuller's earth is used principally for bleaching, clarifying, or filtering edible oils and petroleum products. It is also employed as a substitute for talcum powder and for softening water. Bentonite is used principally as a fuller's earth to decolorize oils, waxes and fats; as a filler in paper and soap; as a suspending agent in ceramic glazes and enamels; and, when mixed with barite, as a drilling mud in oil and gas wells. Arkansas bentonite from Saline and Grant Counties has been used for bleaching lubricating oils.

Fuller's earth in Arkansas has been found near Olsen Switch in Saline County, and in Drew, Pulaski, Searcy, Ouachita, Dallas, Howard, and Grant Counties. The deposits at Olsen Switch are derived from igneous dikes which have been weathered to a depth of from 60 to 200 feet.

There are four known deposits of bentonite in Saline County, two of which have been mined. These are the Long Bell deposit in sec. 23 and the Palmer deposit in sec. 13, both in T. 2 S., R. 13 W. The Durian Switch deposit in sec. 18, T. 5 S., R. 16 W., Hot Spring County, has also produced commercially.

The Saline County fuller's earth deposit was discovered by John Olsen in 1891, and in 1894 a plant was erected which operated near Olsen Switch. Production was reported in 1901, and from 1904 to 1907 Arkansas was the second largest producing state in the United States. During 1909, 1910, and 1911, it was third in output and in value of fuller's earth. From 1894 to 1922 fuller's earth was produced intermittently. The Saline County bentonite deposits have been mined intermittently since 1933.

At Olsen Switch the earth was mined by sinking shafts into the dikes, and mining was done by pick and shovel. The lumps of earth are dried, crushed and screened.

GREENSAND

Greensand is a sandy rock containing glauconite, a green-colored silicate of potassium and iron. It is used as a water-softener and as a fertilizer. The potash content of the Arkansas greensand varies from 2.80 to 4.53 per cent.

Greensand marl is found along Little River near Morris Ferry in Little River County. It also occurs in the vicinity of Washington, Hempstead County. A bed 25 feet thick crops out near the center of Sec. 15, T. 8 S., R. 22 W., along the banks of a branch of Moore's Creek in Clark County.

To date there has been no commercial production of greensand in the state.

GYPSUM

Gypsum is hydrated calcium sulfate. When an enclosed body of sea water is separated from the ocean or an outlet, one of the most common salts to precipitate is hydrous calcium sulfate. Arkansas gypsum occurs as saccharoidal gypsum which resembles lump sugar, as satin spar which has a fibrous appearance, and as selenite which consists of large crystals.

Raw or uncalcined gypsum is employed mainly as a retarder for cement. It also is used as a fertilizer, as a disinfectant, in the manufacture of paper and paint, construction board, and in metallurgy. Calcined or dehydrated gypsum, known as plaster of paris, is utilized for wall plaster and in the manufacture of plaster board. The gypsum of southwest Arkansas has been used almost entirely in the manufacture of cement.

Gypsum deposits are found in the southwestern part of Arkansas in beds of Cretaceous age. They are most abundant in the De Queen limestone member of the Upper Trinity formation, and are exposed in a narrow belt extending westward from the Little Missouri River at Plaster Bluff, Pike County, through Sevier County into Oklahoma. The thickest exposure of pure saccharoidal gypsum is at Plaster Bluff, where it forms a single bed ranging from 10 to 14 feet in thickness. Gypsum also occurs near Highland, Pike County. Selenite crops out near Redfield, Jefferson County, and also in Drew County in Tps. 14 and 15 S., Rs. 6 and 7 W.

There are three operating gypsum quarries in the district at the present time, all of which are owned by the Arkansas Gypsum Company of Murfreesboro. The Plaster Bluff deposit was worked in 1922 and 1923 and the Highland deposit has been worked continuously since 1936. Past operations have been both open pit and underground but at present all the active quarries use the open pit method of quarrying.

LIGHTWEIGHT AGGREGATE

Clay, shale, slate, and mining wastes are the most common raw materials for lightweight aggregates. It is the "impurities" in the material, such as carbonaceous matter, iron compounds, and limestone which are potential sources of gas for bloating.

The growing market for precast building units and lightweight concrete for massive structures has created an enormous demand for lightweight aggregates. Recent developments in the utilization of lightweight aggregates makes possible considerable saving in structural steel and foundation design on new and existing structures.

Three plants produce lightweight aggregate in Arkansas. The first established was that of the Rescolite Corporation at Fort Smith which uses a local shale that is bloated in rotary kilns. The Arkansas Lightweight Aggregate Corporation of England, Arkansas bloats a local clay in rotary kilns as does the plant of the Southwest Concrete Materials Corporation at Poyen in Grant County.

Two conditions are necessary to bring about bloating of a clay. When bloating temperature is reached, the general clay mass must be in a plastic condition, and at the same time gases must be evolving throughout the mass. The plastic consistency is developed by the fluxes that start a fusion, and in this state of the clay the gases do not escape readily. The result is a mass of thin-walled pockets caused by the gas expansion which is light in weight and has high strength characteristics.

Doubtlessly many localities in Arkansas have deposits of clay or shale that would make suitable lightweight aggregate, and such deposits will warrant development at such time as an accessible market is assured.

LIMESTONE AND DOLOMITE

Limestone is a form of calcium carbonate. It commonly occurs as a massive, fine-grained rock. Its color is usually gray, although it may be white, yellow, brown or almost black. It will effervesce readily in any common acid. Dolomite is calcium-magnesium carbonate. Pure dolomite contains 54.28 percent calcium carbonate and 45.72 percent magnesium carbonate. It frequently occurs as a massive, fine-grained rock resembling limestone. Its color may be white, pink, gray, brown or black.

Limestone has been used in Arkansas as building stone, as crushed stone for alumina plants, for road metal, in concrete and railroad ballast, for rubble and riprap, in the manufacture of lime, and as agricultural limestone. Until recently, most of the limestone produced in Arkansas has been utilized in the manufacture of burned lime, which is sold in two forms—quick lime and hydrated lime. At present, most of the limestone produced is used by the aluminum companies. The limestone is roasted with bauxite, causing a chemical reaction, that removes silica and frees the alumina.

Often, little distinction is made between limestone and dolomite; for many purposes they can be used interchangeably, and both are frequently sold under the name of limestone. The most important uses for dolomite for which limestone cannot be substituted are in the manufacture of dead-burned dolomite refractories, and in the preparation of heat-insulating material. At the present time the dolomite produced in Arkansas is used as crushed stone and agricultural limestone. Limestones and dolomites, high in silica, have been used in the manufacture of mineral wool for insulation, and some of the Arkansas rock is suitable for this purpose.

Occurrence and production. All of the dolomite and nearly all of the limestone of Arkansas occur in the Ozark region in a more or less rectangular area about 7,000 square miles in extent. A little limestone is found in the Gulf Coastal Plain. Extensive beds of chalk which chemically are comparable with limestone are present in southwestern Arkansas.

The first reported production of burned lime in Arkansas was in 1846. It is reported that from 1876 to 1892, a total of 278,060 barrels of lime was produced in Benton, Carroll, Independence, Sharp, Washington, and Howard Counties. The first recorded annual production was in 1889. At the present time there is one lime-burning plant operating in north Arkansas, located near Batesville, Independence County. Crushed limestone is also being produced by three companies near Batesville. Most of the crushed material is used in the aluminum industry and as agricultural limestone. Agricultural limestone is also produced from chalk near Foreman, Little River County.

Limestone is quarried from open pits and from underground mines. When used to make burned lime or hydrated lime, limestone is ground to lump size, and burned in gas-fired kilns. Limestone is crushed for alumina plants, for railroad ballast, for road materials, and for use as agricultural lime. It is also quarried as a building stone.

The presence of high quality "chemical grade" limestone in north Arkansas may well result in new industries based in part on this raw material. The present bauxite processing industry is nearly as dependent on this raw

High-calcium limestone quarry on White River, Izard County.

material as on the local bauxite deposits. Lime, which is produced by calcining high-grade limestone, is the commonest and cheapest of alkali chemicals. Nearly 8 million tons was consumed by chemical and other industries in this country during 1957 as compared to slightly over 1 million tons by agriculture and the building trade combined.

MARBLE

In commercial terminology marble is a coarse to fine crystalline limestone generally susceptible to a high polish. The term, however, is frequently applied commercially to ornamental stones which are not limestones. Marbles vary considerably in composition, structure, and appearance. The Arkansas marbles are usually found in various shades of

gray, although pink, chocolate, and black marbles are found at numerous outcrops in the White River basin.

Marble is used for building and house construction, for monuments, for interior decorating, flooring, electrical switchboards, table tops, wash basins, and statuary. Terrazzo, a flooring material, is made from the waste marble chips. Onyx marble, a banded variety of limestone, is used as an interior decorative stone, for statuettes, lamp shades and bases, and in jewelry.

Occurrence and production. Crystalline limestone or marble crops out over an area of 2,000 square miles in northern Arkansas. The beds usually have a workable thickness of from 25 to 50 feet and at some places are 155 feet thick. The limestone belongs to several well-defined horizons. These are: the Boone formation of Mississippian age, the St. Joe marble member of the Boone formation, the St. Clair marble of Silurian age, and the Fernvale, Kimmswick, and Plattin of Ordovician age. The Boone and St. Joe marbles are present throughout the entire area referred to, but the St. Clair, Fernvale, Kimmswick, and Plattin marbles are found only over the eastern and south central part of the region.

The "Batesville" marble has been rather widely used and is usually cut into either small rectangular blocks for house construction, or large blocks for use in buildings. It is a gray stone and is produced from the Boone formation near Batesville. Marble blocks are also quarried near Batesville from the St. Clair, Fernvale, Kimmswick, and Plattin and shipped to Carthage, Missouri where several varieties and grades of stone are cut for interior and exterior use in buildings. Black marble suitable for interior use occurs in the Fayetteville and Pitkin formations of Mississippian age in Independence, Cleburne, Stone, and Searcy Counties. Onyx marble is found in caves in north Arkansas.

Marble quarry on White River, Izard County.

The first piece of marble recorded as shipped out of the state was the one sent to the Washington Monument in 1836, the year in which the state was admitted to the Union. The block, weighing 9,000 pounds was taken from near Marble City, Newton County, and hauled overland by ox wagon to the Arkansas River near Clarksville, whence it was shipped by boat. The first recorded production of marble in Arkansas was in 1899. Production has been intermittent since that time.

NEPHELINE SYENITE

Nepheline syenite is a medium to coarse-grained light-colored rock with an even texture and a granite-like appearance. It can be distinguished from granite, however, by the fact that it contains little or no quartz. It is an igneous rock which, in Arkansas, has been intruded into thick masses of sedimentary rock. The Arkansas nepheline syenite occurs in two varieties known locally to quarrymen as "blue granite" and "gray granite."

The nepheline syenites of Arkansas have high strength and weather resisting qualities, and are crushed for use as roofing granules, road materials, and concrete aggregate. In the past, nepheline syenite has been used as a building, monumental, and paving stone. Also syenite has been used extensively as riprap for the protection of river banks.

Nepheline syenite is found principally in four localities in the state. These are: Pulaski County south of Little Rock, Saline County in the vicinity of Bauxite, Garland County near Potash Sulphur Springs, and Hot Spring County at Magnet Cove. The total area in which this rock is exposed is about 13 square miles.

Nepheline syenite is presently being quarried at Fourche Mountain in Pulaski County where it is crushed and sized for various uses. The Minnesota Mining and Manufacturing Company has a plant south of Little Rock where a colored ceramic coating is applied to the crushed syenite in preparing roofing granules. Nepheline syenite has also been quarried in Saline County, near Bauxite, and at Diamond Jo Quarry in Magnet Cove, Hot Spring County.

NOVACULITE

Novaculite is a hard, fine-grained sedimentary rock consisting almost entirely of silica. It breaks with a smooth shell-like fracture. There are two commercial classes of abrasive grade novaculite, the "Arkansas" stone and the "Ouachita" stone. The Arkansas stone is a very fine-grained homogeneous rock with a waxy luster, is usually white, and is translucent on thin edges. The Ouachita stone is much more porous and has the appearance of unglazed porcelain.

Finished novaculite is used as an oilstone or whetstone for the sharpening of tools and fine surgical instruments. Large quantities of crushed novaculite are utilized for railroad ballast and for road building. Mixtures of novaculite chips and various other materials are used for finishing of machined metal parts, stampings, forgings and castings. Novaculite is also used in the manufacture of silica refractories (fire brick). Some types of novaculite are suitable for the production of ferrosilicon alloys.

Novaculite is widely distributed in the Ouachita Mountains in southwestern Arkansas. Between 200 and 300 miles of narrow, more or less parallel, nearly east-west belts of novaculite crop out from Pulaski County westward to Oklahoma. The Novaculite formation, which is Devonian in age, consists of novaculite, shale, and conglomerate, and has a thickness of from 250 to 900 feet.

The first authentic notation of whetstone in America refers to those of Arkansas. In 1818 mention was made of a quarry of hone stone in Magnet Cove, Hot Spring County, which had been worked for several years. Records show that production, which was from Garland County, was intermittent from 1885 to 1905, and continuous from 1905 to the present time. Novaculite is quarried from open pits and is shipped in blocks. The Arkansas stone is shipped in blocks from 5 to 15 pounds in weight, and the Ouachita stone in blocks up to 1,500 pounds in weight. A company located at Hot Springs recently began production of finished Arkansas oilstone.

PHOSPHATE ROCK

The phosphate rock of Arkansas is made up of a mixture of several minerals. The phosphate mineral is a variety of the mineral apatite (calcium fluo-phosphate) and the other minerals present as impurities are quartz, calcite, limonite, and clay.

The most important use for phosphate rock is in the manufacture of phosphate and super-phosphate fertilizers. Other uses are in the manufacture of matches, household detergents, a wide variety of phosphorus chemicals, and in special purpose alloys such as phosphorus bronze.

The most important phosphate production in the United States comes from the extensive deposits in Florida. Important tonnages are also produced in Tennessee and Idaho. In Arkansas phosphate rock occurs in two general areas: the White River area of northern Arkansas in Stone, Independence, Searcy, and Izard Counties, and in the Searcy-Van Buren County area along Peyton Creek.

In the White River area the phosphate rock occurs locally in the Cason shale formation of Ordovician age.

In the Searcy-Van Buren County area phosphate rock occurs at the base of a sandstone bluff along Peyton Creek in rocks marking the division between Mississippian and Pennsylvanian ages. This phosphate rock has an oolitic texture and contains a very small percentage of uranium.

The only place in Arkansas where phosphate rock has been mined is in the White River area near the junction of East and West Lafferty Creeks in the western part of Independence County. During 1906 and 1907 the Arkansas Fertilizer Company removed about 50,000 tons of crude phosphate rock by tunnelling and by stripping. The rock was shipped to Little Rock where it was manufactured into super phosphate fertilizer. It was found, however, that Tennessee and Florida rock could be processed more cheaply and the development in Arkansas was discontinued.

PORTLAND CEMENT MATERIALS

Portland cement is a material obtained by heating to the point of partial fusion a mixture consisting of approximately three-fourths limestone, and one-fourth sand and clay. The presence of excessive magnesium carbonate, alkalies, and sulfates, is undesirable. Portland cement, common "cement", is used in concrete for many purposes.

Materials suitable for the manufacture of Portland cement occur in many localities throughout the United States, but economy in manufacture requires that plants be constructed only at points which offer adequate transportation facilities, cheap fuel, and easy access to markets.

Within the Gulf Coastal Plain of Arkansas the most favorable localities for Portland cement manufacture are in the southwestern part of the state where the Annona chalk formation is known to crop out. Outcrops are found at Foreman and White Cliffs in Little River County, and along a narrow belt extending from the east side of Saline River in Howard County to a point about one mile southeast of Yancy in Hempstead County. There are two operating Portland cement plants in Arkansas: one is located at Okay, near Saratoga, Howard County; the other is at Foreman, Little River County.

The Ozark Plateaus of Arkansas contain extensive limestone beds many of which are good Portland cement material. The area also contains clay or shale beds of suitable quality. The following limestone formations are relatively widespread in northern Arkansas counties: Pitkin limestone and Boone formation of Mississippian age, St. Clair limestone of Silurian age, and Fernvale, Kimmswick, Plattin, and Joachim limestones of Ordovician age.

The Ideal Cement Company has been manufacturing Portland cement at Okay, Howard County, since 1929, and the Arkansas Cement Corporation began manufacturing Portland cement near Foreman, Little River County, in 1958.

The chalk and marl are quarried, crushed, and fired to the point of fusion in a rotary kiln. The clinker formed by this fusion is finely ground and mixed with gypsum and other additives to make the final Portland cement product.

QUARTZ CRYSTALS

Quartz or silica (SiO_2) is a hard, usually colorless or white, insoluble mineral. Quartz crystals and veins are a very common and striking feature of the Ouachita region of Arkansas.

Arkansas quartz crystals are widely known for their clarity and for their habit of occurring in attractive clusters.

Most of the quartz crystals found in Pulaski, Saline, Garland, and Montgomery counties are sold to tourists, museums, schools, and private collectors. Others, which are essentially free from flaws are cut into "Hot Springs diamonds", and are used for various ornamental purposes.

Quartz crystals, clear, transparent, and free from color or cloudiness have assumed an important position in the construction of radio equipment, range finders, direction-finding apparatuses, periscopes, gun sights, polariscopes, and other precision equipment. During World War II Arkansas quartz crystals were used particularly in radio equipment.

All the quartz crystals are produced from the Ouachita region. A large part of the supply comes from the Crystal Mountains east of Norman, Montgomery County, from the vicinity of Crystal Springs in western Garland County, and north of Mountain Valley in northern Garland County. Most of the crystals are found associated with residual clay which has filled the cavities and fractures in either the Blakely or Crystal Mountain Sandstones.

SALT

Salt is one of the primary human needs, and the history of its production goes back to the beginning of the human race. Now salt has found so many other uses than as a food or food preservative, that it has probably become the most important raw material in the chemical industry.

Pure salt contains by weight 39.34 percent sodium and 60.66 percent chlorine. Rock salt is the solid form, and salt in solution is generally referred to as brine. The largest use of salt is in the chemical industry in the manufacture of numerous sodium and chlorine chemicals. The food manufacturing industry uses large tonnages of salt, and the use of common table salt should be mentioned here. Salt is used also in many industrial and metallurgical processes and as a refrigerant.

Rock salt is the most important commercial source of salt and it occurs in two structural forms: sedimentary beds, and salt domes. In addition to its stratified occurrence with sandstones and shales, salt is interbedded with other saline minerals such as gypsum and anhydrite.

The most familiar occurrence of salt in solution is ocean water. It also occurs throughout the world in waters of inland lakes or lagoons and in the form of subsurface brines that may or may not reach the surface as saline springs. Although there are known occurrences of rock salt and brine in the state there is no commercial production of salt at the present time.

Salt in the form of brines occurs at many localities in Arkansas. In Hot Spring and Clark Counties the surface wells and ponds in the alluvial bottoms between the mouth of De Roche and L'Eau Frais Creeks contain brines that were worked for salt during the Civil War. In about 1815 white settlers preempted brine sources in Saline County from the Indians and these were operated until around 1840. Shallow brine wells also occur in a belt extending from Arkadelphia in Clark County to Ultima Thule, Sevier County. Salt springs are known in Clark, Conway, Crawford, Franklin, Sevier, and Van Buren Counties. Perhaps the most important potential sources of salt brine in the state are the brines associated with the producing oil fields in south Arkansas.

Rock salt does not occur at the surface in Arkansas, but extensive beds of it are known to occur in the Louann formation of Jurassic age in southern Arkansas. At some localities the salt bed exceeds 1000 feet in thickness, and the formation in which it occurs underlies all or parts of Nevada, Ouachita, Bradley, and Union Counties. It is possible that the salt may someday be used by injecting water into the salt beds through deep wells and pumping out the resultant brine.

SAND AND GRAVEL

Sand and gravel are unconsolidated aggregates of grains that range in size from material as fine as clay to material as coarse as boulders. Quartz and siliceous materials usually predominate. The finer aggregates are classed as sand, the coarser as gravel. The dividing line between sand and gravel varies considerably, being placed at a diameter of from 0.1 to 0.25 inches. Arkansas sand is employed chiefly as concrete and plaster aggregate, as engine sand to prevent slipping and, to lesser degree, for molding sand and railroad ballast. The principal uses of Arkansas gravel are for highway construction, paving gravel, railroad ballast, and building purposes.

Sand and gravel are widely distributed throughout the state. In the Gulf Coastal Plain the gravel deposits are found either as stream deposits or higher land deposits. The most prominent high land gravel bed extends irregularly across Pike, Howard, and Sevier Counties, near the northern edge of the Gulf Coastal Plain. This bed is from 20 to 50 feet thick and is known as the Pike gravel member of the Trinity formation of Lower Cretaceous age. Another valuable bed is the Ultima Thule gravel of the Trinity formation, exposed northeast, northwest of DeQueen in Sevier County, immediately to the south of the Pike gravel.

Crowley's Ridge, which extends through Clay, Green, Craighead, Poinsett, Cross, and St. Francis Counties in eastern Arkansas, contains immense deposits of gravel. These may be seen in the sides of eroded ravines, road cuts, and railroad cuts. In many instances the gravel extends to the top of the ridge. The beds and terraces of the Arkansas, Ouachita, Saline, and White Rivers also contain large quantities of sand and gravel.

Mining operations vary in size and complexity from a simple roadside pit, where a few tons are loaded by hand methods without any sizing, to very large plants where thousands of yards of sand and gravel are excavated, washed, and sized each day. Sand and gravel are obtained from river beds by dredging.

SANDSTONE AND QUARTZITE

Sandstone is a sedimentary rock consisting chiefly of quartz sand cemented more or less firmly together with clay, silica, calcium carbonate, or iron oxide. Sandstone with silica cement is usually the strongest and most desired for structural purposes. Some sandstones also contain feldspar or other mineral grains. Quartzite is metamorphosed (changed by heat and pressure) sandstone, and is more firmly cemented and stronger than ordinary sandstone.

Until recently the greater part of the sandstone produced in Arkansas has been crushed stone used for concrete aggregate and in road building. Within the last few years, however, a substantial tonnage of sandstone dimension stone has been produced in the state.

There are practically unlimited quantities of sandstone in the highland area of Arkansas. The Arkansas Valley contains vast supplies of sandstone in the Jackfork and Hartshorne formations. In the Ouachita Mountain region it is found in the Stanley shale, the Hot Springs sandstone, the Blaylock, the Blakely sandstone, and Crystal Mountain sandstone. An almost unlimited amount of sandstone is present in the Boston Mountains and the Springfield and Salem Plateaus, the sandstone occurring principally in the lower portion of the Atoka formation, the Hale formation, the Batesville sandstone, the St. Peter sandstone, the Calico Rock sandstone, and the Kings River sandstone.

Sandstone dimension stone is produced from two districts in Arkansas. The larger production comes from the Logan-Johnson County area which ships substantial tonnages of attractively colored, cut blocks and slabs of Hartshorne sandstone throughout the midcontinent region. A smaller district is located near Batesville, Independence

County, where appreciable amounts of beautifully colored and banded Batesville sandstone blocks are produced. Large amounts of sandstone also are crushed near most of the large cities in the Paleozoic outcrop area of Arkansas.

SILICA SAND

Silica sand is a relatively pure quartz sand. To be used in making glass it must be almost entirely free from such impurities as manganese oxide, iron oxide, magnesia, or clay. The presence of manganese in the sand gives the glass made from it a greenish color; magnesia makes the sand less fusible; and clay tends to cloud the glass. Uniformity of grain size is desirable. At Guion, Izard County, where the sand is quarried, it is white, usually unconsolidated, and resembles granulated sugar.

It is used chiefly for the manufacture of various kinds of glass, for foundry molding, for sandblast sand, and for a variety of other uses. There is an increase in demand for "frac" sand for use in recovering oil and gas by pumping the sand between the strata to increase flow. The silica sand of Arkansas has been utilized principally for glass manufacture and, to a lesser extent, for molding sand and silica flour.

SLATE

Slate is a metamorphosed shale with well-developed cleavage. Common colors are black, gray, red, or green. Black and gray slate owe their color to finely-divided carbonaceous matter; red slate to the presence of iron oxide; and green slate probably to the presence of chlorite.

At the present time most of the slate produced in Arkansas is used for making slate granules, in coating various forms of asphalt roofing. Some slate is finely-ground and

Entrance to underground silica sand mine at Guion.

sold as a mineral filler. Cut blocks of slate are used in roofing, floors, patios, table tops, and walkways.

The best slate in Arkansas occurs in the central part of the Novaculite Uplift of the Ouachita Mountains covering portions of Polk, Montgomery, Garland, Pulaski, and Saline Counties, an area about 100 miles long and 15 miles wide. This slate is found in the Stanley shale, Missouri Mountain Shale, and Polk Creek shale formations. The deposits worked at the present time lie in western Montgomery, eastern Polk, and northern Saline Counties. Ground slate is produced in Saline and Pike Counties.

A new company has recently started producing slate slabs and blocks from a quarry just south of Bigfork in Polk County. Red, green, gray, and black slates are produced for the building industry from this deposit.

SOAPSTONE

Soapstone is a rock composed largely of the mineral talc with lesser amounts of other silicates and carbonates. The rock is either massive or flaky depending on the talc content. It is soft and has a slightly greasy feel when rubbed on the hands. In powdered form soapstone has many applications as a mineral filler and in ceramic ware. It is also used as tailors chalk; and in pencils for marking steel and in block or slab form as a heat or electrical insulator, in the construction of acid-resistant tanks and for table tops and ornamental carvings.

Soapstone occurs in Saline County in altered serpentine intrusives that cut Paleozoic shales and cherts. The Saline County soapstone was first described in 1888. Only recently, however, has there been commercial production from these deposits. Soapstone has been produced from three deposits in the Saline County district to date, and exploration for new deposits is currently in progress.

SULFUR

The first experimental plants in the United States for the recovery of sulfur from natural gas were located in Lafayette and Columbia Counties, Arkansas. These semi-commercial plants, built in 1941, led to the construction of two full-scale commercial plants, one in each of those counties, in 1943. The plant in Lafayette County was built to serve the McKamie Field. The Columbia County plant was intended to serve the Dorcheat-Macedonia Field. The gas from the former field contained as much as 4,500 grains of hydrogen sulfide per 100 cubic feet of natural gas. This "sour" gas was purified to a hydrogen sulfide content of 0.05 grains per 100 cubic feet in the pilot plant operation. The ensuing commercial plant at McKamie Field was producing 65 tons of free sulfur daily by the end of 1943 and was recovering 97 percent of the sulfur in the gas. This plant currently produces about 100 tons of sulfur daily. In the Dorcheat-Macedonia area the hydrogen sulfide content was found to be as high as 2,400 grains per cubic foot. Only one small sulfur recovery operation is being carried on currently in Columbia County. It yields about 10 tons of sulfur daily.

The start of full-scale operations in the McKamie Field marked the initial use of the Claus process for sulfur recovery in this country, that process being the first devised for recovering sulfur from hydrogen sulfide. Basically the Claus process involves burning 1/3 of the hydrogen sulfide to form sulfur dioxide, which then reacts with the unburned hydrogen sulfide in the presence of a surface-active catalyst to form sulfur and water vapor. The sulfur is condensed to liquid form and shipped or stored in that manner or is allowed to solidify for handling as a solid.

Prior to the development of sulfur extraction units, natural gas containing appreciable amounts of hydrogen sulfide was flared because of its corrosive nature and unpleasant odor. If used directly as a boiler fuel, gas may contain as much as 360 grains of hydrogen sulfide per 100 cubic feet and still not be too objectionable. However, natural gas used for domestic purposes is not permitted to contain more than 1½ grains of hydrogen sulfide per 100 cubic feet.

Sulfur is used in making a wide variety of products. Probably the largest eventual market for sulfur will be in the production of chemical fertilizer. The importance of sulfur as a raw material stems from the fact that it can be converted to sulfuric acid, which has numerous industrial applications.

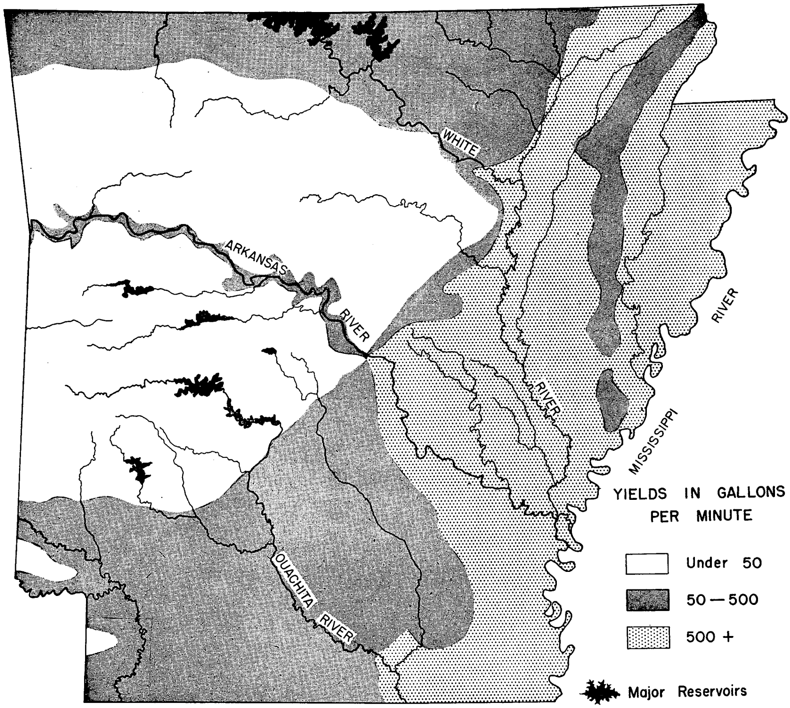
TRIPOLI

Tripoli is a finely divided form of silica derived from the alteration of chert, novaculite, or highly siliceous limestone. Tripoli is used principally as an abrasive or polishing agent. It is particularly suitable for buffing and burnishing and is an important ingredient of many scouring soaps and powders. Compact blocks are cut out to desired shapes and sizes to be used as water filters. Tripoli may also be added to Portland cement for washability, water tightening, and strength.

Tripoli occurs in two general regions in Arkansas: northwestern Arkansas near Rogers, and in the Ouachita Mountains near Hot Springs. In both areas the analyses show higher than 99 percent SiO_2. Both areas have had commercial operations; however, the only active operation at this time is in the Hot Springs vicinity.

The deposits in northwestern Arkansas are derived from the weathering of the cherty limestones of the Boone formation, while the Ouachita Mountain occurrences are developed by the leaching of a limy phase within the Arkansas novaculite formation. Other deposits have been reported in Baxter, Montgomery, Pike, Polk, and Washington Counties.

Tripoli has been mined by both underground and open-cut methods. The material is then dried, crushed, pulverized, and screened or air-floated.



Availability of ground water in Arkansas.

WATER

Arkansas is abundantly supplied with good quality water for domestic, commercial, and industrial purposes.

The southern and eastern parts of the state lie in the Gulf Coastal Plain. In this area great quantities of surface water are available from the Red, Ouachita, Arkansas, White, St. Francis, and Mississippi Rivers. When surface water is not available, ground water is present in large quantities and may usually be obtained from wells drilled to a depth of from 100 feet to 1,200 feet. More than 456 billion gallons of water was pumped from wells in the state during 1954. Water from these wells has a temperature ranging from 55° to 70° F.

The northern and western parts of the state are hilly and mountainous. Although ground water in this area is limited, the existence of numerous streams, a broken terrain, and formations that lend themselves well to the construction of dams renders the impounding of surface water comparatively simple and inexpensive. With a few exceptions Arkansas' major rivers and tributaries are free of pollution.

Water likely will prove ultimately to be our most valued and cherished natural resource. Cities and towns, modern industry and agriculture, a high standard of health, and adequate recreational facilities depend in large measure on dependable water supplies of usable quality.