KANSAS MINERAL RESOURCES FOR WARTIME INDUSTRIES

By

JOHN M. JEWETT and W. H. SCHOEWE

with chapters by

R. M. DREYER, JOHN C. FRYE, R. P. KEROHER, E. D. KINNEY, NORMAN PLUMMER and JOHN F. ROMARY

UNIVERSITY OF KANSAS PUBLICATIONS
STATE GEOLOGICAL SURVEY OF KANSAS, BULLETIN 41
LAWRENCE, KANSAS

STATE GEOLOGICAL SURVEY OF KANSAS, BULLETIN 41

1942 REPORTS OF STUDIES, PART 3, PAGES 69-180, FIGS. 1-13

MAY 9, 1942

KANSAS MINERAL RESOURCES FOR WARTIME INDUSTRIES

By

JOHN M. JEWETT AND W. H. SCHOEWE

with chapters by

R. M. DREYER, JOHN C. FRYE, R. P. KEROHER
E. D. KINNEY, NORMAN PLUMMER and JOHN F. ROMARY[1]

[1] Staff members, Kansas State Geological Survey.

Contents

Illustrations

Tables

Foreword

The following report on "Kansas Mineral Resources for Wartime Industries" obviously has a special purpose, as indicated by its title. Kansas possesses a wealth of necessary materials for building the strength of our nation in time of war, when defense of the American way of life becomes the paramount duty and privilege of all Americans. It is very desirable to take stock of every substance at our command and every aspect of utilizing each one of them that pertains to preserving our lives and liberties. The safety of one's household from despoliation, the sanctity of one's family from violation and the freedom to worship God according to one's choice, may seem unrelated to such things as the existence of Kansas coal beds or the quantity and properties of Kansas natural gas, but there is a connection. The coal may be translated into power for industry that manufactures airplanes, guns and war vessels, into explosives of many sorts that are needed for defense and offense and into rubber, chemicals and innumerable other varied requisites of war. These are the armor and the weapons that must be used to protect household, family and freedom to worship. Natural gas and many other mineral resources, and products of the soil, likewise are very importantly related to the needs of defense. All this is evident, though many persons fail to take notice of it.

The importance of mineral resources to industry is basic. Industrial activity builds cities, states and nations, contributing to higher standards of living, producing new wealth, and adding to general prosperity. Accordingly, the availability of the raw materials needed to establish industry is a vital consideration of those who would operate industry actively or expand it. Especially as regards nations, availability of raw materials means control of their development and distribution. Germany needs and covets Russian oil and manganese, Dutch coal, and French iron ore. Japan needs and covets East Indian oil, rubber and copra, Malayan tin, and great Chinese coal fields. Aggression that has primary origin in demand for minerals with which to feed the industrial ambitions of certain nations is a major underlying cause of the present World War. No other essential reason for Italy's invasion of Abysinnia exists. These observations serve to emphasize the relation of mineral resources to industrial growth and lead to statement of a second objective of the report on Kansas mineral resources that is here offered.

The State of Kansas is endowed by nature to become one of the industrially important parts of the United States. It is already a leader among agricultural states, but beneath the soil there is a variety and a very great quantity of mineral substances that are needed by industry. Kansas now ranks in the top one-sixth of the states as grouped on the basis of annual mineral production. The value of Kansas' mineral production, which in recent years has ranged from 100 to 165 million dollars, considerably exceeds that of a number of the nations now conquered by the Nazis, and the yield from Kansas mineral deposits can be much increased. This means that our state should move steadily forward in building larger and more numerous industries. The importance of the Kansas region in mineral resources, combined with advantages of its central inland geographic location and facilities for transportation, has already led to establishment of several great war industry plants in this area. Modification of these for peace-time pursuits will be made very readily and naturally in the case of some of these plants but less easily in the case of others. At all events, the present developments are in line with a very sound program of industrial growth that should lead to a well balanced economy of agriculture and industry of various sorts based on mineral and agricultural resources. This report serves to advance such a post-war future development by summarizing information on all known mineral resources of the state, both actual and potential. Not previously described in reports of the State Geological Survey are possible commercial production in Kansas of magnesium, aluminum, iron, bentonite, and high-grade light-firing and refractory clays. New data on other mineral deposits, long known to occur in Kansas, are also supplied.

Attention should be called to the large map in five colors, showing Mineral Resources of Kansas, that is published concurrently with this report. The map supplements and illustrates in excellent manner the following descriptions of mineral deposits of the state.

RAYMOND C. MOORE.

Abstract

During the present war emergency the production and available reserves of mineral resources and other raw materials are of paramount importance to the safety of the nation. This report presents a summary of the mineral resources of Kansas, present production and known or estimated reserves, and possible uses of these resources in war industries located in Kansas. The vital relationship of fuels and metals to war industries is well known. The role of nonmetallic mineral resources in war production, although less obvious, is none the less real in both a direct and indirect way.

Fuels are essential to most industrial enterprises. The 3,700,000 tons of coal, 85,416,561 barrels of oil, and 85,632,472,000 cubic feet of gas that were produced in Kansas during 1941 are vitally important to the state and the nation in wartime, but even more important are the vast reserves of these materials and their present and potential by-products. On January 1, 1942, the estimated proved reserves of oil in Kansas were 752,670,000 barrels, which, because of new discoveries, constitute an increase over the previous year. Oil and gas produced in the state are distributed through more than 8,000 miles of pipe line and processed in Kansas at 27 refineries, 15 natural gasoline plants, and 3 carbon black plants. One helium plant not now operating has a capacity of over 8 million cubic feet annually. Coal and petroleum, particularly during wartime, should be considered not only as fuels but as basic raw materials for chemical industries. They represent important raw materials for the manufacture of such products as explosives, plastics, and synthetic rubber.

Metals are used in the manufacture of all implements of war. Aluminum and magnesium are essential to aircraft production, and although neither is now produced in the state, the vast potential reserves of each, shown in this report to occur in Kansas, assume an increasing importance as the supply in the United States of high-grade aluminum ore (bauxite) is depleted and the demand for magnesium rapidly increases. During 1941, 57,000 short tons of zinc and 12,000 short tons of lead were produced in Kansas. The Tri-State zinc and lead district, part of which is in Kansas, is the most important zinc-producing region in the world. Both zinc and lead are important in war industries.

Although non-fuel and nonmetallic mineral resources are not so spectacularly and directly related to war industries, they nevertheless constitute indispensable materials for basic industries. Asphalt rock is used as a road-surfacing material and bentonite is employed as a drilling mud, filter for oil, and a bond in foundry sand. Chalk, the Kansas reserve of which is estimated at more than 50 billion tons, is used as whiting and in the chemical industries. Ceramic products, in addition to being employed by the navy and in war industries, probably will be used to an increasing extent to replace metal products for civilian use. In 1940, Kansas produced structural clay products valued at $1,500,000; the undeveloped reserves of clay in north-central Kansas alone amount to 125 billion tons, of which 40 billion tons are light-firing clays. There is an undeveloped reserve of 1,000,000 tons of diatomaceous marl which can be used in certain types of cement and as a filtering material. The present Kansas production of Portland cement for use in construction is four and one-half million barrels annually, valued at over 5 million dollars, and the

reserve of Portland cement raw materials is enormous. Kansas ranks eighth among the states as a gypsum producer. Salt is an essential material in many chemical industries, such as those producing explosives and synthetic rubber. Kansas now produces annually about 700,000 tons of salt, and the reserves in the state are estimated to be at least 5,000 billion tons. A total of 2,264,871 tons of sand and gravel, valued at $893,962, was produced in Kansas during 1940. This production could be increased many times if additional quantities were needed. Reserves of sand and gravel, rock-wool materials, and stone for construction purposes are inexhaustible. Volcanic ash is used as an abrasive, in cleaners, as a ceramic glaze, and in cement. In 1940 Kansas produced 39,215 tons, valued at $129,959, and the reserves are estimated at more than 10 million tons.

The information given in this report on mineral resources of Kansas demonstrates the wide variety of raw materials and vast reserves, in some cases almost untouched, that occur within the state. These abundant raw materials and the state's geographic position in the heart of the nation make Kansas of great strategic importance as a region for the location for war industries.

Introduction

Kansas possesses a large variety of mineral resources which, together with her great agricultural resources, may be utilized for the production of war materials. Only seven states exceed Kansas in the value of their total annual mineral output. The existence in Kansas of vast resources of oil, gas, coal, salt, building materials, and volcanic ash are fairly well known throughout the state and the midwest, but the existence in the state of many other important or potentially important mineral resources is only partly realized and in some cases almost completely unknown.

The present report has been prepared in response to a large number of inquiries directed to the Survey during the past several months regarding the mineral resources available in Kansas for war industries. In part, the report is an expansion of a report prepared a few months ago at the request of the Kansas State Chamber of Commerce. The purpose of the present report is to give a summary of the resources of Kansas so that future planning for industries, particularly those new industries in Kansas that will produce war materials, may have the advantage of a coordinate picture of the mineral resources of the state.

During the past decade numerous geological reports dealing with various mineral resources of Kansas have been published by the State Geological Survey. These bulletins are available to all and will be sent on request. A list of publications is available and may be had by addressing the Director of the Geological Survey, University of Kansas, Lawrence.

The Geological Survey is actively investigating the existence, distribution, quantity, quality, and uses of the mineral resources of Kansas. These investigations include not only study of known rocks and mineral deposits but also the discoverey and study of new ones. Some of the undeveloped resources of Kansas described in recent reports and in the present report include: aluminum from Kansas clays, iron, magnesium, bentonite, chalk, light-firing clay in north-central Kansas, diatomaceous marl, and rock wool raw materials. The location and distribution of the various mineral resources of Kansas, in addition to locations of pipe lines, refineries, brick plants, and so forth, are shown on a large colored map recently published by the Geological Survey. A large volume of unpublished data pertaining to the resources discussed in this report in contained in the files of the Geological Survey. Interested persons seeking detailed information not here included are urged to contact the Director.

"Kansas Mineral Resources for Wartime Industries" has been compiled under the supervision of R. C. Moore and John C. Frye by J. M. Jewett and W. H. Schoewe, aided by the following staff members of the State Geological Survey: R. M. Dreyer, R. P. Keroher, E. D. Kinney, Jewell Kirby, Norman Plummer and John Romary. The maps accompanying the report were drafted by G. W. Reimer. The manuscript was edited by T. G. Payne.

FUELS

COAL

Summary.—In 1941 production of Kansas coal amounted to approximately 3,700,000 tons. The annual production, however, has been as great as 7,500,000 tons in one year. Known reserves are sufficient to allow continuation of the present production rate for many years.

Coal is classified in three general divisions: (1) brown coal or lignite, (2) bituminous coal, and (3) anthracite or hard coal. The general properties of these three ranks of coal are so well known that they need not be reviewed here. It should be noted, however, that the purposes for which an individual coal may be utilized are dependent on its physical and chemical properties, and the classification given above is by far too simple. Coals of any one of these major ranks may be adapted to various uses. For example, bituminous coal in Kanawha county, West Virginia, is a gas coal; bitum-

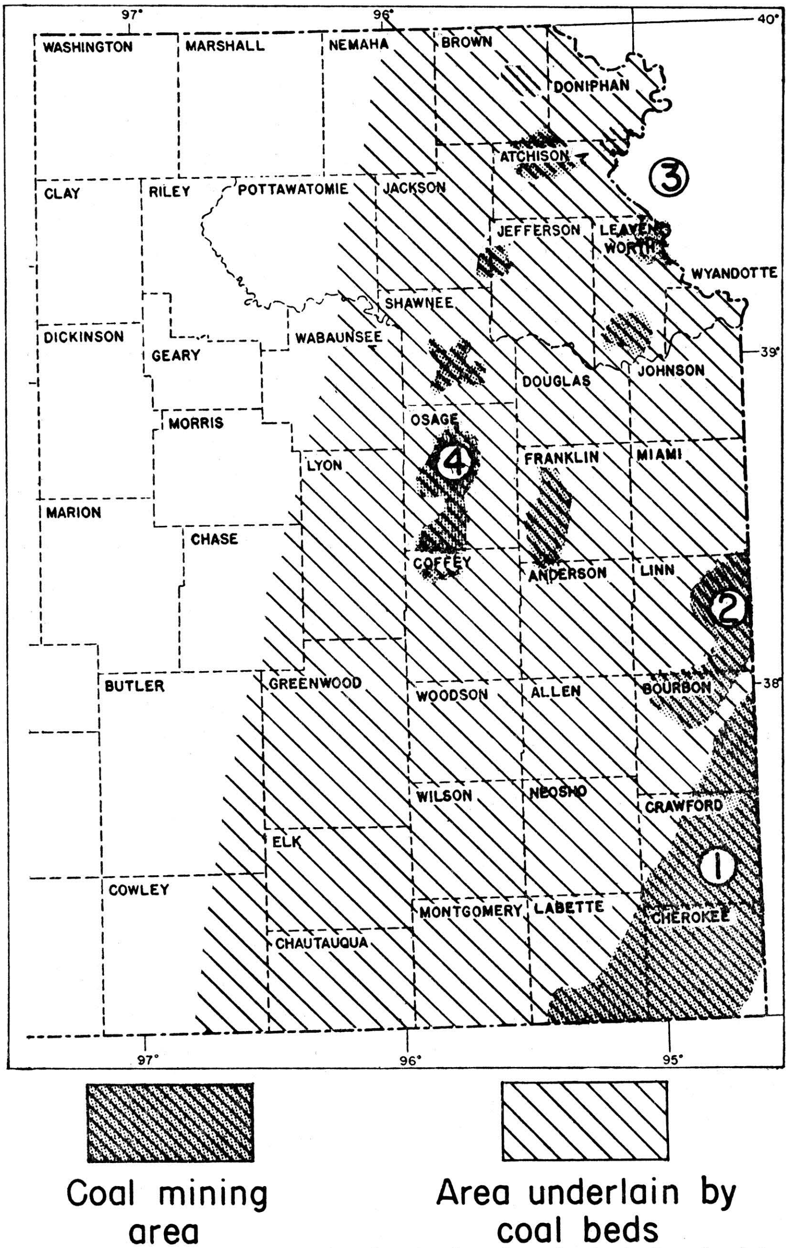

FIGURE 1. Map of eastern Kansas showing location of principal coal-mining areas and of region underlain by more or less continuous coal beds. (1) Southeastern Kansas coal field, (2) Eastern Kansas coal field, (3) Northeastern Kansas coal field, (4) East-Central Kansas coal field.

inous coal in the Collinsville district of Pennsylvania serves as coking coal; and that in the Pocahontas field, Virginia, steam coal (Lilley, 1936, p. 224).

Coal in Kansas.—With the exception of a very small amount of lignite, coal produced in Kansas is classed as bituminous. It is recognized, however, that coals of different beds in the state show considerable differences in character. More technological work must be done on Kansas coals before their best uses can be determined; some such studies have been accomplished among which is the work of Young and Allen (1925).

Kansas has four main coal-mining areas: (1) the Southeastern Kansas coal field, chiefly in Crawford and Cherokee counties, but including a part of Labette and a part of Bourbon county; (2) the Eastern Kansas coal field or the Mulberry coal area in Linn and Bourbon counties; (3) the Northeastern Kansas field, now nearly inactive, in Leavenworth and Atchison counties; and (4) the East-Central Kansas field, chiefly in Osage county, but including parts of Coffey, Franklin, and Shawnee counties. Figure 1 shows the location of the main coal-producing areas in Kansas and of areas of laterally extensive coal beds.

It is not known definitely when and where the first coal mine in Kansas was opened. Available records indicate that the first mine was opened near Leavenworth in 1854 (Crane, 1898, p. 188); it was a shallow pit or short drift constructed near the outcrop of a coal bed in the Lawrence formation. It is probable that the first mine of commercial importance was the one put down near Fort Scott in 1865 (Crane, 1818, p. 178). Soon thereafter, small strips in which coal was mined by hand labor were opened in Crawford county. Coal was mined and sold to a railroad company near Pittsburg as early as 1870, at which time a railroad recently had been completed from Kansas City to Baxter Springs. A shaft mine with a capacity of 40 tons per day was sunk near Pittsburg in 1874 (Crane, 1898, p. 153) and has been reported as the first shaft coal mine in Kansas, but in 1870 a shaft was sunk at Leavenworth to a Cherokee coal bed 713 feet below the surface that had been discovered in 1865 by drilling. The prospecting for the latter mine was done by a company organized by Major Hawn, a geologist, who had a knowledge of coal outcrops in southeastern Kansas and who knew the approximate dip of the beds. Hawn predicted quite accurately at what depth the coal would be reached at Leavenworth.

Coal mining was developed rapidly in the Southeastern Kansas field in the 1870's. In those years large amounts of coal were shipped to Kansas City and to other markets. In 1878 and 1879 a railroad was constructed from Joplin, Missouri, to Pittsburg, Kansas, primarily for the purpose of hauling coal from the Southeastern Kansas field. Mining was started near Weir, Cherokee county, in 1878 and near West Mineral, Cherokee county, in 1895. By 1897, Crawford and Cherokee counties were producing 2½ million tons of coal yearly (Crane, 1898, p. 153).

Development of the East-Central Kansas coal field was initiated with the beginning of coal mining in Osage county in the spring of 1869. The first mine was on Carbon Hill about 2 miles east of Carbondale. In the autumn of 1869 several mines were in operation in the vicinity of Osage City. Mines were opened at Scranton in 1874 and at Burlingame in 1878 or 1879. The East-Central Kansas field soon was producing large amounts of coal, much of which was being consumed by the Santa Fe railroad.

Coal mining was begun near Atchison in 1893, and the first mines were shallow pits and short drifts near outcrops of a 16-inch coal bed in the Lawrence formation. Later, a shaft mine was sunk near Atchison to a coal bed in the Cherokee shale. The Atchison area commonly is included as part of the Northeastern Kansas coal field.

According to Whitla (1940, p. 10), coal mining was started near Pleasanton, Linn county, between 1850 and 1860. Pleasanton is included in the Eastern Kansas field. Shafts and strip pits later were constructed in this field near Mound City, LaCygne, Boicourt, and Prescott in Linn county, and near Hammond and Mapleton in Bourbon county.

Coal mines were established near Thayer, Neosho county, approximately in 1898 (Crane, 1898, p. 133). Mining was started near Williamstown, Franklin county, in 1872. Mining on a small scale has been carried on up to the present time in these areas.

The Southeastern Kansas coal field.—The greater part of the coal mined in Kansas has come from the Southeastern Kansas field, which lies chiefly in Crawford and Cherokee counties but partly in Bourbon and Labette counties (fig. 1).

There are 15 coal beds in the Cherokee shale in the area of its outcrop in Crawford, Cherokee, and Labette counties (Abernathy, 1938, pp. 195-196), where the Cherokee is approximately

450 feet thick. These coal beds range in thickness up to 3 feet, 8 inches. The thicker coals occur in the middle and upper parts of the Cherokee rock section. According to Abernathy, 5 of the 15 coal beds in this area have been mined, but more than 90 per cent of the mined coal has been taken from only two beds. The most important coal bed in this district is called the Weir-Pittsburg coal; it occupies a position near the middle of the Cherokee shale. According to Pierce and Courtier (1937, p. 85) the Weir-Pittsburg coal has been mined to the extent of over 75 per cent of that part which is greater than 2½ feet in thickness. At the present time the greater part of the minable coal in the Southeastern Kansas field has been removed.

It is important to note that core drilling in the vicinity of Edna and Angola, Cherokee county, has revealed the presence of a coal bed 4½ feet thick, lying from 425 to 625 feet below the surface (Pierce and Courtier, 1937, p. 68). This bed probably is stratigraphically equivalent to the Weir-Pittsburg coal. It is probable that extensive deep shaft-coal mining will be developed in this area.

Eastern Kansas coal field.—This field is located in eastern Linn and northern Bourbon counties. In this area a coal bed, known as the Mulberry coal, occurs in the lower part of the Bandera shale formation. The thickness of the Mulberry coal in Kansas ranges from a few inches to 3¼ feet. It has been mined extensively for many years and is still important. In the Eastern Kansas field mining has been carried on near Fulton and Mapleton in Bourbon county and near Mound City, Prescott, Pleasanton, Boicourt, and La Cygne in Linn county. Both shaft and stripping methods are employed. For several years the Mulberry coal has been exploited by large-scale stripping operation in western Missouri, where it is now largely exhausted. About two years ago large-scale stripping operations were extended westward into Kansas, and, as a result, the Eastern Kansas field came into greater prominence. In 1940, Linn was the second largest coal-producing county in Kansas (see table 3).

Prior to 1940 mining activity was on a rather small scale in the Eastern Kansas field; hence there still remains a large reserve of coal. Throughout most of the Eastern Kansas field (fig. 1) the shallow depth of the Mulberry coal makes stripping operations profitable. The value of the farm land below which it lies, however, makes extensive stripping undesirable. It is hoped that in this area mining by means of shallow shafts will become increasingly important. The greatest known thickness of the Mulberry coal is in the vicinity of La Cygne in northern Linn county. Mining operations in the future may be expected to extend northward up Marias des Cygnes river valley into Miami county.

Northern Kansas coal field.—The Lansing-Leavenworth-Atchison area is designated as a coal field because of the fact that deep-shaft mining of coal beds in the Cherokee shale long has been practiced there. The State Penitentiary mine at Lansing produces coal from a bed approximately two feet thick, 712 feet below the surface and 89 feet below the top of the Cherokee shale. At various times in the past, four or more mines in the vicinity of Leavenworth have been in operation. These mines reach the same coal bed that is being mined at Lansing. At Atchison a 3-foot coal bed formerly was mined at a depth of 1,126 feet. This bed also in in the Cherokee shale.

TABLE 1. *Thickness and depth of Cherokee coal beds in the Lansing-Leavenworth area*[1]

Coal beds	Thickness of coal bed, in inches	Depth to coal, in feet
15	12	598
14	6	617
13	6	640
12	14	663
11	6	677
10	24 (bed mined)	709
9	16	728
8	3	889
7	13	918
6	10	993
5	26	999
4	28	1,031
3	12	1,087
2	5	1,097
1	6	1,127
Aggregate thickness of coal beds	197 inches	
Total thickness of coal in beds over 14 inches in thickness	108 inches	

[1] Modified from table by Hinds and Greene (1917).

That the Northern Kansas coal field has important coal reserves is indicated by thickness data in tables 1 and 2.

TABLE 2. *Thickness and depth of coal beds exceeding 14 inches in thickness in Atchison deep boring*[1]

Coal beds	Thickness of coal bed, in inches	Depth to coal, in feet
4	22	801
3	36 (formerly mined)	1,126
2	28	1,190
1	15	1,199
Aggregate thickness	101	

[1] Data from Hinds and Greene (1917).

It should be noted that the Northeastern Kansas coal field borders Missouri river and that recent improvements designed to aid navigation in Missouri river have an important economic and military aspect.

A shallow coal bed in the Lawrence formation has been mined intermittently in the Northern Kansas field. At Atchison this bed is 10 to 16 inches or more in thickness. It crops out in river bluffs and along ravines tributary to Missouri river and formerly was mined in drifts or slope openings 2 to 3 miles south of Atchison (Whitla, 1940, p. 29). A lower coal bed, the Sibley coal in the Stranger formation, has been mined at various times at a locality about five miles north of Leavenworth. The Sibley coal has been mined also in the southern half of Leavenworth county. In Leavenworth county this coal bed ranges from 6 to over 22 inches in thickness.

East-Central Kansas coal field.—This coal-mining area lies principally in Osage county, but the coal bed mined there extends entirely across Kansas from Doniphan county on the north to Chautauqua county on the south. Mines formerly were situated along nearly the whole extent of this district. Production is from the Nodaway coal which lies within the Aarde shale member of the Howard limestone formation. The thickness of the Nodaway coal is reported to be as great as 30 inches locally in Osage county, but averages about 15 inches. According to Whitla (1940, p. 22), its thickness north of Osage county is nowhere more than 12 inches; in Chautauqua county it is 18 inches thick. The Nodaway coal lies a few feet below the Church limestone member of the Howard formation, which acts as a very effective cover protecting the coal from weathering; good quality coal, therefore, can be obtained at very shallow depths. In stripping operations this limestone cap rock must be removed by blasting.

In the East-Central Kansas coal area the Nodaway coal is from 12 to 30 inches thick and lies a few feet below the main ledge of the Howard limestone. This coal is being mined by stripping and shaft methods. There are more than 20 shaft mines in Osage county near Scranton, Burlingame, and Osage City; they range from 25 to 118 feet in depth and are reported to contain no gas and to be unusually dry. Normally about 8 strip mines are operated in Osage and northern Coffey counties.

Areas of small coal production.—The various coal deposits exploited in the four coal fields described above are more or less continuous over a wide region. These and other coal beds in Pennsylvanian rocks underlie the region in eastern Kansas shown in figure 1. Minor coal-producing areas in this region are described in the paragraphs which follow. The seemingly unimportant coal deposits in Kansas, mined on a small scale outside of the four chief coal fields, are described here because of their potential importance as a source of fuel for domestic use in a time of acute transportation problems.

It has been explained that coal beds in the Cherokee shale are mined in and near the outcrop area of the Cherokee rocks and in deep-shaft mines in the Northeastern Kansas coal field. The presence of coal in the Cherokee shale throughout most of eastern Kansas has been determined by study of drilling records. In most areas there are no individual beds which are known to be greater than slightly over one foot in thickness. With the exception of the Angola-Edna area in southwestern Labette county, new fields in Kansas producing Cherokee coal probably will not be developed in the near future. It is to be expected, however, that new developments will occur in southwestern Labette county, and renewed activity may take place in the northeastern Kansas fields.

In northeastern Bourbon county, a coal bed is mined that is about 2 feet thick and occurs in the Little Osage shale member of the Fort Scott limestone formation. The mines in this area are along tributaries of Little Osage river, north and east of Hammond.

A coal bed, called Thayer coal, occurs in the Chanute shale formation and has a maximum thickness of 26 inches near Thayer in eastern Wilson county. This coal bed has been mined near Thayer and near Blue Mound in Linn county.

Two or more thin coal beds in the Lawrence formation have been mined in Leavenworth and Douglas counties. During the depression years that followed 1929 a number of strip, drift, and shaft mines were opened, and coal was sold at local markets. At least one of these coal beds, the Sibley coal, is present under a thin overburden in much of southern Leavenworth county and Douglas county. The Sibley coal is 18 to 20 inches thick in an area extending from a point 6 miles east of Tonganoxie, Leavenworth county, to a point 12 miles northeast of that city (Whitla, 1940, p. 20). The reported thickness in southern Douglas county is 14 inches.

The Williamsburg coal occupies a position in the Lawrence shale about 40 feet below the Oread limestone. It is 20 inches thick near Williamsburg in southeastern Franklin county. This coal has been mined rather extensively in shallow shafts, slopes, and drifts in the vicinity of Homewood and Williamsburg, Franklin county, and near Quenemo in southeastern Osage county.

As indicated in the section on the East-Central Kansas coal field, the Nodaway coal, extensively mined in Osage county, formerly was mined in a belt that extends across nearly the entire width of the state from Brown county to Chautauqua county. Much shallow coal remains in this belt.

The Elmo coal in the Cedarvale formation has been mined in Brown county near Robinson and White Cloud in Doniphan county. A still higher coal, the Nyman, in the Table Creek formation, has been mined in Wabaunsee county near Dover, and in Nemaha county. A 16-inch coal bed mined a few years ago near Admire, Lyon county, is probably the Nyman coal.

Lignite in the Dakota group.—As pointed out by Whitla (1940, p. 25), there are several local lignite beds in Russell, Ellsworth, Lincoln, Mitchell, Jewell, and Cloud counties; they range in thickness from a few inches to three and one-half feet. These beds have been mined for local consumption in the counties named.

Coal production in Kansas.—The foregoing paragraphs indicate that Kansas has a relatively large supply of coal in or near many of the more densely populated counties. At present, approximately 70 per cent of the coal produced in Kansas comes from the Southeastern Kansas field, but over a period of years a somewhat larger percentage of the total production, about 80 per cent, has come from that area. In 1934, 91 per cent is reported to have come from the Southeastern Kansas field. Increasing activity in Linn County has brought the Eastern Kansas field into prominence. According to the State Mine Inspector's report, Kansas' total coal production in 1940 was 3,693,455 tons. Table 3 shows the 1940 produbtion by counties.

TABLE 3. *Coal production in Kansas in 1940*[1]

COUNTIES	TONS
Crawford	1,943,581
Linn	761,425
Cherokee	589,448
Bourbon	196,221
Osage	105,916
Leavenworth	61,134
Labette	17,950
Franklin	14,180
Wilson	3,100
Neosho	450
Cloud	50
Total	3,693,455

[1] From report of State Mine Inspector.

The maximum yearly production of coal in Kansas was in 1918, in which year 7,561,947 tons were mined in the state. It is of interest to note that the 1918 figure was nearly reached as early as 1904, when 7,333,307 tons were produced. During the period from 1904 to 1918, with the exception of the year 1910, the state's annual production remained above 5,000,000 tons. Since 1918, there has been a decline due largely to the increased use of oil as fuel. Table 4 shows annual production figures for the period 1921 to 1940 inclusive.

Quality and uses of Kansas coal.—Coal produced in Kansas is of bituminous rank, with the exception of the small production of Cretaceous lignite. The bituminous coal is somewhat friable but nearly all is non-slaking. Some pyrite is present, but much of it may be removed by washing and sizing operations. Pyrite is a byproduct of the coal industry in the Southeastern Kansas field. Chemical analyses of coals from the Southeastern Kansas field are published in Bulletin 24, of the State Geological Survey of

TABLE 4. *Annual coal production in Kansas during the period 1921-1940*[1]

YEAR	TONS	YEAR	TONS
1921	3,466,408	1931	1,986,870
1922	2,955,170	1932	1,952,885
1923	4,443,149	1933	2,217,622
1924	4,247,733	1934	2,508,254
1925	4,524,251	1935	2,686,164
1926	4,416,480	1936	2,944,028
1927	4,443,762	1937	2,892,560
1928	2,809,724	1938	2,654,141
1929	2,975,971	1939	2,920,000
1930	2,429,929	1940	3,693,455

[1] Data from U.S. Bureau of Mines.

Kansas, and in Bulletin 12, University of Kansas Experiment Station. According to Young and Allen (1925, p. 191), the British thermal unit value (B.T.U. per pound) of Southeastern Kansas coal ranges from 11,100 to 15,270; that of the East-Central Kansas coal ranges from 10,630 to 12,900; and that of coal from Leavenworth and vicinity from 10,810 to 14,240.

Railroads are the largest consumers of Kansas coal. Large quantities are used by power stations, packing plants and other industries. Most of the coal from the smaller fields is used in domestic and industrial heating. According to Pierce and Courtier (Kansas Geol. Survey, Bull. 24, p. 90), coke made from Southeastern Kansas coal has certain disadvantageous features. The coke is rather porous; the cell walls are thin; and it has highly fractured structure and low crushing strength.

Finely-divided coal held in suspension in fuel oil is said to constitute the most compact fuel known, an average bituminous grade containing 1,169,800 B.T.U. per cubic foot. Such "colloidal" fuels are handled and atomized for combustion like fuel oils. They have certain safety factors which ordinary fuel oil does not have.

Reserves.—As indicated elsewhere in this report, Kansas coal reserves are large. The present rate of production in the Southeastern Kansas coal field can be maintained for several years. A new deep-shaft field can be opened in southwestern Labette county. The Eastern Kansas field also can continue to produce, but probably not for long at its present rate inasmuch as the recently instituted large-scale electric shovel stripping entails destruction of valuable farm land. The Eastern Kansas field, however, can continue to produce large amounts of coal from shallow shafts and small scale strippings.

There still remains much unmined coal in the Leavenworth-Atchison area, which has the advantage of river transportation facilities. This coal, as indicated in Table 1, must be reached by deep shafts.

A comparatively large amount of coal still can be produced in the East-Central Kansas field, and small-scale mining operations can be reestablished along the strike of coal beds in the East-Central Kansas field throughout most of a narrow belt extending across the state from Brown and Doniphan counties to Chautauqua county. As explained in other parts of this report, several eastern Kansas counties can produce much of the coal needed for local domestic use.

Age and origin of Kansas coals.—Kansas coal is of Pennsylvanian (Upper Carboniferous) age, with the exception of the lignite in north-central Kansas which is Upper Cretaceous in age. Coal was formed from the accumulation of plant material in swamps that were probably only a few feet above sea level.

Work of the State Geological Survey of Kansas.—The United States Geological Survey in cooperation with State Geological Survey of Kansas has investigated the coal resources of the Southeastern Kansas coal field. Results of these studies were published in 1937, as Bulletin 24 of the State Geological Survey. Coal beds younger than the Cherokee coals were investigated and described in 1940 in Bulletin 32. Surface and subsurface investigations of the geology of eastern Kansas have provided the files of the State Geological Survey with a large body of data pertaining to coal and other stratified rocks.

Additional work pertaining especially to the technology of Kansas coals is planned by the Kansas Geological Survey.

References

ABERNATHY, G. E., *1937,* The Cherokee group of southeastern Kansas: Kansas Geol. Soc., Guidebook 11th. Ann. Field Conference, pp. 18-23, figs. 5-6.

———, *1938,* Cyclical sedimentation of the Cherokee: Kansas Acad. Sci., Trans., vol. 41, pp. 193-197.

CAMPBELL, M. R., *1917,* The coal fields of the United States, general introduction: U.S. Geol. Survey, Prof. Paper 100, pp. 1-33.

CRANE, W. R., *1898,* Special report on coal: Kansas Univ. Geol. Survey, vol. 3, part 2, pp. 107-336, pls. 21-70, figs. 4-54.

HAWORTH, ERASMUS, *1895,* The coal fields of Kansas: Kansas Univ. Quat., vol. 3, no. 4, pp. 297-309.

———, *1898,* Special report on coals: Kansas Univ. Geol. Survey, vol. 3, pt. 1, pp. 1-106, pls. 1-30, figs. 1-3.

HINDS, HENRY, and GREENE, F. C., *1917,* Leavenworth-Smithsville folio: U. S. Geol. Survey, Geologic Atlas of the United States, folio no. 206, pp. 1-13, figs. 1-10, pls. 1-10, 4 maps.

KNERR, E. Z., *1896,* Coal in Atchison county, Kansas: Kansas Acad. Sci., Trans., vol. 14, pp. 216, 217.

LANDES, K. K., *1937,* Mineral resources of Kansas counties: Kansas Geol. Survey, Min. Resources Circ. 6, pp. 1-102, figs. (unnumbered).

LILLEY, E. R., *1936,* Coal: in Economic Geology of Mineral Deposits, New York, pp. 222-278, figs. 99-119.

MOORE, R. C., *1929,* Kansas coal fields: U.S. Bur. Mines, Tech. Paper 445, pp. 3-7.

PIERCE, G. W., and COURTIER, W. H., *1937,* Geology and coal resources of the southeastern Kansas coal field in Crawford, Cherokee and Labette counties: Kansas Geol. Survey, Bull. 24, pp. 1-122, pls. 1-12, figs. 1-13.

SAUNDERS, W. H., *1873,* Coals in Kansas: Kansas State Board of Agr., Trans. 1872, pp. 387-389.

THOM, W. T., *1932,* Status of scientific classification of American coals: Am. Inst. Min. and Met. Eng., Trans., vol. 101, pp. 201-214.

WHITLA, R. E., *1940,* Coal resources of Kansas: post-Cherokee deposits: Kansas Geol. Survey, Bull. 32, pp. 1-64, pls. 1-5, figs. 1-28.

YOUNG, C. M., and ALLEN, H. C., *1925,* Kansas coal: Kansas Univ. Bull., vol. 26, no. 5, pp. 1-202; Kansas Univ. Eng. Exper. Sta., Bull. 13; and Chem. Research Div., Bull. 4.

OIL AND GAS

Summary.—Oil and gas are produced in 62 counties in Kansas. During 1941 a total of 85,416,561 barrels of oil was produced from 21,784 wells. Proved reserves on January 1, 1942, were 752,670,000 barrels of oil. It is estimated that a maximum of 350,000 barrels of oil per day could be produced for a limited period. Kansas has over 8,000 miles of oil pipe lines with a combined capacity of over 200,000 barrels per day. The state has 27 refineries with a crude oil capacity of 175,800 barrels per day, and 15 natural gasoline plants with a daily production capacity of 321,900 gallons of natural gasoline. During 1940 Kansas produced 85,632,472,000 cubic feet of natural gas. Other Kansas products associated with or derived from petroleum include helium, produced in one plant with an annual capacity of 8,000,000 cubic feet, and carbon black, produced in two plants. Petroleum products, in addition to being used as fuels and lubricants, are employed in the manufacture of explosives, synthetic rubber, and fertilizer.

OIL

Distribution of producing areas.—Petroleum and natural gas in commercial quantities are produced in 62 of the 105 counties in

Kansas. Of these, 11 counties produce gas only; 19 oil only; and 32 produce both oil and gas. Petroleum and gas production in the state may be subdivided geographically into five districts: (1) east-central Kansas, (2) southeastern Kansas, (3) southern Nemaha Ridge area, (4) Barton Arch area, and (5) the southwestern gas area.

The east-central Kansas district includes a group of 7 counties, 3 of which are situated immediately north of and 4 south of Kansas river. The southeastern Kansas district includes 14 of the 15 counties in the southeastern corner of the state. The nine producing counties here designated as the Nemaha Ridge district lie immediately west of the southeastern district and constitute an area approximately two counties wide which extends in a northerly direction from the southern edge of the state to a point about half way across the state. The Barton Arch district includes 20 counties in the central third of the state and extends in a northwest-southeast direction across the entire state in the form of a belt two to four counties wide. The southwestern gas district includes a group of 8 counties in the southwestern corner of the state. Locations of Kansas oil fields are shown in figure 2.

Production statistics.—According to data published by the Kansas State Corporation Commission, Kansas produced a total of 85,416,561 barrels of oil during 1941. The production per month in 1941 increased from 5,639,256 barrels in January to 9,811,469 barrels in December. The latter figure is based on the monthly allowable permitted under proration rather than on actual runs. This allowable usually varies but little from actual production.

In December, 1941, a total of 21,784 wells were producing in the state, of which 7,143 were prorated and 14,641 were unprorated. Of the total production for the year prorated wells accounted for 66,638,557 barrels of oil and unprorated wells for 18,778,004 barrels. The average daily production per well was 3.07 per cent of the average daily potential.

According to the Kansas State Corporation Commission's report for December, 1941, the allowable permitted under proration for December consisted of 8,193,458 barrels of oil. Of this amount, 3,304,252 barrels, or approximately 40 per cent of the total estimated production for the month, were allocated to wells having an allowable of less than 1.5 per cent of the daily potential; 658,791 barrels of oil, or 8 per cent of the total, were allocated to wells in which the allowables range from 1.5 to 3 per cent of the daily potential. Thus, almost half of the oil produced in the state comes from wells which are producing at a rate of less than 3 per cent of the daily potential for the entire state.

The unusually strict proration laws in Kansas reduce the rate of production in the state to a point considerably below the maximum possible rate. It is difficult to arrive at an estimate of the maximum amount of oil that could be produced in a year without complete engineering data on every producing unit. It has been estimated (Ingram, 1941, p. 93) that if proration were eliminated entirely, Kansas could produce approximately 350,000 barrels per day. This would result in a total annual production of 127,750,000 barrels, which is 50 per cent greater than the actual production for 1941.

If the 2,480 prorated wells in Kansas were permitted to produce at 3 per cent of the potential, that is, at approximately the same rate as the average of all the wells of the state, the total increase per month would be 3,304,252 barrels and the total yearly increase would amount to nearly 40,000,000 barrels, almost one-half of the total yearly production for 1941.

The state as a whole unquestionably could produce at a rate greatly in excess of 350,000 barrels per day for a limited time, but such an increase probably would result in a greatly lessened ultimate recovery.

Kansas production compared with other states.—In comparison with other states, Kansas in 1941 ranked sixth in production of oil in the United States. This position would have been improved greatly if the production of other states, in which proration is more lenient or non-existent, had been calculated on the same basis as that of Kansas.

Kansas was the only major producing state in the United States in which reserves added during the first half of 1941 were in excess of withdrawals during the same period. The United States as a whole showed a net loss of 16 per cent during this period, whereas Kansas showed a net gain of over 40 per cent (Howard, 1941, p. 39).

The comparatively shallow depth to oil in Kansas is of importance if the elements of expense, time, and material necessary to complete a well are considered. The average depth to oil in three of the six top-ranking states ranges from 400 to more than 1,200 feet greater than in Kansas.

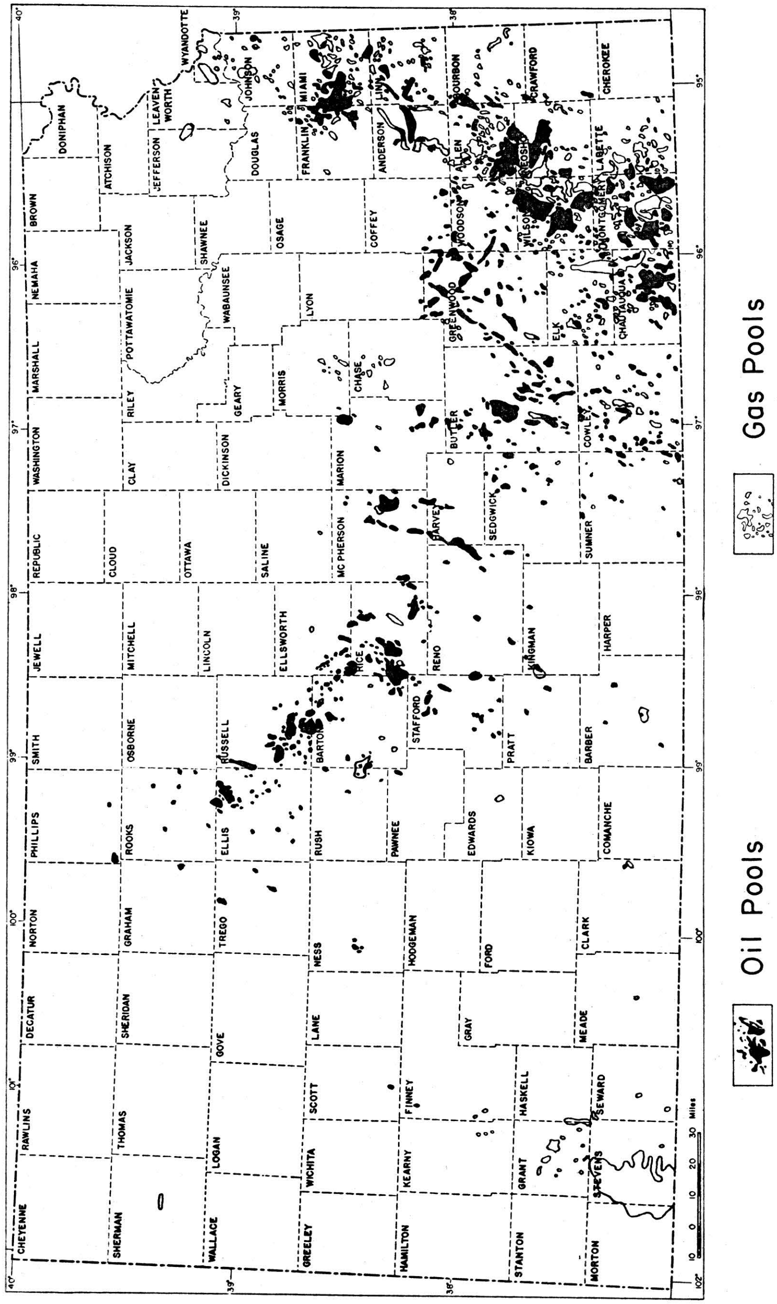

FIGURE 2. Map of Kansas showing location of oil and gas fields.

The ratio of dry holes to producing wells in Kansas is approximately the same as in the other highest ranking states.

In addition to the above-mentioned advantageous features of Kansas as a producer of petroleum, the state is strategically located in the central portion of the continent.

Cumulative production.—The total cumulative production of crude oil up to and including 1941 was 1,175,881,100 barrels. The daily average production in 1941 was 225,760 barrels of oil. The lowest daily average production for a given month was 181,911 barrels of oil per day in January, and the highest was 316,499 barrels of oil per day in December. The daily average oil production per well in 1941 was 10.34 barrels. Forty-three new fields were added in 1941, and new producing zones were discovered in ten old fields. These discoveries were made in 16 counties, 3 in the eastern part and 13 in the western portion of the state. One county, Kearny, previously had not produced oil or gas. A total of 2,112 wells was drilled in 1941, 1,436 oil wells with a total initial production of 1,482,313 barrels of oil, 79 gas wells, and 597 dry holes.

Reserves.—The estimated provéd reserves in Kansas on January 1, 1942, were 752,670,000 barrels of oil.

Uses of petroleum.—By far the most important use of petroleum is in the production of liquid fuel and lubricating oils. Ninety-nine per cent of the liquid fuel produced in the United States is obtained from petroleum; the remaining 1 per cent is derived from coal by means of processes of hydrogenation. Approximately 8 per cent of all motor fuel comes from natural gasoline, 31 per cent from straight-run refining processes, 51 per cent from thermal cracking and reforming processes, 5 per cent from catalytic cracking and reforming processes, and 4 per cent from polymerization and alkylation processes. The last two processes are used in the manufacture of gasoline of high octane rating for use as aviation fuels.

The approximate percentage of the major refined products from crude oil are gasoline 43.9 per cent, kerosene 5.5 per cent, fuel oil 38.8 per cent, and lubricants 3 per cent.

By means of polymerization processes the unsaturated hydrocarbon, butadiene, may be converted to "synthetic rubber," a rubber-like material which has many of the essential properties of natural rubber and in addition many important properties which natural rubber does not possess. Its resistance to swelling and deterioration in the presence of crude oil and gasoline is one of its most important properties.

Glycerine and toluene, petroleum derivatives, are particularly important at the present time because of their use in the manufacture of explosives.

The most important use of ammonia in peace time is in the manufacture of fertilizers. In addition, it is used in water purification, as a corrosion preventative, and in refrigeration processes. During wartime ammonia is important in the manufacture of explosives.

Other products of the petroleum refining industry are asphalt, paraffin wax, petroleum coke, plastics, solvents, synthetic resins, synthetic fibers, artificial leather, safety glass, photographic film, printing ink, cosmetics, medicinal items, antifreeze for automobile radiators, paint remover, dewaxing agent for mineral oil, rotogravure and intaglio ink, and artificial silk.

Refineries.—Kansas has 27 refineries with a total crude oil capacity of 175,800 barrels per day and a cracking capacity of 92,440 barrels per day. Five of these plants are shut down at the present time. Locations of refineries in Kansas are shown in figure 3.

Pipe lines in Kansas.—Seventeen pipe lines carrying crude oil, with a combined capacity of over 200,000 barrels per day are operating in the state. The daily average Kansas pipe line runs for 1940 were 180,096 barrels of oil. In 1939 Kansas had a total of 8,110 miles of pipe line of which 4,011 miles were trunk lines and 3,999 miles were gathering lines. Of the trunk-line mileage 3,296 miles carried crude oil and 715 miles carried refined products. Although the transportation facilities in the state are adequate for the present rate of production, any considerable increase in production of crude oil would necessitate a corresponding increase in pipe line or other transportation facilities. Locations of pipe lines in Kansas are shown in figure 3.

Work of the State Geological Survey of Kansas.—A considerable part of the work of the State Geological Survey of Kansas is directed toward the development of oil and gas resources of the state. The types of work include research, accumulation of statistics, preparation of reports and other publications, and the holding of conferences.

The Survey's files of statistical and geological information include a constantly growing volume of records of wells drilled throughout the state. These logs are available to the public, although they must be consulted in the offices of the Survey. This type of information is extremely important to those in the industry who are interested in extending production to new areas. In many cases the decision to drill or not to drill in a given area is based upon information obtained from records of previously drilled wells. Accordingly, the Survey is making every effort to make this file as complete as possible.

The Survey, in addition to maintaining a file of the logs of wells, also maintains a large collection of samples of drill cuttings from wells drilled throughout the state. These samples are also available for study by any qualified person. For the convenience of operators in the western part of the state a branch office and sample storage warehouse is located at Wichita. Studies of these samples by geologists in the industry add to their knowledge of subsurface conditions and thus influence decisions regarding location of new areas in which to drill for oil and gas.

Oil and gas research work carried on by the Survey is somewhat similar in character to that done by oil companies. Effort is made, however, to avoid as far as possible duplication of work done by the companies. For example, geological work done by oil companies commonly is of a very detailed nature over a limited area. The Geological Survey, on the other hand, is more concerned with problems that are regional or statewide in scope and which supplement the detailed work done by private organizations.

The results of research studies by members of the Survey staff are made available to the public by means of the publications of the Survey. These publications are distributed from the office of the Geological Survey at the University of Kansas upon payment of a small mailing charge. Lists of available publications are sent free upon request.

The members of the staff of the Geological Survey are called upon very frequently to confer with geologists and operators on their geological problems. This is of especial value in areas where consulting geologists are not available.

Natural Gasoline

Kansas has a total of 15 natural gasoline plants with a daily capacity of 321,900 gallons of natural gasoline. The average production per month for the first three months of 1941 was 6,607,000

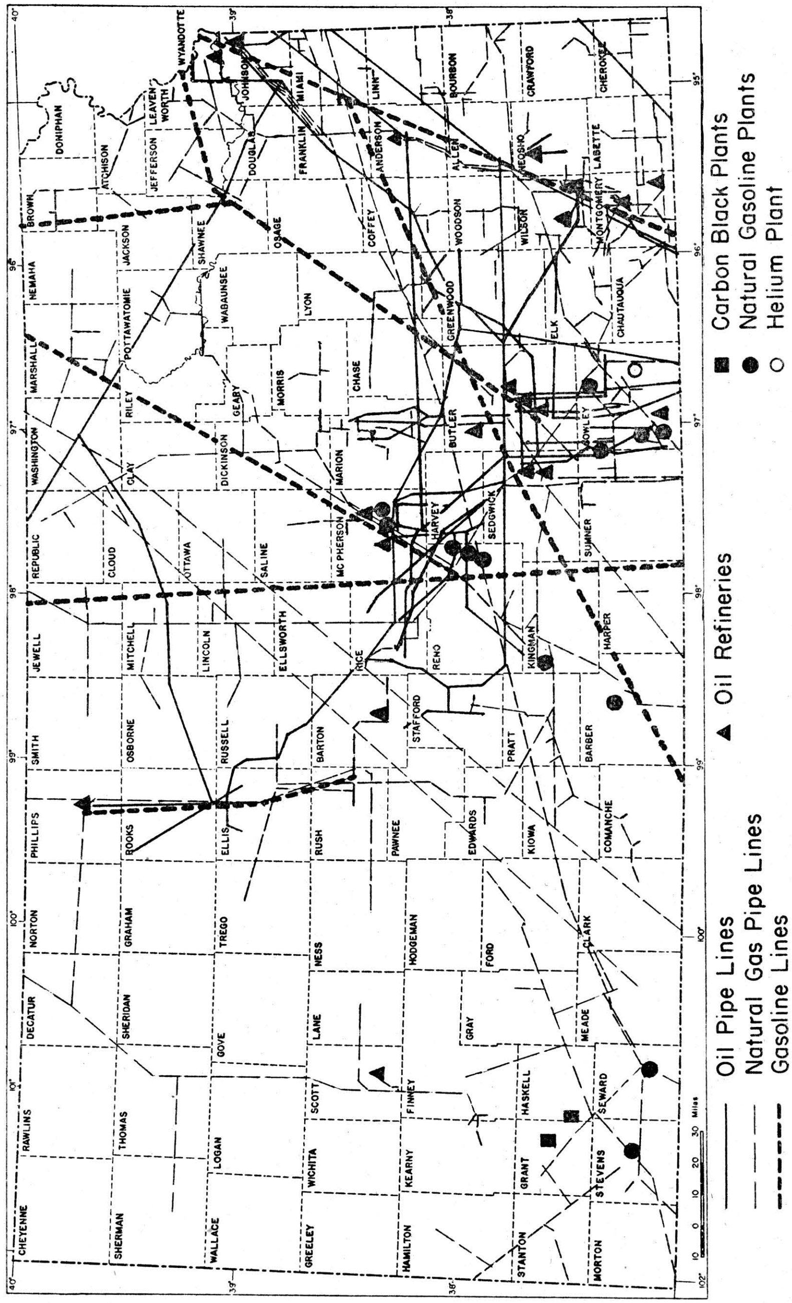

FIGURE 3. Map of Kansas showing location of pipe lines, oil refineries, carbon black plants, natural gasoline plants, and helium plant.

gallons. This is approximately 4.5 per cent of the production of the entire United States.

Natural Gas

From 1886 to 1940 the cumulative production of gas in Kansas amounted to 1,643,923,126,000 cubic feet. The production for 1940 was 85,632,472,000 cubic feet. In 1941, 10 gas fields were discovered with an initial potential of 37,531,000 cubic feet. These discoveries were made in 8 counties, 4 in the eastern portion and 4 in the western portion of the state. Locations of natural gas fields in Kansas are shown in figure 2.

During 1940 a total of 96 gas wells were drilled, 72 wells in the western part of the state and 24 in the eastern part. According to available reports, the total potential added during 1940 was 1,330,859,000 cubic feet of gas per day. Of this amount, 41,900,000 cubic feet, or 3 per cent, were reported from eastern Kansas. If complete statistics were available, this figure would be increased considerably.

Helium

Helium is present in small amounts in natural gas from many fields. It commonly constitutes less than 0.3 per cent by volume of the gas. In Cowley County, in the Dexter-Otto district, the helium content of the gas ranges from 1 to 2.1 per cent.

A helium extraction plant at Dexter (fig. 3), now owned by the United States government, has been shut down for several years. Before the plant was purchased by the government, a considerable quantity of helium was sold to the government at $34.70 per 1,000 cubic feet. In 1929 the plant was described as having an annual capacity of 8,000,000 cubic feet of helium.

It is belived that the helium fields in south-central Kansas could be extended.

Carbon Black

Carbon black is made by burning natural gas under conditions in which the oxygen supply is insufficient to produce complete combustion. It is being produced in two plants in Grant and Haskell counties (fig. 3), and other plants in Kansas are being constructed. In 1939, production in Kansas and Oklahoma totaled approximately 20,000,000 pounds.

Carbon black is used mainly in the rubber industry, an average automobile tire containing about two pounds. The material is also used in paints, inks and polishes.

References

ABERNATHY, G. E., *1940,* Oil and gas in Montgomery county, Kansas (with chapters by R. P. Keroher and Wallace Lee): Kansas Geol. Survey, Bull. 31, pp. 1-29, pls. 1, 2, figs. 1-6.

DOTTERWEICH, F. H., *1941,* Natural gasoline yields many by-products: Oil and Gas Jour., April 24, p. 39.

EMMONS, W. H., *1931,* Geology of petroleum, 2d ed., pp. 1-736, figs. 1-435.

JEWETT, J. M., *1940,* Oil and gas in Linn county, Kansas (with chapters by Wallace Lee and R. P. Keroher): Kansas Geol. Survey, Bull. 30, pp. 1-29, pls. 1-3, figs. 1-7.

———, *1941,* The geology of Riley and Geary counties, Kansas: Kansas Geol. Survey, Bull. 39, pp. 1-164, pls. 1-17, figs. 1, 2, tables 1-6.

LANDES, K. K., and KEROHER, R. P., *1939,* Geology and oil and gas resources of Logan, Gove, and Trego counties, Kansas: Kansas Geol. Survey, Mineral Resources Circ. 11, pp. 1-45, pls. 1-4, figs. 1-8.

———, *1938,* Geology and oil and gas resources of Rush county: Kansas Geol. Survey, Mineral Resources Circ. 4, pp. 1-31, pls. 1-2, figs. 1-4.

LEE, WALLACE, *1939,* Relation of thickness of Mississippian limestones in central and eastern Kansas to oil and gas deposits: Kansas Geol. Survey Bull. 26, pp. 1-42, pls. 1-3, figs. 1-4.

LEUM, L. N., *1941,* Chemistry in petroleum refining: Oil and Gas Jour., March 27, p. 85.

LILLEY, E. R., *1928,* Geology of petroleum and natural gas, 1st ed., pp. 1-524, figs. 1-173, tables 1-62.

MOORE, J. I., *1938,* Secondary recovery of petroleum, pt. I, Bibliography: Kansas Geol. Survey, Bull. 25, pp. 1-103.

Natural gasoline plants in the United States, *1941,* Oil and Gas Jour., April 24, p. 92.

NELSON, W. L., *1941,* Hydrogenation of coal; insurance for the oil and automotive industries: Oil and Gas Jour., May 8, p. 55.

Oil and Gas Journal, *1942,* Annual Number, January 29, pp. 1-239.

Oil and gas field development in the United States, *1941,* National Oil Scouts and Landmens' Assoc., Yearbook 1941 (Review of 1940), pp. 1-664.

Petroleum development and technology: Am. Inst. Min. Eng., Trans., 1925-1941 (yearly volumes).

Refineries operating in the United States, *1941,* Oil and Gas Jour., March 27, p. 189.

STEPHENSON, E. A., and MOORE, J. I., *1941,* The Otis gas and oil pool, Rush and Barton counties, Kansas: Kansas Geol. Survey, Bull. 38, pt. 12, pp. 1-44, pls. 1-17.

VER WIEBE, W. A., *1941,* Exploration for oil and gas in western Kansas during 1940: Kansas Geol. Survey, Bull. 36, pp. 1-109, pl. 1, figs. 1-40.

METALS

Aluminum from Kansas Clays

Summary.—Clays of central and north-central Kansas constitute a vast potential reserve of low-grade aluminum ore. Millions of tons of clay having an alumina content ranging from 28 to 32 per cent could be mined economically by stripping methods. Smaller tonnages of clay ranging from 32 to 39 per cent alumina also are available. Several processes can be used to extract alumina from clays. A modified sulphuric acid process has been approved by Secretary Ickes for the extraction from clay of aluminum for war industries.

European countries have been recovering aluminum from clay for several years. The processes used are well known and are theoretically sound. Clays have not been used as a source of aluminum in this country because of the fact that the metal can be recovered from bauxite ($Al_2O_3.2H_2O$) at a lower cost. Kaolin, the clay richest in aluminum, has the composition $Al_2O_3.2SiO_2.2H_2O$. Bauxite contains 50 to 60 per cent alumina (Al_2O_3), whereas the maximum content of alumina in pure clay is 39.5 per cent. Bauxite contains 530 to 630 pounds of metal per ton of ore, whereas only 210 to 420 pounds of metal occur in a ton of raw high-grade clay. The supply of high-grade bauxite ore in the United States is sufficient for but a few years, and we now import about 50 per cent of our requirements from South America.

The consumption of aluminum has increased greatly in the past two years and will continue to do so. Aluminum is of vital importance in the production of war materials. Availability rather than cost will be of primary importance during the critical period of the war, but it seems reasonable to assume that, even without the necessities of a war economy, the vast deposits of clay in Kansas will come to be regarded as an important source of aluminum within the next few years. Clay has a far greater metallic content than that of many metallic ores now successfully treated.

Metallurgy of aluminum.—There are two main steps in the recovery of aluminum from its ores: (1) the production of high purity alumina, and (2) the electrolytic reduction of alumina to aluminum. Aluminum-bearing minerals are dissolved from the ore either by the alkaline or the acid process and later converted to alumina. The alkaline process is the common method now used in treating bauxite. The acid method, while theoretically sound and suitable for treating clays, has not been used for commercial production in this country.

The first step in the process of recovery of aluminum from a clay ore consists of calcining the clay at a temperature of 500 to 600° C. to eliminate organic material and to increase the solubility of the alumina. In general, the alkaline process for the extraction of alumina from clays is not considered satisfactory because of the fact that the silica also is soluble. The alkaline process, however, has been successfully used by the Russians. A modification of this process is described by Kammermeyer and White (1940, pp. 683-699). A mixture of clay, limestone, and soda ash is fired to clinker in a rotary kiln and subsequently leached with water. Extractions of 85 to 90 per cent of the total Al_2O_3 and Na_2O in the clinker are possible.

Hydrochloric or sulphuric acid commonly is used in the acid extraction process. If hydrochloric acid is used, the calcined clay is decomposed by the acid at about 100° C.; aluminum chloride is removed by a hydrochloric gas current, leaving the iron chloride in solution. At 300° C. the aluminum chloride separates into alumina and hydrochloric acid; the latter is recovered and used again.

The United States Bureau of Mines has developed an improved sulphuric acid process. Secretary Ickes has proposed that a number of plants be constructed in which aluminum sulphate or alum could be produced from clay and other siliceous ores of aluminum. The alum, or other intermediate products, would be shipped to centrally located plants to be converted into aluminum.

The Kalunite process recently has been developed for extracting alumina from clay. This process has been described in a recent paper by Eicheberger (1941). The calcined clay is treated with sulphuric acid and potassium sulphate to form potash alum. The potash alum solution is autoclaved at 200° C. and 250 pounds per square inch pressure to give a basic potassium aluminum sulphate. This is heated to drive off the sulphur oxides, and the potassium sulphate is leached and removed in water solution for re-use. The residue is alumina, from which the metal, aluminum, is recovered by the well-known electrolytic process which also is used in extracting alumina from bauxite.

In the alkaline process a reasonably small amount of iron oxide in the ore is not objectionable, but silica causes trouble. Clay, being high in silica, generally is considered unsuitable for the alkaline process. Conversely, silica is not objectionable in the acid process whereas iron oxide gives trouble. Many Kansas clays are low in iron and could be treated by the acid process.

A very important factor in aluminum production is the cost of power. In general, manufacturers pay less than 3 mills per kilowatt hour for the 20,000 to 25,000 kilowatt hours needed to produce one ton of the metal. Kansas has an extremely large fuel reserve, available both for primary power and the generation of electricity. Although it may not be possible to produce power from this source for as little as 3 mills per kilowatt hours, it is possible that its use would be feasible in the war emergency. If this fuel reserve were used for power, the entire process of extracting the metal from clay could be carried out in Kansas. Either hydrochloric or sulphuric acid can be used in the extraction process. Kansas has a very large reserve of salt, which is used in the manufacture of hydrochloric acid, and a fairly adequate supply of sulphuric acid could be obtained from the pyrite which is washed out of Kansas coal.

The State Geological Survey of Kansas is undertaking research on methods of mechanical concentration of the alumina content of clay. Such mechanical processes, if developed on an economical basis, will not only improve the quality of fire clays but may become the first step in the production of aluminum from clay.

Kansas reserves of high-alumina clay.—The high alumina clays of Kansas are discussed elsewhere in this bulletin in the section headed *Clay,* in which the age, origin, and ceramic properties and uses are discussed. The clays specifically described crop out in central and north-central Kansas, and in restricted areas in southwest Kansas. These clays differ from other Kansas clays which have been tested in that the dominant clay mineral is kaolinite. The principal mineral, other than kaolinite, found in these clays is finely divided quartz (SiO_2). All proportions of silica and kaolinite are found in the material ranging from nearly pure silica to pure kaolin. At least half of the total tonnage available consists of clays of intermediate purity, in which class are included all clays having an alumina content ranging from 20 to 30 per cent. Millions of tons of clay having an alumina content of 28 to 30 per cent are readily available. The iron content ranges from 0.5 per cent to 1.8 per cent ferric oxide.

The largest deposit of this high-alumina clay exposed at the surface was found in an area in southern Cloud and northern Ottawa counties. Outcrops extending over an area about a quarter of a mile wide and more than two miles long were sampled. The beds are approximately horizontal, are fairly uniform in thickness, and are covered with an overburden of moderate thickness over a considerable portion of the area. The high-alumina part of this bed averages about 7 feet in thickness. A more siliceous, light-firing, refractory clay occurs below the high-alumina clay. The same bed of high-alumina clay was sampled also in Washington and Lincoln counties. Analyses of samples taken from this bed in three counties in Kansas are given in table 5.

TABLE 5. *Analyses of a bed of high-alumina clay sampled in three counties.*

(Analyses by Raymond Thompson in laboratories of State Geological Survey of Kansas.)

Constituents	Cloud county	Ottawa county	Washington county
	(per cent)	(per cent)	(per cent)
SiO_2	59.94	62.09	59.88
Al_2O_3	29.38	27.45	31.11
Fe_2O_3	1.20	0.58	1.69
CaO	1.10	0.94	0.24
Ignition loss	8.60	8.90	7.20
Total	100.32	99.96	100.12

When calcined, the above samples contain 32.01 per cent, 30.18 per cent, and 33.48 per cent alumina, respectively; this is based on the assumption that the ignition loss is due entirely to the loss of hygroscopic and chemically combined water in the clay.

TABLE 6. *Representative analyses of north-central Kansas high-alumina clays.*

(Analyses by Raymond Thompson in laboratories of the State Geological Survey of Kansas; laboratory numbers of sample analyzed given at heads of columns).

Constituents	El-12-4	W-19-A	El-52-3	L-30-4
	(per cent)	(per cent)	(per cent)	(per cent)
SiO_2	60.26	60.70	56.40	45.60
Al_2O_3	28.69	28.44	31.00	39.50
Fe_2O_3	0.49	2.88	1.08	0.67
CaO	0.21	0.27	0.18	0.16
Ignition loss	9.81	7.33	11.15	14.00
Total	99.46	99.62	99.81	99.93

The clays discussed above have not been developed commercially because prior to 1938 they were not known to exist, and because of the fact that their existence was not publicized until much later. Carload samples for plant trials have been shipped from four different deposits in the outcrop area. The experience gained from removing the carload lots has demonstrated that the clay can be easily mined and that the quality is uniform, at least within the limits of the small tonnage taken out.

No facilities have been set up for loading the clay from any of the deposits directly onto railroad cars. In most cases, the better deposits of clay are a few miles from the nearest railroad siding. Clay from some of the larger deposits, however, can be trucked over all-weather roads to the sidings.

References

EICHELBERGER, F., *1941,* Aluminum from western alunites: Min. Cong. Jour., vol. 27, no. 11, pp. 37-39.

KAMMERMEYER, K., and WHITE, A. H., *1940,* Extraction of alumina from kaolin and other silicates: Am. Inst. Chem. Eng., Trans., vol. 36, no. 1166, pp. 683-699.

SASSE, G., *1937,* Producing aluminum from clays: Ceramic Age, vol. 30, no. 2, p. 46-47.

Iron

Summary.—Although iron is not now produced in Kansas, there are two potential sources for small-scale production.

Iron from mine waters.—Kansas has a potential source of iron, now unused, in the mine waters of the lead and zinc area in Cherokee county. Practical methods of removing objectionable acid and iron from mine waters discharged from lead and zinc mines in Cherokee county have been described (Kinney, 1941). Kinney's studies show that mine waters in the Baxter Springs area contain as much as 6,000 parts per million of iron and that several tons of iron hydroxide are deposited daily in settling ponds and in river channels. According to Kinney, a plant treating daily 5,000,000 gallons of mine water containing 1,000 parts per million of iron would produce in one year the equivalent of 10,845 tons of Fe_2O_3, if operating at 100 per cent efficiency.

Manufacturers of Portland cement are finding it necessary to add iron to the common raw materials in order to produce a certain kind of cement used in mass concrete work. At present, pyrite cinder is being shipped from St. Louis to Kansas cement mills; iron hydroxide from mine waters could be substituted. Other uses for iron recovered from mine water will be found, and it should be remembered that mine operators have lowered production because of their reluctance to discharge additional untreated waters into surface drainage channels. Thus, it seems that treating plants are necessary to bring about the desired increase in lead and zinc production and that economic use of the recovered iron is highly desirable to offset the cost of treating the mine waters.

Iron from hematite and limonite.—Hematite and limonite, which are commercial iron ores at various places in the United States, occur in Kansas, although no large deposits are known and no ore is mined. Hematite is iron sesquioxide (Fe_2O_3), containing 70 per cent iron. Limonite is the hydrous sesquioxide of iron ($2Fe_2O_3$-$.3H_2O$); it contains 59.8 per cent iron. Possibly the best known prospect is in the SE¼ sec. 13, T. 13 S., R. 11 W., Russell county. Here a bed of hematite and limonite eight feet thick crops out in the top of the Dakota formation of Cretaceous age. This potential ore is of sedimentary origin and is stratified. It is somewhat contaminated by thin interbedded layers of sandstone parallel to the stratification, although in places individual layers of iron oxide as thick as ten inches free of sandstone can be observed. Deposits of this kind might furnish iron ore for chemical purposes, such as for the cement industry.

References

KINNEY, E. D., *1941,* Treatment of mine waters as a factor in the mineral production in southeastern Kansas: Kansas Geol. Survey, Bull. 28, pt. 1, pp. 1-16.

PLUMMER, NORMAN, and ROMARY, JOHN, *1942,* Stratigraphy of the pre-Greenhorn-Cretaceous rocks of north-central Kansas: Kansas Geol. Survey, Bull. (in preparation).

Magnesium

Summary.—Magnesium-bearing oil field brines and beds of rock dolomite in Kansas constitute important potential sources for production of the metal, magnesium.

Attention is here directed to the strategic importance of the metal, magnesium, and to the fact that magnesium is present in large quantities in deep ground waters in Kansas and in certain rock dolomites in the state.

Magnesium is a silvery white metal of great strength. It is the lightest of all the known metals that are comparatively little altered under ordinary atmospheric conditions. Its specific gravity is 1.74. The specific gravity of aluminum is 2.7. Copper is more than 5 times as heavy as magnesium. Magnesium does not occur in native form; that is, it is not found naturally in the uncombined, or metallic, state. It is, however, one of the most abundant of metals. It is a part of many rocks, and its compounds are present in many natural waters. Ordinary sea water contains more than 0.1 per cent magnesium, and the magnesium content of many "mineral waters" is much higher.

Magnesium is produced from natural and artificial magnesium chloride ($MgCl_2$) by electrolysis. It also is obtained from the calcined form of magnesite ($MgCO_3$) and recently from rock dolomite, the only common ores of magnesium. Calcined magnesite (MgO) is reduced with coal in electric furnaces. The temperature employed is high enough to volatilize the magnesium, which is later condensed. In the United States, magnesium is being produced from brines obtained from wells in Michigan and from ocean water at Freeport, Texas. It is reported that the Texas plant uses 500,000,000 gallons of water and produces annually 7500 tons of metallic magnesium. In the process of extracting magnesium from natural brines the magnesium-bearing water is treated with slaked lime to produce magnesium hydroxide. The magnesium hydroxide is treated in turn with hydrochloric acid to produce magnesium chloride. An artificial magnesium chloride thus is made available for the electrolysis process.

It has been suggested that in Kansas it might be advisable to use slaked dolomite instead of chalk and thus produce magnesium hydroxide simultaneously from the brine and from the dolomite. This would be particularly advantageous in the south-central area where the dolomite deposits are nearer the oil fields than are chalk or limestone deposits.

Recently, several magnesium plants utilizing different processes have been constructed in Nevada and California. In some of these plants dolomite is being used as a source of magnesium.

Uses of magnesium.—Magnesium is used as a deoxidizing and desulphurizing agent in the manufacture of metals and alloys. Until recently, this perhaps was its greatest use. It now is used extensively in making castings. Magnesium castings as aircraft parts include crank cases, pistons, oil pans, bearings, and control levers. Magnesium castings are used also as parts in surveying instruments, motion picture machines, field glasses, microscopes, and in many other instruments. Magnesium is made into sheets, rods, and tubing, which have a multitude of uses wherever material of light weight and great strength is desired. The usefulness of magnesium in aircraft construction is extremely significant at the present time.

Several magnesium alloys now are being produced. Magnesium and aluminum alloys are especially useful in the manufacture of airplane parts. In some of these alloys as little as 0.5 per cent magnesium is used. It is reported that an alloy containing 93 per cent magnesium, 7 per cent aluminum, and 0.04 per cent manganese has a tensile strength of 30,000 pounds per square inch. Magnesium is combined with beryllium to produce one of the lightest known alloys, and is combined with lead to give a much harder product than lead alone.

Magnesium is used in making tracer bullets, tracer shells and incendiary bombs, and in making flash-light powders, photographic flares and other articles useful and essential in modern warfare and industry.

It has been suggested that several small plants for the partial completion of the magnesium extraction process might be set up in Kansas and in other Mid-Continent states. Such small plants would concentrate from the brines either magnesium hydroxide, $Mg(OH)_2$, which contains 834 pounds of magnesium per ton, or magnesium chloride, $MgCl_2$, which contains 510 pounds of magnesium per ton. These concentrates would then be shipped to a centrally located plant at a place where cheap electricity is available for the final extraction of metallic magnesium.

The possible extraction of magnesium from oil-field brines is of especial interest because it may be a means of converting into a valuable mineral resource a by-product of the petroleum industry that heretofore has been regarded only as deleterius waste.

MAGNESIUM FROM KANSAS OIL FIELD BRINES

Reconnaissance studies of available data pertaining to Kansas oil field brines have shown that over a wide area there are natural brines having magnesium content several times that of ordinary ocean water. Official water sample analyses made by the Kansas State Board of Health have provided much of the data used in these studies. Table 7 shows in parts per million the magnesium content of a selected group of water samples. These analyses were selected from the files of the Board of Health and from other sources because of their high magnesium content, and it should be stated that because of the limited number of samples available this table probably does not list all Kansas counties in which brines of high magnesium content can be obtained. From several hundred analyses those showing a magnesium content of 3,000 parts per million, or about 25 pounds of magnesium per 1,000 gallons of liquid, or more were selected and included in the table. A large number of deep brines in Kansas have a magnesium content as high, or generally higher, than that of ocean water (about 1,400 parts per million, or less than 12 pounds of metal per 1,000 gallons of liquid).

TABLE 7. *Magnesium content of selected Kansas oil field brines, as sampled from disposal systems.*

Name of field	County	Formation, source of water	Total solids, parts per million	Magnesium, parts per million
Bloomer	Barton	Topeka ls.	193,000	3,400
Burrton	Reno	"Chat"	108,000	1,700
Burrton	Reno	Hunton ls.	72,000	1,150
Burrton	Reno	Arbuckle ls.	66,000	935
Caldwell	Sumner	Wilcox fm.	223,000	2,400
Cunningham	Kingman	Kansas City ls.	224,000	3,700
Rainbow Bend	Cowley	Kansas City ls.	225,000	3,500
"	"	Bartlesville ss.	229,000	2,300
"	"	Layton ss.	217,000	3,300
"	"	Hoover ss.	200,000	2,800
			225,000	3,700
Ritz-Canton	McPherson	"Chat"	103,000	2,000
Sullivan	Russell	Arbuckle ls.	—	2,700
Valley Center	Sedgwick	Kansas City ls.	211,000	3,500
"	"	Mississippi ls.	100,000	1,200
Voshell	McPherson	Hunton fm.	74,000	1,700
"	"	Wilcox fm.	38,000	580
"	"	Arbuckle ls.	43,000	634

Table 7, above, shows the magnesium content of selected water samples from different stratigraphic units in individual wells in different locations in Kansas. Table 8 shows the average mag-

TABLE 8. *Magnesium content of selected Kansas deep brines, as pumped from oil wells.*

County	Name of well, lease or field	Sec.	Township	Range	Formation, source of water	Depth, in feet	Magnesium, parts per million
Butler	Miner No. 6	9	29S	4E			3920
Cowley	Udall field	28	30S	5E			3130
"	Shafer field	15	31S	3E			3220
"	Clark field	6	31S	4E	Composite brine		3620
"	Texas-Little lease	21	31S	4E	Composite brine		3050
"	Shafer field	19	32S	3E			4540
"	Waite No. 1B	12	32S	4E	"Oswego lime"		4020
"	Graham field	10	33S	3E			3510
Ellis	Fairport field	36	12S	16W	"Oswego lime"	2975	3125
"	Phillips-Schneider No. 2	18	12S	17W	Kansas City ls.		3115
Ellsworth		7	17S	10W	Kansas City ls.	3100	3750
McPherson	Ritz-Canton field	9	19S	2W	Kansas City ls.	2435	3950
Reno	Abbyville field	24	24S	8W	Kansas City ls.	3500	3560
Rice	Porter-Dierdorf No. 1		18S	7W		1400	4470
"	"		"	"		1925	3820
"	"		"	"		2590	3590
"	Porter-Dierdorf No. 1		18S	7W		2740	3550
"	Campbell No. 1		18S	8W		1400	5040
"	"		"	"		2600	3750
"	"		"	"		2715	3310
"	"		"	"		2855	3730
"	"		"	"		2920	3310
"	Brandenstein field	11	19S	10W	Kansas City ls.		4030
"	Raymond field	21	20S	10W	Lansing ls.	3130	3726
					Arbuckle fm.	3330	
"	"	"	"	"	Kansas City ls.	3200	3830
Russell	Central-Benso No. 1B	4	14S	15W	"Oswald lime"	3027	4260
"	Signal-Taylor No. 1	26	15S	13W			3000
Sedgewick	Continental-Casey No. 2	16	25S	1E			4160
"	Jacobs No. 2	22	25S	1E			4500
"	Valley Center field	7	26S	1E			4290
"	Phillips Willhite No. 1	27	26S	1E			3500

nesium content of water from various formations in several Kansas oil fields.

Large volumes of brine are included in the wastes brought to the surface in Kansas oil fields, and the problems of disposal of oil-field brines have received much attention. Until recently, the general method of brine disposal has been impounding on the lease. At the present time, large volumes of brines are returned to the subsurface formations through disposal wells. Some brines are used in water flood operations as a means of secondary recovery of oil.

Figures expressing the exact volume of brine produced in various Kansas oil fields are not easily obtained, but estimates believed to be fairly accurate can be made. It is believed that in general the ratio of water to oil in the fluids being pumped in Kansas is about 2 to 1. Some fields are producing 85 to 90 per cent water and 10 to 15 per cent oil. In several of the major fields disposal wells are in operation that have a daily capacity of 30,000 to 50,000 barrels of water. If the brine disposed of in such wells has a magnesium content of 4,000 parts per million, then about 40,000 pounds of magnesium are disposed of daily. The concensus of opinion is that in some of the larger oil pools in Kansas producing from the Arbuckle or "siliceous lime" the volume of brine that can be produced is limited only by the available pumping equipment. Water from other stratigraphic formations is not so abundant. More than 6,863,100 barrels of water having a magnesium content of 3199 parts per million have passed through a single disposal system in the Burrton field, Reno county, in the past five year.

Because of the fact that brines of high magnesium content are produced in the oil fields, it seems reasonable to suggest that the possibility of practical magnesium recovery from oil-field brines should be carefully considered. Additional samples of Kansas brines are now being collected for analysis in the chemistry laboratories at the University of Kansas. In some cases it may be found feasible to treat water passing through disposal systems for magnesium extraction. It may even be practical to pump brine from abandoned wells or from wells drilled especially for brine production. It should be noted that not all brines with high magnesium content are associated with oil fields. Analysis of brine from a well drilled many years ago at Lawrence, Douglas county, showed 6,309 parts per million of magnesium, or more than 50 pounds of magnesium per 1,000 gallons of brine (Bailey, 1902, p. 151). The Lawrence well was drilled to a depth of 1,400 feet; the depth from which the brine was produced is unknown. It is reported that the well flowed for several years before being filled.

MAGNESIUM FROM DOLOMITE

Rock dolomite in the Permian rocks in central and southern Kansas constitutes another potential magnesium ore. The mineral dolomite, which is the dominant constituent of rock dolomite, is the carbonate of magnesium and calcium; its chemical formula is $CaMg(CO_3)_2$, and the theoretical composition is carbon dioxide (CO_2) 47.8 per cent, calcium oxide (CaO) 30.4 per cent and magnesium oxide (MgO) 21.7 per cent. Varieties of rock dolomite occur in which the proportion of calcia to magnesia deviates from this proportion because of the presence of calcite (calcium carbonate) or other substances.

Dolomite in Kansas.—Dolomite occurs in the surface rocks of Kansas in two formations. One is the *Stone Corral dolomite* that crops out in Rice, Reno, Kingman and Harper counties. This deposit is about 6 feet thick in Rice county but is somewhat thinner farther south. In the subsurface some distance from the outcrop this rock is an aggregate of dolomite and anhydrite crystals, but in the shallow subsurface and in surface exposures the anhydrite portion has been removed by action of ground water. This has rendered the rock somewhat cellular, and because anhydrite has been in part replaced by calcite, the relative proportion of the latter has been somewhat increased.

The thickest surface expression of the Stone Corral dolomite is in T. 20 S., R. 6 W., eastern Rice county. There the rock is well situated for convenient stripping operations. It is estimated that a single strip pit, from which it would be necessary to remove only a few feet of overburden, could be developed over at least one-half of one square mile. There are other favorable stripping localities, especially in Reno and Kingman counties.

The *Day Creek dolomite* is a thinner deposit, being about 2½ feet in thickness. There are excellent outcrops in the vicinity of Ashland, Clark county. These outcrops are not so favorably located for large-scale strip mining, but it is estimated that at least a million tons could be mined easily with the removal of a comparatively small volume of overburden.

Locations of outcrops of both formations are shown in figure 12. The eastern band of outcrops is the Stone Corral dolomite and the western area is the Day Creek dolomite.

Chemical analyses of samples from both of the above-described dolomite formations are presented in tables 9 and 10, below.

TABLE 9. *Chemical analysis of sample of Day Creek dolomite, T. 32 S., R. 23 W., Clark county*

CONSTITUENTS	PER CENT
SiO_2	1.64
Al_2O_3	1.28
Fe_2O_3	1.98
CaO	31.54
MgO	18.02
Loss on ignition	46.34
Total	100.80
$CaCO_3$, calculated	56.14
$MgCO_3$, calculated	37.66

TABLE 10. *Chemical analyses of five samples (1-5) of Stone Corral dolomite, from T. 20 S., R. 6 W., eastern Rice county*

CONSTITUENTS	PER CENT (1)	(2)	(3)	(4)	(5)
SiO_2	3.04	2.48	2.52	4.26	2.68
Al_2O_3	1.43	2.61	2.89	5.34	2.54
Fe_2O_3	0.53	0.35	0.35	0.98	0.54
CaO	36.22	35.92	36.44	29.66	33.82
MgO	14.40	14.08	13.52	16.33	15.35
Loss on ignition	41.40	43.46	43.29	41.02	43.25
Total	97.02	98.90	99.01	97.59	98.18
$CaCO_3$, estimated	64.70	64.02	65.00	52.92	60.35
$MgCO_3$, estimated	30.10	29.43	28.24	34.10	32.09

Because of the urgent need for magnesium it is believed that Kansas dolomites should be thoroughly investigated as a potential magnesium ore.

Kansas reserves.—Conservative estimates indicate that at least 15,000,000 tons of rock dolomite can be mined easily by stripping methods from the Stone Corral deposit, and that 1,000,000 tons can be obtained in the same way from the Day Creek bed. The magnesium content of one ton of ore that contains 20 per cent magnesium oxide is about 240 pounds. It has been suggested that the "chat" piles of southeastern Kansas might constitute a possible source of magnesium. Although there is some dolomite in the "chat", the presence of a considerable amount of chert and limestone probably would make the material unsuitable for such development.

Age and origin.—The two dolomites described above are of Permian age and are the result of deposition from marine waters in what probably was an enclosed marine basin.

References

Bailey, E. H. S., *1902,* Special report on mineral waters: Kansas Univ. Geol. Survey, vol. 7, pp. 1-343, frontispiece, pls. 1-22.

Norton, G. H., *1939,* Permian red beds of Kansas: Am. Assoc. Petroleum Geologists, Bull. 23, pp. 1751-1819, figs. 1-24.

Schmidt, Ludwig, and Wilhelm, C. J. *1938,* Disposal of petroleum wastes on oil-producing properties (with a chapter on soils and water resources of Kansas oil areas, by Ogden S. Jones): U.S. Bur. Mines, Rept. of Investigations 3394, pp. 1-25.

Taylor, S. S., Wilhelm, C. J., and Holliman, W. C., *1939,* Typical oil-field brine-conditioning systems; preparing brine for subsurface injection: U.S. Bur. Mines, Rept. of Investigations 3434, pp. 1-71, figs. 1-15, tables 1-19.

Wilhelm, C. J., Thorne, H. M., and Pryor, M. F., *1936,* Disposal of oil-field brines in the Arkansas river drainage area in western Kansas: U.S. Bur. Mines, Rept. of Investigations 3318, pp. 1-28, figs. 1-3, tables 1-11.

Pyrite

Summary.—Pyrite is used chiefly in making sulphuric acid. The Kansas reserves are related to coal reserves and production inasmuch as Kansas pyrite is a by-product of the purification of coal.

Description.—Pyrite or iron pyrites is an opaque, brittle, pale brass-yellow metallic mineral consisting of iron and sulfur (FeS_2). Because of its color, it commonly is called *fool's gold.* Pyrite commonly crystallizes in the form of cubes or pyritohedrons. It occurs also in massive, fine granular and sometimes in nodular, stalactitic, or subfibrous radiated forms. When struck on steel, pyrite gives off sparks. The mineral is hard (6.0 to 6.5) and has a specific gravity of 4.9 to 5.1. It breaks with a conchoidal or uneven fracture. Pyrite occurs in rocks of all ages, mainly associated with coal-bearing deposits and in veins, but also in clay and shale and argillaceous sandstones.

Kansas pyrite is produced solely as a by-product of the purification of coal. Impurities in the coal, amounting to about 3 per cent and consisting largely of shale and pyrite, are removed in the purification process. A process of classification is employed which uses settling cones with a heavier than water medium; coal floats and the impurities sink in the medium. From the impure portion, pyrite is recovered in another concentrating process. The recovery of pyrite is approximately 10 pounds per ton of coal.

Uses.—Kansas pyrite is sent to a chemical plant in St. Louis, where it is converted into sulfuric acid.

Reserves.—The reserves of pyrite are intimately related to the reserves and production of coal, which are discussed elsewhere in this report.

ZINC AND LEAD

Summary.—During 1940, Kansas produced about 57,000 short tons of zinc and about 12,000 short tons of lead. The known reserves are small but may be extended by recent exploration studies of the State Geological Survey.

Location of deposits.—The zinc and lead ore deposits of Kansas are part of those of the Tri-State district of southeastern Kansas, northeastern Oklahoma, and southwestern Missouri. Zinc and lead mining in Kansas is confined to the southeastern corner of Cherokee County, comprising the Kansas portion of the district.

Character and occurrence of ore.—The ore in the Tri-State district occurs in definite stratigraphic horizons in the Mississippian limestones; these horizons in general lie 100 to 200 feet below the contact with the overlying Cherokee shale. Unconformably overlying the Mississippian limestone in the greater part of the Kansas area of the mining district is a cover of barren Cherokee shales and interstratified sandstones, which reach a maximum thickness of about 250 feet in the Kansas portion of the district. Inasmuch as the Mississippian and Pennsylvanian rocks dip gently northwestward, the ore is found at progressively greater depths toward the west. The depth to ore in the Kansas portion of the field varies from about 150 to 400 feet. The ore tends to be concentrated in portions of the district which have been subjected to intense fracturing and brecciation.

The principal ore mineral is sphalerite (zinc sulphide). In certain parts of the field there also are considerable amounts of galena (lead sulphide). Associated with these two ore minerals in some places are the iron disulphides, pyrite and marcasite. The ore also contains minor amounts of greenockite (cadmium sulphide) and chalcopyrite (copper iron sulphide). Generally, the sulphide mineralization is associated with intense chertification. Dolomitization likewise is found in some places. Sphalerite, the principal ore mineral, commonly is brown to black in color, has a resinous luster, a hardness of about 4.0 and a specific of 3.9 to 4.1. Galena, the lead ore mineral, commonly is found in steel-gray cubes having cubic cleavage and a specific gravity of 7.4 to 7.6. The ore bodies are very irregular in shape. In the past, the outlines of the ore bodies have been delineated by intensive churn-drilling programs. Generally, the individual bodies have relatively large horizontal dimensions.

Lead and zinc production.—The Tri-State district is the largest zinc-producing district and the third largest lead-producing district in the United States. In 1940, the mine production of zinc in the Tri-State district was 232,437 short tons, or 35.0 per cent of the total United States mine production and 14.2 per cent of the total world's smelter production. Of the total Tri-State production, 24.5 per cent comes from Kansas.

In 1940, the mine production of lead in the Tri-State district was 35,311 short tons or 7.7 per cent of the total United States mine production and 2.6 per cent of the total world smelter production. Of the total Tri-State production, 33.8 per cent comes from Kansas. Tables 11 and 12 present a statistical summary of Kansas zinc and lead production for the past five years.

TABLE 11. *Kansas zinc production*[1]
(Mine production in short tons)

Year	Kansas	Tri-State district	Per cent of Tri-State production coming from Kansas	Total United States production	Per cent of U.S. production coming from Kansas.	World smelter production (in metric tons)
1936	79,017	226,857	34.83	575,574	13.73	1,464,000
1937	80,300	236,585	33.94	626,362	12.82	1,626,000
1938	73,024	196,174	37.22	516,703	14.13	1,568,000
1939	68,971	224,446	30.73	583,807	11.81	1,635,000
1940	57,032	232,437	24.54	665,068	8.58	Not avail.

[1] Minerals Yearbook, U.S. Bureau of Mines, 1940.

TABLE 12. *Kansas lead production*[1]
(Mine production in short tons)

Year	Kansas	Tri-State district	Per cent of Tri-State production coming from Kansas	Total United States production	Per cent of U.S. production coming from Kansas.	World smelter production (in metric tons)
1936	11,409	38,842	29.37	372,919	3.06	1,478,000
1937	16,008	50,274	31.84	464,892	3.44	1,679,000
1938	15,239	39,400	38.68	369,726	4.12	1,704,000
1939	13,697	44,176	31.01	413,979	3.31	1,741,000
1940	11,927	35,311	33.78	457,392	2.61	Not avail.

[1] Minerals Yearbook, U.S. Bureau of Mines, 1940.

Ore dressing.—After mining, the first treatment is milling to produce zinc and lead concentrates carrying 60 and 75 per cent of the metals respectively. The waste part of the ore, mostly chert, is rejected and forms the "tailing" or "chat" piles common in the district. The milling process consists of crushing the ore until the mineral grains are released, followed by gravity concentration, flotation concentration, or both. In gravity concentration the heavy zinc and lead minerals separate to the bottom of the concentrating device. In the flotation process certain minerals, usually those of metallic luster, such as zinc and lead sulphides, cling to air bubbles, if the ore is finely ground and agitated in water and air. The affinity of "flotable" minerals for air bubbles is increased by the addition of small amounts of oil and chemicals. The floated minerals rise to the top of the agitated mixture and are recovered in a froth. The waste part of the ore settles and is run to waste. The method of milling has changed much in recent years. Instead of having a large number of small concentrators, much of the ore is sent to large central mills that handle the ore from many mines. The largest of these mills, located in Oklahoma near Picher, has a daily capacity of at least 10,000 tons of ore. Here a new ore concentrating process employing a differential density cone, known as the "sink and float" or Wuensch process, has replaced older machines. Instead of using water as in jigging, an emulsion of finely-divided lead sulphide and water is employed. The density of the medium is such that heavy mineral particles settle, while the waste part of the ore is carried away.

Smelting Kansas zinc and lead ore.—Zinc can be produced either by the retort or the electrolytic process. The former process accounts for 75 per cent of the zinc smelted in the United States. Practically all Kansas ore is treated by the retort process. Formerly, Kansas had its own zinc smelters. With the depletion of favorably situated gas fields and as a result of unfavorable freight rates, zinc smelting in the state ceased. The ore is smelted in Oklahoma, Arkansas, or the eastern states.

The smelting of zinc ore is somewhat complicated. As received at the smelter, the zinc sulphide concentrate contains about 60 per cent zinc. It is roasted to drive off sulphur, used in making sulphuric acid. The sulphide thus is converted to the oxide. The oxidized ore, mixed with an excess of coal, then is placed in a fire-clay retort, heated to white heat, and reduced to zinc. A peculiarity of the process is that the zinc, at the high temperature of reduction, is in the form of vapor. The vapor passes to a condenser attached to the retort, condenses to liquid, is ladled and cast. The smelting is accomplished in long narrow furnaces fired by natural gas. Some 250 retorts are arranged in rows on either side of the furnace with condensers protruding through the side walls. The metal produced, called "spelter", carries 98 per cent zinc.

The smelting of lead ore is relatively simple. Much of the Kansas lead concentrate is treated at Galena, Kansas, where the usual process of reduction smelting is followed. The 70 per cent lead concentrate is roasted to remove sulphur and then charged into a blast furnace together with limestone flux and coke. Blast furnaces produce metallic lead. Lead produced in the Mississippi Valley region is quite pure and requires no important refining operation. After tapping, and with little further treatment, it is ready for market.

Uses for zinc and lead.—The principal uses of zinc are in galvanizing and brass making. Large amounts of zinc also are used in die casting, battery cans, and photoengraving. Zinc salts are widely used as high-grade pigments. Because of its use in brass, galvanizing and die castings, zinc has become a strategic metal in the national rearmament program. Lead and lead alloys are used in storage batteries, cable coverings, ammunition, solder, foil, bearing metal, and type metal. Lead salts are widely used as pigments.

Ore reserves and future production.—The high-grade ore reserves of the Tri-State district are being rapidly exhausted. Reserves of low-grade ore are known, and it is possible that some of these submarginal ores could be mined if the government sees fit to grant sufficient subsidies. Inasmuch as the Tri-State district constitutes the principal source of zinc in the United States, it is important that attempts be made to locate new high-grade ore reserves. It is generally recognized that possibilities for new ore discoveries are better in the Kansas portion of the field than elsewhere. For this reason, the State Geological Survey of Kansas recently has made intensive efforts to develop new methods of exploration which could be used by the ore producers in their search for ore. During the summer of 1941 the State Geological Survey, working in cooperation with the University of Kansas Engineering Experiment Station and with the Tri-State Zinc and Lead Ore Producers' Association, began a comprehensive program of geophysical investigations in the Tri-State area. The purpose of these investigations was to develop some geophysical method or combination of methods which could be used to guide the drilling programs. It was hoped that the application of geophysical methods would serve not only to reduce the total cost of ore exploration in the district, but also would serve considerably to accelerate exploration as well as to aid in the finding of new ore bodies which normally might not be found in the course of the churn-drilling program. The first phase of the geophysical work has been completed and has indicated that geophysical methods of exploration can be successfully used to map structures associated with ore mineralization. Such geophysical methods are now in a stage in which they can be used successfully to guide exploration in the Tri-State district.

References

BASTIN, E. S., et. al., *1939*, Contributions to knowledge of the lead and zinc deposits of the Mississippi Valley region: Geol. Soc. America, Special Paper 24, pp. 1-156, figs. 1-27, pls. 1-4, tables 1-4.

FOWLER, G. M., and LYDEN, J. P., *1932*, The ore deposits of the Tri-State district: Am. Inst. Min. Metall. Eng., Trans., vol. 102, pp. 206-251.

———, and LYDEN, J. P., *1934*, Sequence of structural deformation in the Oklahoma mining field: Min. Metall., vol. 15, pp. 415-418.

———, LYDEN, J. P., GREGORY, F. E., and AGAR, W. M., *1935*, Chertification in the Tri-State mining district (with discussions): Am. Inst. Min. Metall. Eng., Trans., vol. 115, pp. 106-163.

HOFMAN H. O., *1922,* Metallurgy of zinc and cadmium; McGraw-Hill Book Co., New York, pp. 1-341, figs. 1-261, tables 1-51.

KINNEY, E. D., *1941,* Treatment of mine water as a factor in the mineral production of southeastern Kansas: Kansas Geol. Survey, Bull. 38, pt. 1, pp. 1-16, figs. 1-3.

LANDES, K. K., *1937,* Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110, unnumbered figures.

PIERCE, W. G., and COURTIER, W. H., *1937,* Geology and coal resources of the southeastern Kansas coal field: Kansas Geol. Survey, Bull. 24, pp. 1-122, figs. 1-13, pls. 1-12.

SIEBENTHAL, C. E., *1915,* Origin of the zinc and lead deposits of the Joplin region, Missouri, Kansas, and Oklahoma: U.S. Geol. Survey, Bull. 606, pp. 1-283.

WEIDMAN, SAMUEL, *1932,* Miami-Picher Tri-State district: Univ. Oklahoma Press, Norman, pp. 1-177, figs. 1-12, pls. 1-11, tables 1-26.

NONMETALLIC MINERAL RESOURCES

ASPHALT ROCK

Summary.—One plant in Kansas has been producing asphalt rock for several years. The known reserves in Kansas exceed 25 million tons.

Natural asphalt consists of solid or semisolid hydrocarbons that have been formed by natural processes from petroleum by the evaporation of the lighter hydrocrabons and the partial oxidation of the residue. Artificial asphalt is obtained as a residue from distillation of some crude oils; a large part, 80 per cent or more, of the asphalt produced in the United States is obtained in this way. Natural asphalt may occur in "lakes" at the surface, as in the Burmudez asphalt lake in Venezuela and on the island of Trinidad. A more widespread mode of occurrence of asphalt is in the voids of porous rocks, where it may serve as a cement binding the rock particles together or may occupy interstices in rocks bound by other mineral cementing material. Rock that contains an appreciable amount of asphalt is known as asphalt rock. The asphaltic content in most cases ranges from about 5 to 15 per cent. Asphalt rock generally is in the form of impregnated porous sandstone or limestone. Some writers prefer to use the term *bitumen* to designate the hydrocarbon material in such rocks. The term *asphalt* is used in this paper.

Asphalt rock in Kansas.—In eastern Kansas there are commercial deposits of asphalt rock in Linn county; in the same county there are several other deposits that are not being worked. Old oil seeps in Miami county would warrant exploration. In Labette county, pockets of very heavy crude oil in porous, cavernous limestone together with partly impregnated porous limestone at the surface indicate that commercial deposits of asphalt rock may be found. Weathered outcrops of impregnated rock have lost most of their asphalt. The commercial deposits have been found in artificial exposures or by shallow drilling. Other counties in eastern Kansas also may be profitably tested by drilling in areas where porous rocks lie close below the surface. It should be noted, however, that the presence of asphalt is unusual; that is, one may expect to examine a great many porous rocks without finding asphalt.

Linn county is the only county in Kansas in which asphalt rock is being produced. A quarry in asphaltic sandstone is located in sec. 25, T. 24 S., R. 24 E. High-grade asphalt rock is being quarried there, and the material is processed in a plant at Pleasanton. The reserves in this part of Linn county are believed to be large. Samples of asphalt rock from Linn county contain approximately 12 per cent hydrocarbons. Asphalt has been seen on the surface or in shallow excavations in Linn county in secs. 19, 24, 25, and 36, T. 21 S., R. 24 E., and in sec. 30, T. 21 S., R. 25 E. All of these occurrences are in the same sandstone stratum.

Limestone asphalt rocks occur in both the northern and southern parts of Linn county. A quarry in sec. 20, T. 20 S., R. 24 E. was worked for some time by the Kansas Rock Asphalt Company, and high-grade material was obtained. A similar occurrence is in sec. 21, T. 19 S., R. 24 E., where a quarry was opened several years ago but has been abandoned. There is good reason to believe that the above-mentioned areas contain a considerable reserve of asphalt rock of limestone type.

It is believed that by systematic exploration additional commercial deposits of asphalt rock could be found in eastern Kansas. Miami, Bourbon, and Crawford counties seem to have favorable indications of the presence of asphalt rock. Areas in Kansas wherein deposits are known or believed to be present are shown in figure 4.

Production in Kansas.—For several years high-grade asphalt has been produced at a plant at Pleasanton. This material has found a market in several states, and its fitness as a paving material has been proved.

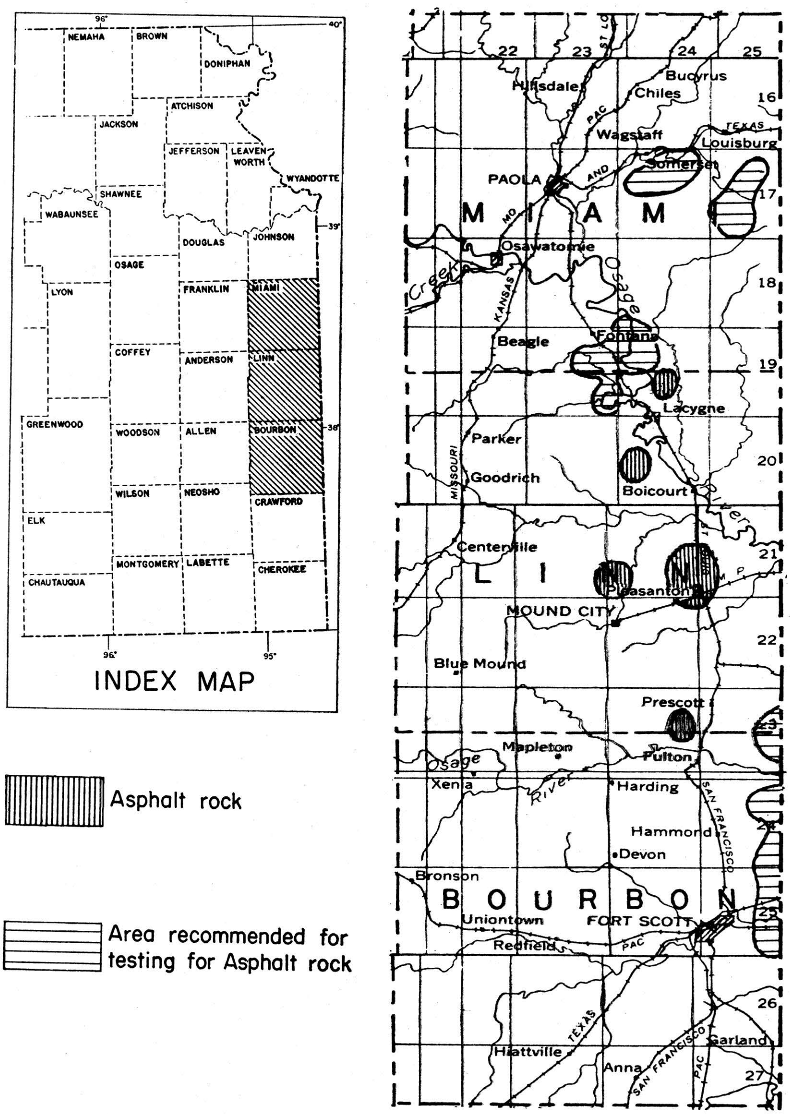

FIGURE 4. Index map of eastern Kansas showing location of Miami, Linn, and Bourbon counties. Enlarged detail map of the three counties showing asphalt rock deposits and areas recommended for prospecting.

Uses of asphalt rock.—Where artificial asphalt is used in paving, aggregate must be added; where crushed asphalt rock is employed, both the aggregate and binding material are present. In practice, artificial asphalt often is added to lean asphalt rocks after crushing. Kansas asphalt rock is of both the sandstone and limestone types; hence two kinds of aggregate are available which can be blended to produce almost any desired mixture. Attention is called to the present demand for asphalt for use in the construction of paved runways at airports.

Kansas reserves.—The deposits in Linn and Miami counties lie in an area of asphalt rock extending into Vernon and Barton counties, Missouri. It has been estimated that there are approximately 90,000,000 to 100,000,000 tons of asphalt rock in Linn county, Kansas, and in Barton and Vernon counties, Missouri. Between 20,000,000 and 25,000,000 tons are estimated to be present in Linn county alone. Additional discoveries, through prospecting at the sites of former "tar springs" in Miami county, probably would increase greatly the known reserve.

Age and origin.—The asphalt in Kansas asphalt rock deposits is believed to have been formed by evaporation of more volatile parts of crude oil that formerly was held in porous sandstone and limestone. The asphalt is the partly oxidized residue of petroleum. All asphalt rocks in eastern Kansas are Pennsylvanian in age.

Work of the State Geological Survey of Kansas.—The State Geological Survey of Kansas (Bull. 29, 1940) has located and described areas in Kansas of known asphalt rock deposits and areas recommended for prospecting. Additional work, especially the investigation of favorable areas, is planned.

References

Heinz, C. E., and Netzeband, W. F., *1932*, The Missouri-Kansas rock-asphalt deposits: Roads and Streets, vol. 65, no. 10, pp. 419-422.

Jewett, J. M., *1940*, Asphalt rock in eastern Kansas: Kansas Geol. Survey, Bull. 29, pp. 1-23, pls. 1-2, figs. 1, 2 (including map).

Redfield, A. H., *1937*, Industrial minerals and rocks (chapter on Native Bitumens): Am. Inst. Min. and Met. Eng., New York, pp. 527-532.

Bentonite

Summary.—Kansas bentonite deposits are unexploited and undeveloped. Experiments have shown that they are well adapted for use in drilling muds, bleaching oils, and bonding material for foundry sands.

Description.—Bentonite is a clay or claylike material derived from the alteration of volcanic ash. The chief constituent of bentonite is the clay mineral montmorillinite, a hydrous aluminum silicate. In general, bentonites are of three types: (1) those that swell greatly in water, (2) those that do not swell in water any more than ordinary plastic clays or fuller's earth, and (3) those that show a degree of swelling intermediate between types 1 and 2. The high-swelling type of bentonite absorbs large quantities of water and remains in thin water dispersions, whereas the non-swelling type absorbs no more water than ordinary plastic clays and settles rapidly in thin water dispersions. Mineralogically, bentonites may be classified as alkaline bentonite, alkaline sub-bentonite, alkaline-earth bentonite, and alkaline-earth sub-bentonite.

The Kansas bentonites thus far discovered and investigated belong to the intermediate type (3), as far as swelling is concerned. Mineralogically, they include all four of the above-mentioned classes. They are fine, plastic and most commonly of some shade of gray or green. Colors reported are: very light gray, greenish gray, light-yellow gray, bluish gray, brownish gray, olive green, pale olive-green, gray-green, greenish white, maroon, brown, and chocolate-brown. Some of the bentonites, such as those in Wallace county, are interbedded with soft, dusty grit and sand, whereas others, such as some in Phillips county, are interbedded with shale. Thickness of bentonite beds range from 6 to 30 feet. In Wallace county some of the deposits occur in more or less isolated, long narrow mounds, as a result of erosion. The overburden varies from 3 to 40 feet. Experiments conducted by the State Geological Survey of Kansas show that the Kansas bentonites when immersed in distilled water have a percentage increase of from 200 to 300 per cent.

Chemically, bentonites should be high in silica and alumina in order to be classed as economically important. Analyses by Kinney (1942) of the State Geological Survey of Kansas show that the Kansas bentonites have a high silica and alumina content. The average chemical composition of ten bentonites from Phillips and Wallace counties is given in table 13 below.

TABLE 13. *Average chemical composition of ten bentonites from Phillips and Wallace counties. (Analyses by E. D. Kinney).*

CONSTITUENTS	PER CENT
SiO_2	54.72
Al_2O_3	18.58
Fe_2O_3	2.77
CaO	3.50
MgO	0.38
Na_2O and K_2O	0.82
TiO_2	0.01
H_2O lost at 105°C	0.89
Ignition loss (900°C)	17.10
SO_3	1.00
Total	98.96

The chemical analyses also show that Kansas bentonites contain only normal amounts of impurities consisting of lime, iron oxide, and sulphates. It should be noted that impure bentonite deposits often are situated very near purer material, a condition calling for selective mining to assure a uniformly good product.

Distribution.—The known deposits of bentonite in Kansas are in Phillips and Wallace counties (fig. 5). The Phillips county deposits occur in an area that extends in a northeasterly direction from sec. 35, 3 miles due south of Long Island, to sec. 11, T. 1 S., R. 18 W. This area is approximately 12 miles long and from one-half to three-quarters of a mile wide. Samples have been collected from the SE¼ sec. 10, T. 1 S., R. 18 W., and NE¼ sec. 35, T. 1 S., R. 20 W. The Wallace county bentonite deposits also are extensive. Bentonite is known to be present in Wallace county at the following locations:

NW NE sec. 29, T. 11 S., R. 41 W.
NW NE sec. 30, T. 11 S., R. 41 W.
NE sec. 26, T. 11 S., R. 42 W.
NW sec. 8, T. 12 S., R. 41 W.
NW SW sec. 8, T. 12 S., R. 41 W.
SW sec. 19, T. 12 S., R. 41 W.
sec. 1, T. 12 S., R. 42 W.
sec. 2 T. 12 S., R. 42 W.
SE sec. 14, T. 12 S., R. 42 W.
SW NW sec. 6, T. 12 S., R. 41 W.

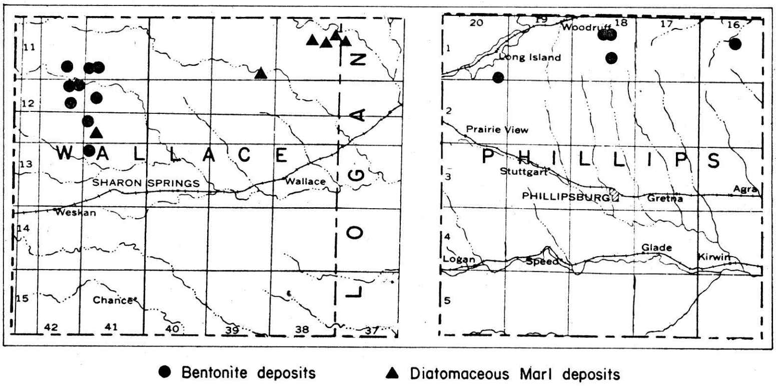

FIGURE 5. Maps of Wallace and Phillips counties, and part of Logan county, Kansas, showing location of known bentonite and diatomaceous marl deposits.

Bentonite undoubtedly is present at places other than those mentioned above, not only in Phillips and Wallace counties but also in counties from which bentonite thus far has not been reported.

Uses.—Experiments thus far conducted on Kansas bentonites (Kinney, 1942) indicate that they are suitable for the purpose of filtering oils, as an ingredient in moulding sands, and for purposes of sealing to prevent the percolation of water in the construction of dams. Kansas bentonites swell only a little over three times their original volume, compared with 15 times in the case of the Wyoming bentonites. Furthermore, Kansas bentonites tend to form thick colloidal pastes with moderate amounts of water. These facts, together with their cheapness and accessibility, should render them useful as oil-drilling muds, especially for use in local drilling. Experiments have shown that Kansas bentonites are unusually good as bonding cement in foundry sands.

Bentonite is used as a thickening agent in drilling muds, for the purpose of sealing walls against water filtration, and as a bonding medium for heat and sound insulation blocks, plasters and cements. Bentonite is a standard suspending, spreading and adhesive agent in horticultural sprays and insecticides. It is used for the purpose of clarifying turbid waters and purifying sewage, for emulsifying asphalts and other water immiscibles; and as an admixture in concrete to improve workability and flow and to prevent segregation. Bentonite also is employed to inhibit the gumming of screens in dewatering paper pulp, to gelatinize mash poultry foods, and in the preparation of cosmetics and pharmaceuticals.

Production and reserves.—Up to the present time (April, 1942), Kansas bentonite deposits have not been exploited or developed, and the extent and volume of reserves is not known. In 1938, a considerable number of auger holes were drilled in sec. 35, T. 1 S., R. 20 W. and in sec. 10, T. 1 S., R. 18 W., in Phillips county. Bentonite was found in most of the auger holes, and thicknesses of 25 feet were reported in some. As indicated previously in this report, further intensified search and test drilling undoubtedly will reveal bentonite deposits other than those already known, not only in Phillips and Wallace counties but also in other Kansas counties.

The importance of searching for and developing Kansas bentonite deposits is suggested by the table below, which shows the great increase in the volume of bentonite sold in the United States from 1931 to 1940 inclusive. During this period production and value increased almost five times.

TABLE 14. *Bentonite sold by producers in the United States, 1931-1940*[1]

YEAR	SHORT TONS	VALUE IN DOLLARS
1931	52,293	429,842
1932	57,743	489,803
1933	84,993	719,345
1934	146,187	977,208
1935	157,445	1,047,600
1936	177,807	1,367,420
1937	194,768	1,500,758
1938	192,183	1,373,182
1939	219,720	1,702,393
1940	251,032	1,919,461

[1] Minerals Yearbook, U.S. Bureau of Mines, 1940.

Wyoming and South Dakota are the largest producers of bentonite in the United States. Other states in which bentonite is sold or used by producers include: Alabama, Arizona, California, Colorado, Mississippi, Nevada, New Mexico, Oklahoma and Utah.

Origin and age.—Bentonite is derived from the alteration or weathering of volcanic ash. Kansas bentonites are of at least two ages. In Wallace county, bentonite is found in the Tertiary Ogallala formation. Some of the Tertiary bentonite may be Miocene and some early Pliocene in age. The Phillips county bentonite is found in the lower part of the Weskan shale member of the Pierre shale formation of Cretaceous age.

Work of the State Geological Survey.—The State Geological Survey has carried on a preliminary exploratory survey in Phillips and Wallace counties. Recently, the Survey has completed a series of chemical analyses of Kansas bentonites and has performed various tests to determine their physical properties and uses, especially as oil drilling muds, bleaching materials for oils, bonding material in ceramic mixtures and as bonding cement in foundry sands. A report on Kansas bentonites and their uses is now in preparation and will be published in the near future as a bulletin of the State Geological Survey of Kansas.

References

Davis, C. W., and Vacher, H. D., *1928,* Bentonite, its properties, mining, preparation, and utilization: U.S. Bur. Mines, Tech. Paper 438, pp. 1-51, fig. 1, tables 1-5.

Industrial Minerals and Rocks, *1937,* Bentonite (chapter by Paul Bechtner), pp. 129-134.

Kinney, E. D., *1942,* Kansas bentonite: Kansas Geol. Survey, Bull. (in preparation).

Ross, C. S., and Shannon, E. V., *1926,* Minerals of bentonite and related clays and their physical properties: Am. Ceram. Soc., Jour., vol. 9, pp. 77-96.

Chalk

Summary.—The production of Kansas chalk up to the present time has been on a small-scale basis. It is estimated that at least 50 billion tons could be mined in Kansas by stripping methods.

Deposits of chalk are of sparse geographic distribution. The only important deposits of chalk in North America are in a few of the midwestern states. A large proportion of the chalk in this area is within the boundaries of Kansas. In the past, most of the chalk used in the United States has been imported from England and France. These chalks are of late Cretaceous age and, according to Wilson (1937, p. 14), are composed dominantly of the fossil remains of minute organisms, coccalithophores, and foraminifers. The term *whiting* originally was applied to the water-ground chalks from these countries. Since about 1918, any material composed dominantly of calcium carbonate and having the requisite degree of fineness, plasticity and purity is called whiting.

Chalk industry in Kansas.—Very little chalk has been produced commercially in Kansas. This is due in part to the fact that until recent years European chalks could be shipped to this country very cheaply by water. The principal reason for the fact that Kansas chalks have not been developed is that their suitability as a source of whiting was not known until very recently. Subsequent to a preliminary investigation of Kansas chalks in 1937 and 1938, several carloads were shipped from a locality north of Gaylord in Smith county.

Uses.—Chalk, after grinding for use, is given the trade name *whiting*. At the time whiting was imported in considerable amounts, about 50 per cent of the material was used as a paint filler, 35 per cent as a rubber filler, and about 10 per cent was used in making putty (Wilson, 1937). Putty is manufactured by grinding the chalk or whiting with linseed oil. For these uses, the physical characteristics of the chalk, such as particle size, plasticity and color, are more important than the chemical composition.

The proportion of chalk used for ceramic whiting evidently was. not included in the percentages given above. Chalk used for ceramic whiting must meet rather exacting requirements as to chemical composition. Three samples of Kansas chalk that have been analyzed meet these requirements with the exception of the iron oxide content. The standard specifications (American Ceramic Society, pp. 928, 378) designate a maximum Fe_2O_3 content of 0.25 per cent. In the three Kansas samples analyzed, the Fe_2O_3 content ranged from 0.33 to 0.60 per cent. It is probable that the Kansas chalks would meet the requirements if carefully quarried so as to eliminate material from iron-stained joints and bedding planes.

English chalk is the standard of purity in the whiting industry. In table 15, analyses of three samples of English chalk and of a sample of Kansas chalk from Smith county are listed for purposes of comparison.

The slight excess of iron oxide in Kansas chalks would not be detrimental in many ceramic uses of whiting. Whiting is used in glazes, enamels, and in porcelain and whiteware bodies. Chalk is more suitable than other naturally occurring forms of calcium carbonate because of its fine particle size and consequent ability to stay in suspension in water.

Kansas reserves.—The Fort Hays chalk formation in Kansas is

TABLE 15. *Chemical analyses of English chalk and Kansas chalk*

Constituents	English chalk[1] Per cent, three samples			Kansas chalk (Smith county)[2] Per cent
CaO	54.4	55.0	54.0	54.80
SiO_2	1.5	0.7	1.7	1.50
Fe_2O_3	0.08	0.07	0.18	0.55
Al_2O_3	0.4	0.4	0.4	1.35
MgO	0.4	trace	0.4	0.55
Loss on ignition	43.0	43.1	42.8	42.18
Total	99.78	99.27	99.88	100.93
$CaCO_3$, calculated	97.2	98.3	97.2	97.8

[1] Analyses from U.S. Bureau of Mines, Bull. 395.
[2] Analysis by Raymond Thompson in the laboratories of the Kansas Geological Survey.

60 to 80 feet in thickness and crops out in an irregular belt extending in a southwest direction from the Kansas-Nebraska line in Jewell county to a point about 15 miles northwest of Garden City (fig. 12). There is enough chalk in Kansas to supply the entire United States for many centuries at the present rate of use. It is estimated that at least 50 billion tons could be mined by stripping methods.

Age and origin.—The most important commercial reserve of chalk in Kansas is the Fort Hays limestone, basal member of the Niobrara chalk of late Cretaceous age. Chalk is a marine sedimentary deposit derived largely from the calcareous remains of microscopic organisms.

REFERENCES

ANONYMOUS, *1928,* Standard specifications for materials: Am. Ceram. Soc. Jour., vol. 11, no. 6, pp. 378-386.

WILSON, HEWITT and SKINNER, KENNETH, *1937,* Occurrence, properties and preparation of limestone and chalk for whiting: U.S. Bur. of Mines, Bull. 395, pp. 1-155, figs. 1-48, tables 1-32.

CHAT

Summary.—Large amounts of chat are available in Cherokee county for concrete aggregate, railroad ballast, and road metal.

Chat is a by-product of the mining of zinc and lead ore in the Tri-State district. Chat constitutes the rock waste with which the lead and zinc minerals are associated. The minerals comprising chat are essentially chert, limestone, and calcite. Mining operations during a great number of years have resulted in the accumulation of large chat piles in the Tri-State district. Until very recently these chat piles were not extensively utilized. At the present time, however, some of the chat piles containing lead and zinc minerals in sufficiently large amounts are being reconcentrated to remove these minerals, which were not recovered during earlier milling operations. In recent years, attempts have been made to find uses for the chat. Considerable amounts now are being utilized for railroad ballast, concrete aggregate and road metal. A large reserve of chat is available in the Kansas portion of the Tri-State area.

CLAY

Summary.—The value of structural clay products produced in Kansas during 1940 was approximately $1,500,000. The known reserves of Cretaceous clay in north-central Kansas are 125 billion tons, and of this amount 46 billion tons are light-firing clays. The reserves of red-firing clay in eastern and southeastern Kansas are enormous.

One of the world's oldest crafts is that of molding useful or ornamental articles from wet clay, drying and firing them to temperatures sufficiently high to make them permanently resistant to weather. Fired bricks over 10,000 years old have been found below the level of the Nile valley, and excellent types of glazed pottery were made in Egypt as early as 3000 B.C.

Clay industry in Kansas.—In the early days of Kansas, the brick and pottery industries were much more widely distributed over the state than they are now, although the total tonnage probably was not much greater. Many small communities made hand-molded bricks and fired them in scove kilns. These bricks were used locally in the construction of buildings, many of which are standing today. Small potteries were established over the state to supply local needs.

Production.—The high point of brick production in Kansas came in the period from 1900 to 1925. The highest annual production of common bricks was in 1906, when nearly 315 million bricks were produced. The high in vitrified brick production was attained in 1924, with an annual production valued at $1,237,853. The production of vitrified bricks declined rapidly thereafter, because concrete replaced bricks in paving. The highest annual production of face bricks and drain and building tile was attained in 1929, in which year the output of face bricks was valued at $730,116 and that of drain and building tiles at $106,823.

The annual production in 1940 of all structural clay products was valued at approximately $1,500,000. If roofing tiles were included in the list, the figure for 1941 would be considerably higher. Kansas has the second largest roofing-tile plant in the world. During the latter part of 1940 and most of 1941, this plant was running about 20 percent over capacity because of large government contracts.

Clay production in Kansas has been increasing slowly since the extreme low in 1932 and 1933. It is reasonable to expect that production will continue to increase in the future. In the opinion of experts, the timber supplies of this country are not adequate to permit continuance of the present rate of use. In the future the more durable materials, brick and concrete, may replace, wherever possible, lumber used in construction.

Most of the production in Kansas is that of structural clay materials, such as bricks, hollow tiles, and roofing tiles. These products are made mostly from red-firing shale of Pennsylvanian age that occurs in southeastern Kansas. Buff facing brick and tiles are made from a Cherokee underclay at Weir. The demand for light-colored bricks has increased in the past few years. It is probable that within the next few years larger and larger amounts of light-firing clays will be produced from the enormous reserves in north-central Kansas.

Uses.—In general, the use of clay and shale for the manufacture of building materials is well known. Less well known are the various types of refractories, chemical ware, and pottery which can be made from these materials.

Refractory fire clays are made into bricks for lining boilers and for constructing blast furnaces, kilns, and regenerators. These fire clays are used also in the manufacture of a variety of special-shaped articles, such as locomotive firebox crowns, glass tank blocks, crucibles, and pot furnaces. Such products are necessities in many industrial processes, including those employed in wartime industries. Perhaps the most critical use of fire clays, and the one in which the requirements are the most exacting, is in the construction of fireboxes of our navy's ships.

Pottery is a general term including a variety of products ranging from flower pots to fine china, and from art ware to chemical stone-ware. The types of clays used are equally varied. Some cheaper types of ware are made from red-firing clays, but the greater proportion is made from clays firing to colors ranging from white to buff. White vitreous china or porcelain is made from kaolin, white-firing ball clay, and feldspar. This class of ware includes "china" table ware, spark plug porcelains, chemical ware, lavatory and toilet bowls, and bathtubs.

Many articles that commonly have been made from metals can be made equally well from clay, thus releasing the metals for wartime uses. An extensive list of ceramic (clay and glass) substitutes for materials needed in wartime was compiled by the United States Department of Commerce, and appeared in Ceramic Industry in the issue for December, 1941. The general classes of articles ordinarily made from metal for which fired-clay ware could be substituted are as follows: cooking utensils, electric and gas range parts, officer's mess outfits, refrigerator parts, washing machine parts, containers and linings for use in chemical and industrial processes, and containers for canning food.

Russia has successfully used hard-burned clay or shale containers in military operations for placing charges of explosives in what are termed land mines. Clay containers have an advantage over those made from iron and steel in that they cannot be detected by magnetic devices. In addition, metal is saved for more critical uses. Some Kansas clay is of a type satisfactory for this use.

The ore from which aluminum commonly is extracted is bauxite. In the United States the supplies of high-grade ore, containing 50 to 60 per cent alumina, will last but a very few years. Kansas clays, containing 20 to 40 per cent alumina, are a good potential source of aluminum. It is possible to extract alumina from clay by the acid method, and it seems not too visionary to expect that the vast deposits in Kansas will be utilized in the not too distant future as a source of metallic aluminum. Methods of extracting aluminum from clay are discussed in the section on Aluminum.

An associated Press news item (Feb. 15, 1942) states that Secretary Ickes has proposed a vast program aimed at the utilization of low-grade ores. This program, which was prepared at the request of the Senate Public Lands Sub-Committee, calls for the construction in the western United States of 17 power projects costing $350,603,000. Clay is first on Secretary Ickes' list of substances.

The State Geological Survey is planning to conduct experiments

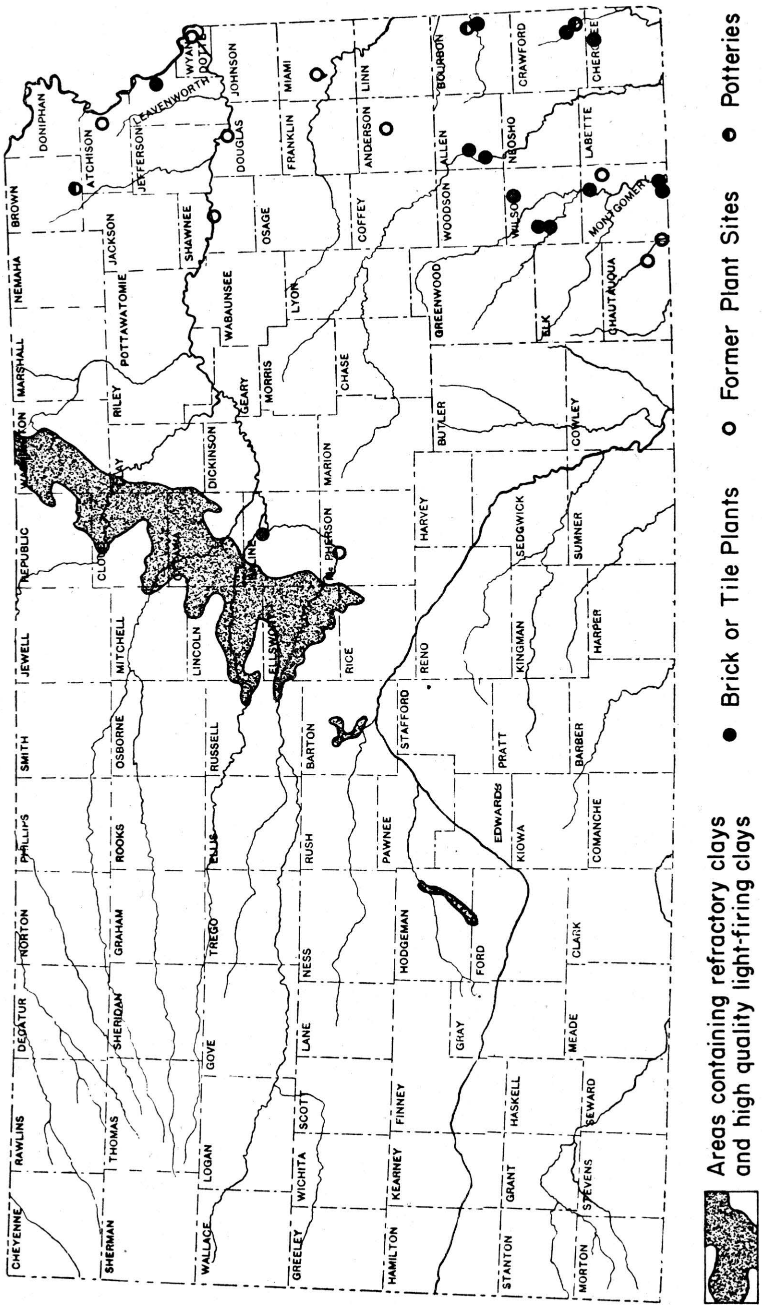

FIGURE 6. Map of Kansas showing location of refractory clay deposits and of ceramic plants.

on the concentration of alumina from fire clays by mechanical methods. The process will include heating, grinding, and flotation. This process, if successful, might lower the cost of producing aluminum from clays.

Kansas reserves.—Many of the red-firing shales of Pennsylvanian age in eastern and southeastern Kansas are admirably suited to the manufacture of structural clay products, and have been so used for many years. All the important Kansas production is now in that area. It is impossible to estimate the tonnage available, but it is known to be enormous. Usable shale deposits occur also in the Permian system cropping out in the central third of the state.

The most valuable clays in Kansas have been found by the State Geological Survey in central and north-central Kansas (fig. 6). These clays consist of plastic to siliceous fire clays, pottery clays, ball clays, and some kaolin clays. Those of greatest value fire to colors ranging from white to buff. They are capable of withstanding high temperatures, inasmuch as they have fusion points ranging from 2,900 to 3,000° F. An even larger supply of clays firing to colors ranging from dark-buff to red also is available in this area.

It is estimated that a minimum of 125 billion tons of these clays could be obtained by stripping methods. Of this reserve tonnage, over 40 billion tons consists of high-grade, light-firing clays.

Age and origin of Kansas clays.—The clay and shale deposits of Pennsylvanian (late Carboniferous age) that are so extensively used in the manufacture of bricks, hollow tiles, roofing tiles and drainage tiles, are of both marine and nonmarine origin. The formations that have been used most commonly are the upper Cherokee shale, the Galesburg or Coffeyville shale, and Lane-Bonner Springs shale, the Weston shale, and the Lawrence shale.

The large deposits of high-grade light-firing clays in central and north-central Kansas occur in the Dakota formation of Cretaceous age. They are nonmarine in origin.

References

Anonymous, *1941,* Is this the golden age of ceramics?: Ceramic Industry, vol. 37, no. 6, pp. 19-21.

Kruger, Edward V., *1940,* The outlook for Kansas clay products industries: Univ. of Kansas, Ind. Res. Ser. no. 1, pp. 1-42, tables 1-12.

DIATOMACEOUS MARL

Summary.—Kansas diatomaceous marl is unexploited and undeveloped. Reserves are estimated to be more than 1,000,000 tons.

Description.—Diatomaceous marl is an impure variety of diatomite, the latter being known also as diatomaceous earth or tripolite. Diatomite is a hydrous or opaline form of silica and is composed largely of tiny, skeletal remains of diatoms, which are microscopic, one-celled water plants. Table 16 (Hatmaker, 1931) shows the range in composition of diatomites from various parts of the United States.

TABLE 16. *Range in chemical composition of diatomites from various parts of the United States* (Hatmaker, 1931).

CONSTITUENTS	RANGE IN PER CENT
SiO_2	65—97
Al_2O_3	0.45—11.71
Fe_2O_3	Trace—3.34
CaO	0.11—2.61
MgO	Trace—1.06
K_2O	0.0—3.58
Na_2O	0.0—1.43
Ignition loss (H_2O and organic matter)	3.40—14.01

Diatomite, when pure, is white. When impure, it is gray, brown, pink or green. It is highly porous, bulky, a very poor conductor of heat, and is chemically inert in the presence of ordinary reagents. It appears to be similar to chalk, for which it sometimes is mistaken and from which it can be differentiated by the fact that, unlike chalk, it does not effervesce when acid is applied.

Kansas diatomaceous marl is a snow-white to grayish chalky rock, light and very fragile. Its specific gravity is about 1.53. It is composed of the siliceous tests or hard parts of fresh-water diatoms and of flaky calcium carbonate. Scattered among the diatom tests are long, thin and smooth spicules of sponges, grains of fine- to medium-sized colorless quartz, some pinkish feldspar and occasionally skeletons and scales of small fish. Analyses show that the Kansas marl consists of about 75 per cent of acid soluble material, chiefly calcium carbonate, and the rest of acid insoluble material of which 90 to 95 per cent is made up of the siliceous tests of diatoms and siliceous spicules of sponges. Rough estimates indicate that about one-half of the rock by volume is made up of diatoms. The thickness of the marl varies from 2 to 11 feet. Diatomaceous marl usually is massive and is cut by widely spaced vertical joints into large blocks. It is horizontally bedded and can be broken with comparative ease along the closely spaced bedding planes.

The diatomaceous marl occurs in the Ogallala formation and is overlain by a thin limestone and in some places by grit, gravel and loess as much as 30 feet thick. Inasmuch as the Ogallala formation, which contains the marl, is slightly folded, the marl occurs at various levels. At the Marshall ranch deposit, in Wallace county, the marl is about 60 feet above the level of Smoky Hill river at the west end of the exposure, and from 80 to 120 feet above the river in the middle and eastern parts. The diatomaceous marl, together with the overlying thin limestone, resists weathering and forms low cliffs and benches. In a few places erosion has formed separate cliffs of the marl, which are scattered on the smooth, gently descending slopes of the Smoky Hill river valley.

Distribution.—The diatomaceous marl in Kansas has been found by the State Geological Survey to occur at three localities in Wallace county and one in Logan county (fig. 5). The largest known deposits is on the Marshall ranch in secs. 10, 11 and 12, T. 11 S., R. 38 W. and extends into sec. 7, T. 11 S., R. 37 W. in Logan county. It extends for a distance of more than 3 miles. A second deposit is in the SE SE sec. 35, T. 11 S., R. 39 W., at the head of one of the numerous draws on the south side of Lake Creek. The third deposit is in the NE cor. NW sec. 29, T. 12 S., R. 41 W., about one-half mile east of the Collins ranch. Small deposits also occur in Meade and Seward counties, representing extensions of the Beaver county, Oklahoma, diatomaceous marl deposits.

Uses.—Kansas diatomaceous marl is especially suitable for use in the manufacture of hydraulic cement or "hydraulic lime," that is, a cement that will "set" under water. Some of the marl possibly may be used as an absorbent for nitroglycerin, as a source of silica for water glass, and as a constituent of sound and heat insulators. It also may be used as an abrasive.

Production and reserves.—Up to the present time the Kansas diatomaceous marl deposits have not been developed, and extensive search for them has not been made. It has been estimated that about one million tons of diatomaceous marl are present on the

Marshall ranch in secs. 10, 11, and 12, T. 11 S., R. 38 W., in Wallace county, and in the adjoining sec. 7, T. 11 S., R. 37 W., in Logan county. This estimate includes only that marl that could be stripped where the overburden does not exceed 30 feet. The extent of the marl at the other two Kansas localities is unknown.

In 1940, California and Oregon were the chief producing states of diatomite and its varieties. Other producing states include Florida, Idaho, Nevada, New Mexico, New York and Washington. The average annual sales of diatomite for the years 1933 to 1938 amounted to 87,331 short tons valued at $1,335,130 (Minerals Yearbook, 1940, p. 1241).

Origin and age.—The diatomaceous marl of Kansas is a fresh-water deposit, as indicated by the tests of fresh-water diatoms and the crushed shells of fresh-water gastropods, pelecypods, and other fossils associated with the overlying limestone cap rock. The diatoms are microscopic water plants that are able to precipitate silica from the waters in which they live; out of this material they manufacture their siliceous skeletons. Diatoms are short-lived but are exceedingly abundant and multiply rapidly, as is suggested by the fact that as many as 50 million individual skeletons may be found in a cubic inch of diatomite (Hatmaker, 1931). On death of the diatom, the organism decomposes but its skeleton sinks to the bottom of the lake, swamp or ocean in which it lived; multitudes of such skeletons gradually build up extensive deposits of diatomite. The Kansas diatomaceous marl occurs in the Ogallala formation of Tertiary age.

Work of the State Geological Survey.—The Diatomaceous marl of Wallace county has been studied by Elias (1931) and is described by him in the two State Geological Survey publications cited in the references. Diatomaceous marl has been sent by the Survey to the United States Bureau of Standards for testing in order to determine the suitability of the marl for making hydraulic lime. Preliminary reports indicate that it is satisfactory in quality for such use. A graduate chemical engineer at the University of Kansas has been investigating other possible uses for the marl.

References

Cummins, A. B., and Mulryan, H., *1937,* Diatomite: Industrial Minerals and Rocks, Am. Inst. Min. and Met. Eng., New York, pp. 243-260.

Elias, M. K., *1931,* The geology of Wallace county, Kansas: Kansas Geol. Survey, Bull. 18, pp. 1-254, figs. 1-7, pls. 1-42.

———, *1931,* Diatomaceous marl from western Kansas, a possible source of hydraulic lime: Kansas Geol. Survey, Mineral Resources Circ. 3, pp. 1-5.
HATMAKER, PAUL, *1931,* Diatomite: U.S. Bur. Mines, Infor. Circ. 6391, pp. 1-20.
MINERALS YEARBOOK, *1941,* Review of 1940: U.S. Bureau of Mines, pp. 1241-1242.

FILLERS FOR PLASTICS

Summary.—Kansas contains several types of mineral deposits which may prove to be satisfactory as a filler for plastics.

Plastics is a general term used to designate a wide variety of materials, including hard rubber, phenol-formaldehyde resins, urea-formaldehyde, cellulose compounds, and casein plastics. Such materials are formed into usable articles both by extrusion and by press molding, either at room temperature or at moderate temperatures ranging up to 300° F. The complex organic compounds are mixed with fillers before being molded into articles. The fillers serve to reduce shrinkage and to increase strength and resistance to abrasion and high temperature.

Organic fillers, such as wood-flour, paper, and cotton flock (a fibrous substance that grows around pods of cotton seeds), commonly are used. Inorganic fillers, such as slate dust, asbestos, mica, graphite, kaolin, pulverized marble and diatomaceous earth, are used for articles in which resistance to abrasion or high temperatures is required. As much as 50 per cent of the plastic substance may consist of filler.

Requirements of a filler for plastics.—The specific gravity of the majority of plastic molding compounds ranges from 1.3 to 1.7. In general, it is desirable to use a filler which will not increase the specific gravity. Some plastic compounds have a specific gravity as high as 3.0. The filler should not be of an excessively abrasive character; otherwise it will be injurious to the molds. Furthermore, it should be of a composition such that it will not react chemically with the plastic material used. The maximum particle size should be 300-mesh.

Kansas materials.—Kansas could produce enormous quantities of inorganic materials which might prove suitable for use as fillers in plastics. Members of the staff of the State Geological Survey are now undertaking studies of some of these materials to determine possible methods of preparation and grinding. Some of the Kansas materials that seem most promising for this use include diatomaceous marl, volcanic ash, chalk, tripoli, and calcined light-firing clay.

Gypsum

Summary.—Kansas ranks eighth among the states as a gypsum producer. The known reserves, particularly in the southern Kansas area, are very large.

Gypsum has been utilized in a variety of ways since very ancient times. The writings of Pliny show that before the time of Christ the Greeks made plaster of Paris casts from calcined gypsum and that they used transparent gypsum (selenite) in roofs of greenhouses, much as modern greenhouses are made with ordinary glass. Gypsum was used as windows in palaces in ancient Greece and Italy. Rock gypsum was used as a building stone by the Arabs. In Egypt and elsewhere the alabaster variety was used in very remote times in making urns, vases, and sculptured articles.

Gypsum now is used for many purposes, and it is employed both in the calcined and uncalcined form. Large quantities go into the making of cements and plasters and fabricated building materials.

Gypsum is hydrous calcium sulphate. Its formula is $CaSO_4$-$.2H_2O$. It is 79.1 per cent calcium sulphate and 20.9 per cent water of crystallization. The mineral calcium sulphate without water is termed *anhydrite*. When gypsum is completely calcined, the product is termed *dead-burned gypsum*. This is artificial anhydrite, and, like natural anhydrite, it has no cementing properties. Plaster of Paris is made by calcining gypsum until only a part of the water content is driven off. If about half of the water is removed, the material sets quickly but does not have the strength and hardness of plaster of Paris that has been calcined until only 15 to 18 per cent of the water remains.

Five varieties of gypsum are recognized: (1) tabular crystals and cleavable masses called *selenite;* (2) a fibrous material with silky luster called *satin spar*; (3) *alabaster,* which is a massive, generally fine-grained variety; (4) *rock gypsum,* the name applied to a compact and granular variety; and (5) *gypsite,* which is the accepted name for granular gypsum earth of secondary origin.

Gypsum in Kansas.—Although gypsum, mostly as disseminated crystals, is of widespread occurrence in Kansas rocks, the workable deposits are chiefly confined to three areas (fig. 7). The areas of workable deposits are (1) the Blue Rapids area in Marshall and eastern Washington counties, (2) the central Kansas gypsum area in Dickinson, Saline, and Marion counties, and (3) the southern Kansas gypsum area in Barber and Comanche counties. Outside

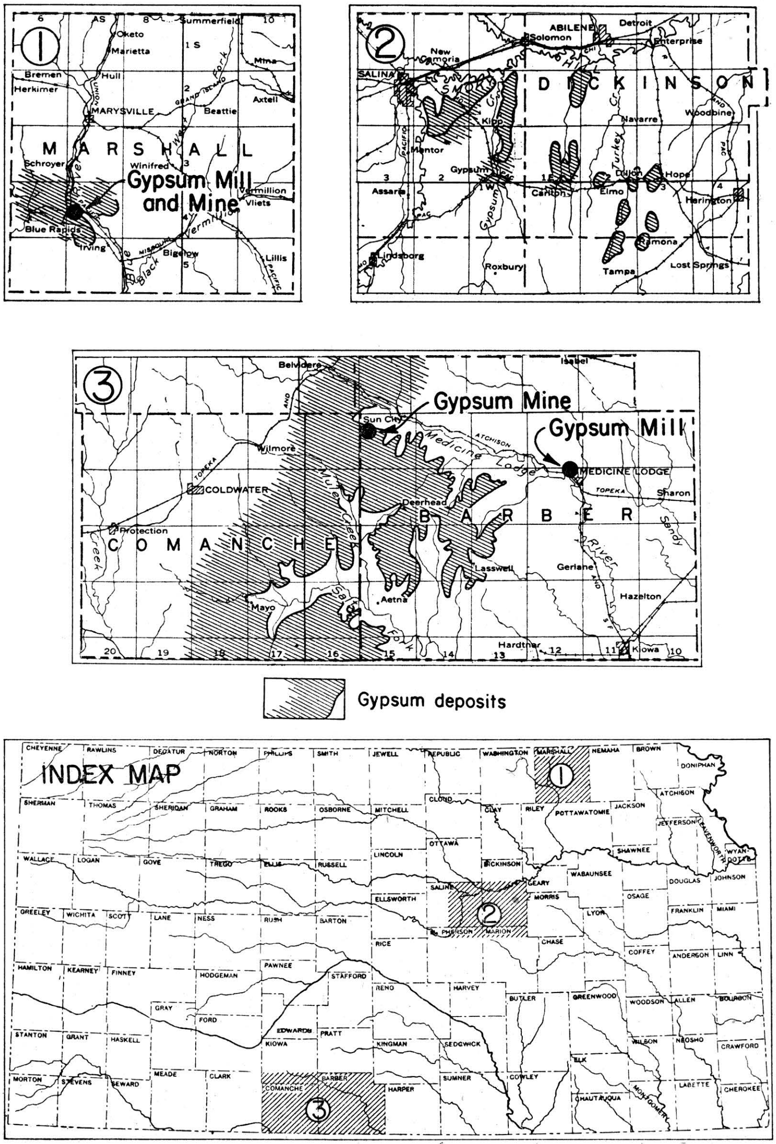

FIGURE 7. Index and detail maps showing distribution of three areas of Permian gypsum deposits, and location of gypsum mills and mines.

of these areas, smaller deposits of both bed-rock gypsum and gypsum earth are known in Clay, Sedgwick, Sumner, and Harvey counties. Gypsum has been mined at several localities from these smaller deposits, and it has been rather extensively produced in the three chief areas. The active plants now are confined to the Blue Rapids and southern Kansas areas.

Plaster of Paris was made experimentally at Blue Rapids in 1871, and the gypsum industry became well established there in the following year. Soon after a gypsum mill was built on the west bank of Big Blue river at Blue Rapids, barges drawn by a small steam tug were used to haul the raw material down the river from the mine to the mill. Water power was used to grind the rock. Blue Rapids has been an important gypsum products center since the first mill was built.

The first gypsum mine in the central Kansas area was a strip mine at Hope, Dickinson county, opened in 1885. In 1894 a shaft mine was sunk at that locality to a depth of 80 feet, and at about the same time a mine and mill were located on Gypsum creek in Saline county, about 6 miles southwest of Solomon. Gypsite or "gypsum dirt" was discovered at Gypsum City, Saline county, in 1873, but development did not start there until 1889. Products from Gypsum City were shipped to many parts of the United States. Plaster made there was used in the World's Fair buildings in Chicago in 1892, and large quantities of plaster made in Gypsum City were used in government buildings at Fort Riley and Fort Leavenworth. These central Kansas gypsum mines and mills operated for several years.

Soon after the discovery of gypsite at Gypsum City, similar deposits were found in Clay, Saline, Dickinson, Marion, Harvey, and Sedgwick counties. Soon seven mills were making plaster of Paris from gypsite. None of these deposits are now being exploited. In 1885, a gypsum mill was built on a farm 5 miles west of Peabody, Marion county. "Rock gypsum" was mined nearby, and the mill operated for about two years.

The first gypsum mill in the southern Kansas area was built at Medicine Lodge in 1889. Keene's cement, which is a very hard and durable cement, and other high-grade products have been produced there for many years. Formerly, a mill was operated at Sun City, about 20 miles northwest of Medicine Lodge. At present, the mining operations of the area are near Sun City. Gypsum is shipped by train to the mill at Medicine Lodge.

Blue Rapids area.—As indicated in figure 7, workable gypsum deposits are believed to underlie an area of considerable size in the vicinity of Blue Rapids, Marshall county. As shown by mine workings and outcrops, the average thickness of the bed of gypsum is about 8½ feet. The rock is described as having a sugary texture and is nearly white. A thin layer of satin spar occurs locally in the upper and lower parts of the bed. The gypsum rock crops out along Big Blue river not far above water level. It lies directly on the Middleburg limestone, uppermost member of the Bader formation of the Council Grove group, Permian system. Information pertaining to whether the rock is anhydrite rather than gypsum at some distance from the outcrops is not at hand.

Central Kansas area.—There are several layers of gypsum in the central Kansas gypsum area, as shown in figure 7. Former mine records and outcrops suggest that this area has a large reserve. A bed 14 feet thick and 80 feet below the surface was mined at Hope. At the time of mine workings along Gypsum Creek in eastern Saline county, several gypsum beds were exposed there. A 5-foot bed, a 3-foot bed and several thinner ones were recorded. Natural outcrops occur in the vicinity of Hope and in eastern Saline county. Even though these beds may be represented by anhydrite in areas where they are more deeply covered, there is ample reason to believe that there are large reserves of gypsum in this area. It was in the central Kansas area that several years ago a number of gypsite deposits were developed.

Southern Kansas area.—The southern Kansas gypsum area is part of an extensive region underlain by gypsum and anhydrite, extending far southwestward in Oklahoma, New Mexico and Texas. These gypsum beds, associated with red beds of fine sand and silt, crop out in an area extending from near Medicine Lodge westward through Barber and into Comanche county and southward into Oklahoma. They dip westward under younger sediments, and north of their outcrop area they are overlapped by younger beds. The most prominent and thickest gypsum bed of the area caps a range of hills known as the Red Hills. This bed, called the Medicine Lodge gypsum, is about 30 feet thick at its outcrop. Two beds of gypsum that are only slightly thinner occur a few feet higher in the stratigraphic section. These are the Nescatunga and Shimer gypsum members of the Blaine formation. The Medicine Lodge gypsum is the basal member of the same formation.

It is known that at some distance down dip these gypsum beds grade into anhydrite. Great reserves of gypsum, however, are present in the area because the belt of outcrop is a long and winding one, and it is only under an overburden of considerable thickness that anhydrite instead of gypsum is found.

Production in Kansas.—Kansas normally holds eighth place among the states as a producer of gypsum. Generally, somewhat less than half of the state's output is marketed as raw or uncalcined gypsum. High-grade gypsum products are being produced at Blue Rapids in Marshall county and at Medicine Lodge in Barber county.

Uses of gypsum.—Uncalcined gypsum is used chiefly as a retarder in Portland cement. In the usual procedure of Portland cement manufacture approximately 2 pounds of raw gypsum are added to every 100 pounds of clinker, either before or after the preliminary grinding. Gypsum ordinarly is shipped in lumps and is ground by the cement producer. Small amounts of raw gypsum are used as fertilizer.

Calcined gypsum leaves the mills in the form of plaster of Paris, cement plasters and fabricated products. Another product is Keene's cement, made by calcining gypsum to red heat and recalcining it after an alum solution is added; it sets slowly into a comparatively hard material that resembles marble. Plaster of Paris is used as molds in pottery and metal plants, relief work on walls and ceilings, making beds for the polishing of plate glass, and in surgical and dental work. Cement plasters are products to which filler and retarders have been added. Fabricated products include wall board, tiles, blocks, and so forth. Gypsum plasters and fabricated forms are excellent heat and sound insulators.

Kansas reserves.—As indicated under other headings in this paper, Kansas has great reserves of easily accessible gypsum. Sufficient data are not available to say more than that the reserves in the southern Kansas gypsum area seem to be very large, that large reserves are present also in the two other areas, and that probably the central Kansas area ranks second in this respect.

Age and origin of Kansas gypsum.—The workable bedrock deposits of gypsum in Kansas are of Permian age. The deposits in the

Blue Rapids area are in rocks of the Council Grove group in the Wolfcamp series. The bedrock gypsum deposits in the central Kansas area are in the Wellington shale in the Sumner group, Leonard series. The deposits of the southern Kansas area occur near the top of the Leonard series.

The deposits of gypsite or "gypsum dirt" have been formed recently by the evaporation of ground water that carried gypsum in solution. Some of the deposits were found with a covering of clay 10 feet thick and others with little or no covering. Thus, it seems that the gypsum, which has the appearance of dark granular earth and is commonly found in low, swampy ground, has been deposited during Recent geologic time and chiefly in the present cycle of erosion of the region.

Like salt and anhydrite, gypsum deposits occurring as bed rock have been formed from evaporating sea water in shallow bays or lagoons. The temperature of the water may have been a factor determining whether anhydrite or gypsum was formed. It is believed also that if a deposit of calcium sulphate precipitated from sea water falls through a deeper layer of concentrated brine, it is deposited directly as anhydrite. Gypsum may have been converted into anhydrite by the action of superadjacent salt beds. It is well known that anhydrite changes to gypsum in the presence of water; hence, anhydrite deposits commonly are represented by gypsum at the outcrop and for some distance down the dip of the beds, ground and surface water having brought about the change. This seems to be the case in the deposits of the southern Kansas gypsum area.

It is indicated in the foregoing statements that gypsum and anhydrite may be deposited directly in evaporating sea water in a closed or partly closed basin, and that primary deposits of either mineral may be converted subsequently into the other. It is possible that a given deposit may have undergone more than one conversion.

References

Adams, G. I., and others, 1904, Gypsum deposits of the United States: U.S. Geol. Survey, Bull. 223, pp. 1-129.

Grimsley, G. P., and Bailey, E. H. S., *1899,* Special report on gypsum and gypsum cement plasters: Kansas Univ. Geol. Survey, vol. 5, pp. 1-83, frontispiece, pls. 1-30, figs. 1-20.

Landes, K. K., *1937,* Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110, maps.

———, *1938,* The Kansas minerals industry: Kansas Yearbook, Kansas State Chamber of Commerce, Topeka, pp. 235-237.

NEWLAND, D. H., and BROWN, H. J., *1937,* Gypsum: Industrial minerals and rocks, Am. Inst. Min. and Met. Eng., New York, pp. 353-374.

STONE, R. W., *1920,* Gypsum deposits of the United States: U.S. Geol. Survey, Bull. 697, pp. 1-326.

PORTLAND CEMENT

Summary.—Present production of cement in Kansas is about 4,500,-000 barrels annually, valued at $5,200,000. Reserves of cement materials in the state are inexhaustible.

Portland cement consists of compounds, the chemical constituents of which include calcium oxide, silica, alumina, and iron oxides; this material is capable of hardening into a solid mass. In setting, the compounds form chemical combinations with water. This cement is made from calcareous and argillaceous materials. The calcareous material used is some form of calcium carbonate, including limestone, marl, chalk, oyster or other shells, and the precipitates formed in the manufacture of alkalies. Argillaceous materials include clay, shale, cement rock (argillaceous limestone), slate, and blast-furnace slag. Modern cement mills use a combination of one of the calcareous materials and one of the argillaceous materials.

The beginning of Portland cement dates from 1756 when an Englishman, John Smeaton, discovered that by burning and slaking an impure limestone a cement was made that would set under water as well as in air. Forty years later another Englishman, John Parker, obtained a patent for *Roman cement,* which was made by burning "nodules of clay" in a lime kiln and grinding the clinker. Many plants for making Roman cement were built in England and a little later in America. Portland cement, produced by calcining a mixture of limestone and clay, was patented in England by Joseph Aspdin in 1824. The early Portland cement differed from that of today chiefly in that it was burned at a lower temperature and was pulverized by slaking rather than by grinding. Cement made at Allentown, Pennsylvania, in 1875 was probably the first true Portland cement made in America.

Operations involved in Portland cement manufacture are: (1) mining the raw materials, (2) crushing, (3) drying, in the "dry process", or adding water to produce "slurry", in the "wet process", (4) grinding, (5) mixing the desired proportions, (6) pulverizing, (7) burning to incipient fusion at about 2500 to 3000° F., and (8) grinding the clinker to fine powder. About 2 per cent of raw gypsum is added to the mix before or after grinding the clinker. Gypsum serves as a retarder.

Raw materials in Kansas.—Kansas contains an abundance of raw materials suitable for the making of Portland cement. The supply is virtually inexhaustible. Limestones, including chalk of central and western Kansas, are the source of the calcareous materials, and shales and clays provide the argillaceous materials. Limestones of Carboniferous and Permian age crop out in bands crossing the eastern third of the state in a north-south direction. Many of the limestones occur in beds a few tens of feet in thickness, and many of the beds are nearly pure calcium carbonate. Shales occur interbedded with the limestones. At many sites the two materials can be taken from the same quarry. Cement rocks are also abundant in Kansas, and some are reported to be natural Portland cement rocks. At six places in eastern Kansas Portland cement is being made from Pennsylvanian (Upper Carboniferous) limestones and shales.

In central and western Kansas Cretaceous chalk and shales are abundant. Some years ago chalk and shale were used in cement making in Ellis county.

Gypsum is produced in Kansas in Marshall and Barber counties. Figure 7 shows the areas in Kansas underlain by gypsum deposits; they have been discussed elsewhere in this report.

Both natural gas and powdered coal have been used as fuel in cement mills in Kansas. Natural gas now is used exclusively. As indicated in other sections of this report, Kansas has an abundance of both coal and natural gas.

Production of Portland cement in Kansas.—Six Portland cement mills are now operating in Kansas. The locations are: (1) Bonner Springs, Wyandotte county; (2) Iola and (3) Humboldt, Allen county; (4) Chanute, Neosho county; (5) Fredonia, Wilson county; and (6) Independence, Montgomery county. All the Kansas plants use Pennsylvanian limestone and shale. Natural gas is used as fuel.

The capacity of the plants now operating in Kansas is said to exceed 8,000,000 barrels per annum. From 1910 to 1928 the total

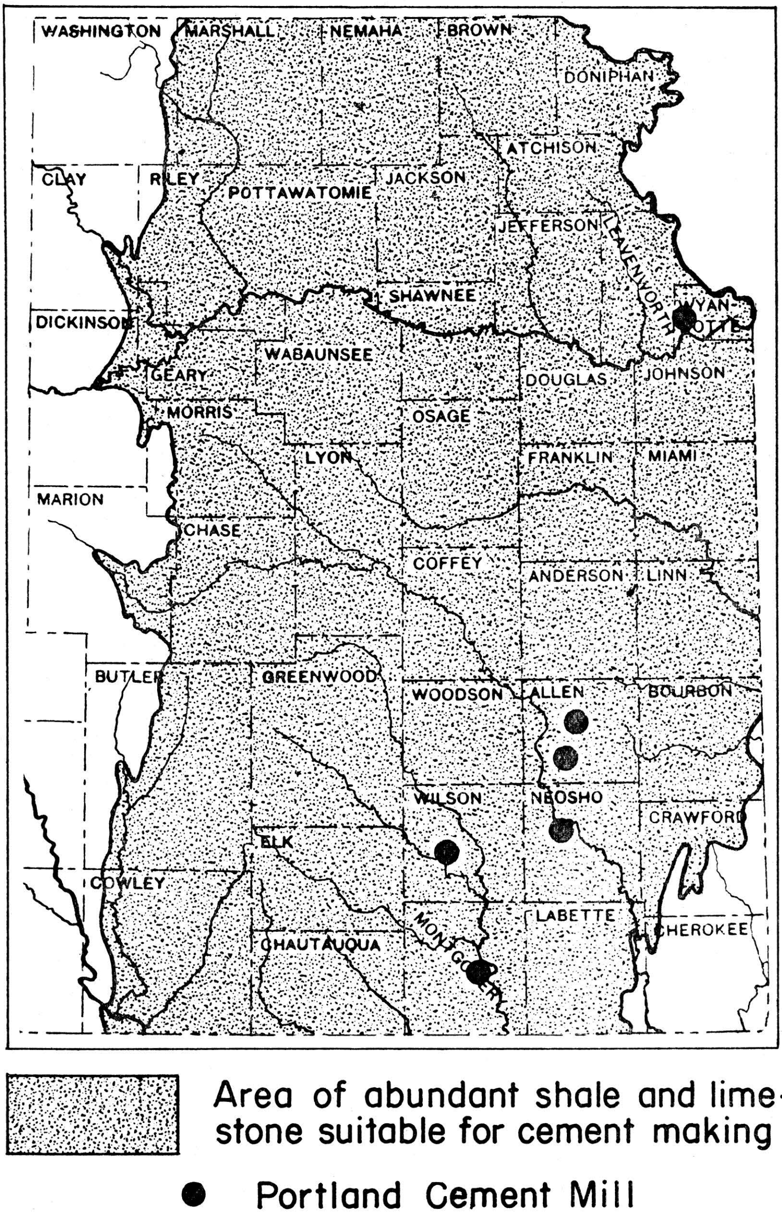

FIGURE 8. Map of eastern Kansas showing location of Portland cement mills and of region of abundant raw materials for cement manufacture.

yearly output ranged from a low of 2,586,834 barrels (1918) to a high of 6,574,219 barrels (1928); and the average yearly production for the years 1927 to 1936, inclusive, was 4,254,417 barrels. The production in 1940 was 4,509,742 barrels, having a total value of $5,192,160. The greater part of the cement produced in Kansas has its market outside the state.

Table 17, below, shows annual production figures of Portland cement in Kansas for the ten year period prior to 1941.

TABLE 17. *Portland cement production in Kansas*

YEAR	BARRELS	YEAR	BARRELS
1931	4,478,823	1936	3,568,090
1932	2,224,079	1937	3,500,684
1933	2,189,137	1938	3,217,407
1934	2,425,867	1939	3,746,370
1935	2,487,888	1940	4,509,742

REFERENCES

BOWLES, OLIVER, *1918,* Rock quarrying for cement manufacture: U.S. Bur. Mines, Bull. 160, pp. 1-160.

GIESE, HENRY, *1939,* A practical course in concrete: Pamphlet published by Portland Cement Association, pp. 1-62, illustrated.

MILLER, B. L., *1937,* Cement materials: Industrial Rocks and Minerals, Am. Inst. Min. and Metall. Eng., New York, pp. 163-190, figs. 1-2, tables 1-7.

ROCK WOOL MATERIALS

Summary.—Rock wool has been manufactured in Kansas for so few years that no significant data are available on production in the state. The reserve of raw materials is greatly in excess of any future needs.

Rock wool is a fluffy, usually white material composed of minute fibers of glass. It is manufactured by melting rock in a copola or reverboratory furnace and pouring the molten glass into a blast of steam or air. The glass is drawn out into thin fibers by the current of steam or air. Rock wool is made either from a mixture of approximately 50 per cent limestone and 50 per cent shale, clay, or sand or from naturally occurring rocks, such as calcareous shales, siliceous marls, or siliceous limestones, which have the required chemical composition. The dominant chemical constituents of most rock wools are calcium carbonate and silica, these being present in approximately equal proportions.

Rock wool industry in Kansas.—The State Geological Survey of Kansas tested rock samples for their suitability in the manufacture of rock wool in the years 1936 and 1937. These tests demonstrated that rock wool of excellent quality could be made from Kansas rocks. Since that time three plants have been built in the state. The two larger plants at Winfield and at Parsons are still operating. The third operated in conjunction with the brick plant at Neodesha and is now shut down because the manufacture of bricks has been discontinued.

Uses.—The chief use of rock wool is in the insulation of dwellings and other buildings, but it has many other applications. It is effective in preventing freezing in house pipes and underground pipes. Its use prevents loss of heat from pipes carrying steam, molten sulphur, hot oil, and so forth. Rock wool is valuable in the insulation of ovens, furnaces and stoves, including steam boilers, fractionating colums, and towers; in the insulation of annealing, baking and smelting ovens, retorts, and metallurgical and chemical furnaces. It is used also in various refrigeration devices, and for sound control. Rock wool is used as a packing for acid carboys, as a filter medium for corrosive fluids, as an air filter in hot air heating, as a component of insulating cement, as a fire preventive, and as lining between planking and metal sheathing of ships.

The many uses of rock wool are determined by the fact that it is relatively inexpensive and by the fact that it is essentially a refractory glass, which means that it can withstand relatively high temperature, that it does not transmit heat readily, and that it is non-deteriorating, fireproof, and vermin proof.

Kansas reserves.—The Kansas rocks tested for suitability in manufacture of rock wool are of widespread geographic distribution (fig. 11) and range in age and stratigraphic position from the Cherokee shale of lower Pennsylvanian age to Pleistocene "mortar beds". The quantity of material available at any one of the locations sampled is far in excess of future needs. The majority of the fifty samples tested were mixtures of calcarious and siliceous rocks, but several were natural wool rocks. The latter class includes the Lenapah limestone of southern Kansas, the Florence limestone and the Grant shale of central Kansas, and the "mortar beds" of western Kansas.

References

LAMAR, J. E., WILLMAN, H. D., FRYLING, C. F., and VOSKUIL, W. H., *1934*, Rock wool from Illinois mineral resources: Illinois Geol. Survey, Bull. 61, pp. 1-262, figs. 1-34, tables 1-39.

PLUMMER, NORMAN, *1937*, Rock wool resources of Kansas: Kansas Geol. Survey, Mineral Resources Circ. 5, pp. 1-74, figs. 1-28.

———, *1937*, Rock wool resources of Kansas: Kansas Geol. Survey, Mineral Resources Circ. 8, pp. 1-28, figs. 1-13.

Salt

Summary.—The present production of salt in Kansas is about 700,000 tons annually. The reserves are estimated at 5,000 billion tons.

Common salt, or halite, is composed of sodium chloride (NaCl). In the pure state it contains, by weight, 33.34 per cent sodium and 66.66 per cent chlorine. The greatest reserves are in ocean waters, but vast amounts are stored as layers of rock, and large quantities are present as a part of natural brines in deeply buried porous rocks.

Human existence is dependent on salt. It is an essential part of man's diet and must be fed to his domestic animals. Salt always has been a strategic mineral; large quantities are used in industries that are essential to modern civilization.

Salt in Kansas.—The salt industry in Kansas had its beginning in about 1892. The industry grew rapidly, and Kansas is now the most important salt-producing state west of the Mississippi river. Production has centered around Lyons and Little River in Rice county, Hutchinson in Reno county, Kanopolis in Ellsworth county, and Anthony in Harper county. As early as 1898 the state produced yearly 250,000 tons of salt and recently the average yearly production has ranged around 800,000 tons. Plants and mines are now operating at Hutchinson, Lyons and Kanopolis.

As shown in figure 9, salt underlies a large area in central and southwestern Kansas. An area extending along the Kansas-Oklahoma line from Sumner county westward to Seward county and northward to Rooks, Osborne and Mitchell counties is underlain by a thick vertical section of salt beds in the Wellington shale formation. In central Reno county salt beds form the dominent portion of a rock section 500 feet thick; the salt-bearing section is about 200 feet thick in central Osborne county. The deposits are thicker in the central part of the salt area. A well in Pratt county

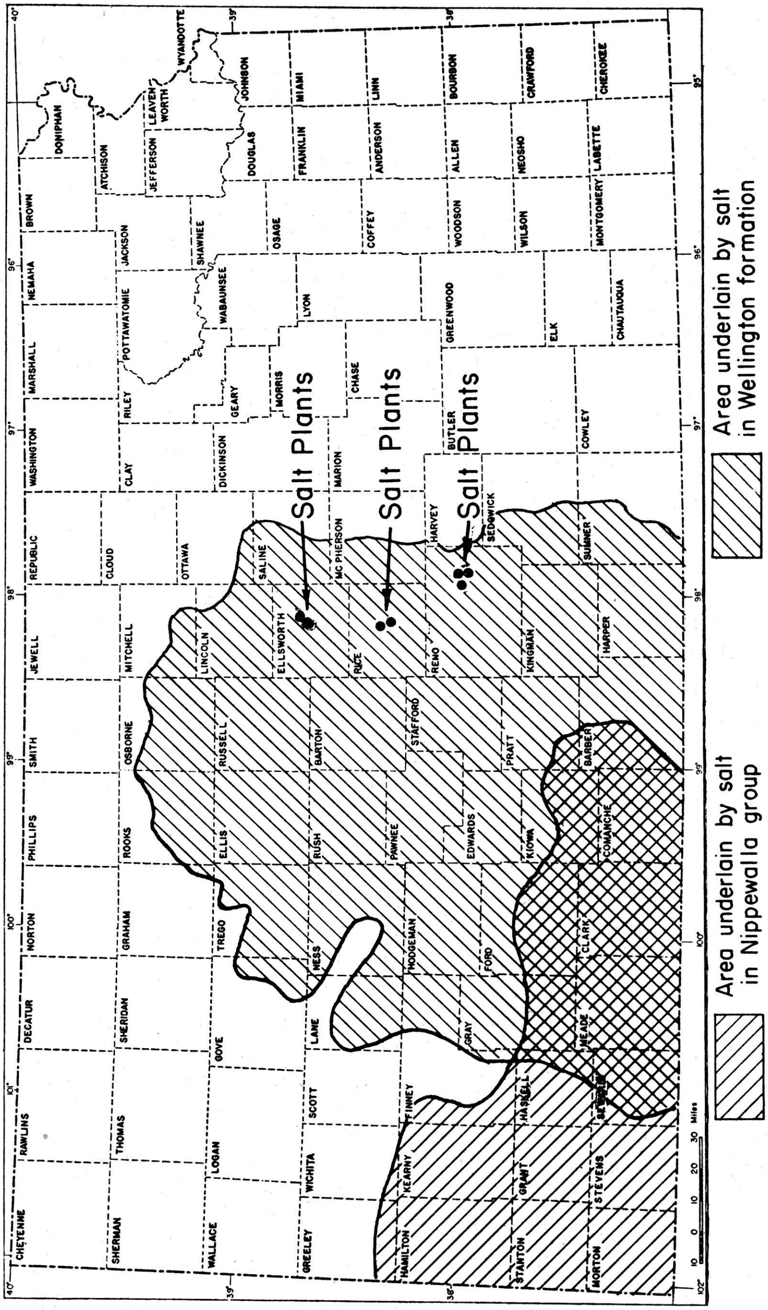

FIGURE 9. Map of Kansas showing location of salt plants and of areas underlain by Permian salt deposits.

has been drilled through as much as 800 feet of rock, which is chiefly salt. This deposit extends for some distance into Oklahoma.

The layers of rock, including the rock salt, dip gently westward. Because of this westward dip and because of the westward increase of land surface elevation, the salt is nearest the surface along the eastern margin of the salt area. Because of its solubility the salt does not crop out at the surface. That part of the salt beds mined by shaft methods is about 600 feet below the surface at Hutchinson, about 900 feet below the surface at Lyons, and about 860 feet at Kanopolis. At Anthony the same portion of the salt section is about 1200 feet below the surface. Logs of oil wells in northwestern Hodgeman county indicate that salt beds are encountered about 1800 feet below the surface.

The southwestern Kansas salt deposits are part of a large assemblage of salt beds extending far to the south and west in Colorado, Oklahoma, New Mexico, and Texas. The southwestern Kansas area (fig. 9) is underlain by one or two thick deposits of rock salt that occur in red beds of the Nippewalla group of Permian rocks. The area underlain by Nippewalla salt is partly coextensive with the area of Wellington salt (fig. 9).

Production in Kansas.—Kansas normally produces about 800,000 tons of salt each year. The average value of a year's output is approximately $3,000,000. Table 18, shown below, lists production figures for the twenty year period prior to 1941.

TABLE 18. *Salt production in Kansas.*

YEAR	TONS	YEAR	TONS
1921	665,968	1931	691,160
1922	749,459	1932	688,178
1923	845,163	1933	732,947
1924	794,303	1934	768,133
1925	812,540	1935	608,204
1926	729,880	1936	704,164
1927	794,780	1937	654,089
1928	821,950	1938	597,909
1929	840,370	1939	641,752
1930	759,800	1940	684,053

Two methods of extracting salt are employed. One is direct mining, in which shafts are driven to the deposits and the salt is mined by room and pillar method. Modern electrically driven machinery is used. The other method is hydraulic mining in which wells are drilled to the salt deposits and water is pumped down to dissolve the salt. The water, saturated with salt, is returned to the surface and is evaporated by heating. Brine wells are in operation at Hutchinson and at Lyons. Shaft mines are in operation at Hutchinson, Lyons and Kanopolis.

Uses of salt.—The uses of salt are numerous. In a large industrial country such as the United States, chemical industries consume more than half of the salt used. A large number of sodium-bearing chemicals are made from it. Of these, the soda alkalies are quantitatively the most important, but many other sodium salts are made from common salt. Metallic sodium, hydrochloric acid, and chlorine are other derivitives.

Salt is of great importance in meat packing, and much Kansas salt is used for this purpose. Kansas City, Kansas, ranks second in the United States as a meat-packing city, and packing plants are in operation in other Kansas towns, including Wichita, Topeka and Salina. Food manufacturing and processing consume great quantities of salt. Its use in the home is on a smaller scale but is for the same general purposes as in the packing and food industries, that it, to give flavor to food and to aid in its preservation.

Salt is used as a fertilizer, as a refrigerant, as an ingredient of stock feeds, and for the purpose of killing weeds. It is used also in making and packing ice cream, as a refrigerating agent in refrigerator cars and trucks, and for the purpose of melting ice on railroads and highways. Salt is used in the manufacture of many articles, including glass and clay products, dyes, pulp and paper, rayon, soap, and textiles. It is used in the iron and steel industry, in tanning, in tobacco manufacture, and in the making of rubber.

Kansas reserves.—It is estimated that 5,000 billion tons of salt lie beneath the surface of Kansas. At the present rate of consumption this amount would supply the entire United States for a period of a half million years.

Age and origin of Kansas salt deposits.—Salt occurs in Permian rocks in Kansas. Salt beds constitute the major portion of an 800-foot rock section included in the Wellington shale, a rock unit of the Leonard series of the Permian system. This deposit is of great economic importance. Other salt beds in Kansas, approximately

700 feet higher in the stratigraphic column, occur in the Nippewalla group of the Leonard series. It is not easy to account for the accumulation of such vast deposits of salt, and detailed descriptions of the theories would be out of place here. It is sufficient to say that the salt accumulated through evaporation of sea water in subsiding shallow bays, lagoons, or inland seas or lakes. Arid climatic conditions must have prevailed. The areas of accumulation continued to subside for some time, and the salt was burried beneath layers of mud and sand. The salt, other chemical precipitates, mud, and sand are now the materials of rock beds. Subsequent uplift has brought the rocks into their present position.

References

Landes, K. K., *1937,* Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110, maps.

———, *1938,* The Kansas mineral industry: Kansas Yearbook, Kansas State Chamber of Commerce, Topeka, pp. 235-237.

Phalen, W. C., *1917,* Technology of salt making in the United States: U.S. Bureau of Mines, Bull. 146, pp. 1-149.

———, *1919,* Salt resources of the United States: U. S. Geol. Survey, Bull. 669, pp. 1-284.

———, *1937,* Salt: Industrial minerals and rocks, Am. Inst. Min. and Metall. Eng., New York, pp. 643-670.

Sand and Gravel

Summary.—Kansas possesses unlimited supplies of sand and gravel. Annual production in 1940 was 2,264,871 short tons valued at $893,962.

Sand and gravel are unconsolidated materials resulting from the disintegration, decomposition or weathering of rocks, and the transportation and sorting of the rock fragments by running water. The terms *sand* and *gravel* denote size and shape of particles rather than mineral or chemical composition. At the present time there is no strict conformity in the usage of the terms sand and gravel. According to Thoenen (1937, p. 671), sand generally is considered to be unconsolidated material, the grains of which are coarser than 0.0029 inches and finer than 0.25 inches in diameter; this material is retained on a 200-mesh screen (0.074 sieve openings). Gravel represents similar unconsolidated particulate material, the grains of which are coarser than one-fourth of an inch and finer than 3½ inches in diameter. Another classification scheme employed by certain workers designates sand and gravel according to the Wentworth classification, as given below in Table 19.

TABLE 19. *Wentworth classification of sand and gravel*

SIZE CLASS	LIMITING DIMENSIONS, IN MM.
Gravel	
Boulder	Greater than 256
Cobble	64—256
Pebble	4— 64
Granule	2— 4
Sand	
Very coarse	1— 2
Coarse	½— 1
Medium	¼— ½
Fine	⅛— ¼
Very fine	1/16— ⅛

Sand and gravel may be well sorted or homogeneous as to grain size or composition, or both. The flint gravels of southeastern Kansas are an example of a deposit well sorted or homogeneous as to composition. On the other hand, sand and gravel may be heterogeneous as to size or composition; an example of this condition of poor sorting is provided by glacial sands and gravels of northeastern Kansas.

Sands.—Dune sand commonly has a larger percentage of quartz than has ordinary river sand and, furthermore, tends to be of more uniform grain size.

Kansas stream sands generally consist of a mixture of quartz, feldspar, mica, hornblende, magnetite, and other mineral grains; quartz commonly predominates. Texturally, stream sands vary from very fine to very coarse, changing both vertically and horizontally in short distances. The grains are angular to well rounded. Cross-bedding and pocket-and-lens types of structure are common. More or less discontinuous gravel layers are associated with the sands. Stream sands are commonly buff, yellowish gray, or brown in color. Thickness of the sand deposits vary considerably.

North and west of Atchison, in Atchison county, and in the vicinity of Frankfort, Marshall county, very light buff to white lake sand deposits occur. These sands in general are much finer than are river sands, are horizontally bedded, and consist dominantly of quartz grains. They are believed to represent lake deposits; at places they have a thickness of more than 50 feet. Lake sands also are known to be present in the vicinity of St. George, in Pottawatomie county, and southeast of Holton in Jackson county.

Gravels.—Gravel deposits vary greatly in composition, grain size, shape, roundness, thickness, color, and structure. Glacial stream and lake gravels occur in northeastern Kansas and stream gravels are present in the High Plains of the western part of the state. In southeastern Kansas there are gravels which consist essentially of only one kind of material; namely, flint or chert. At certain places in Kansas gravels are made up entirely of local limestones. The flint or chert gravels of southeastern Kansas are composed of flint or chert weathered from Carboniferous and Permian rocks, and distributed by streams probably during Tertiary or Quaternary times. These gravels generally cap the uplands. The flint or chert fragments are rounded to angular and commonly are of light-buff color, although shades of yellow, red and dark gray are not uncommon. Limestone gravels are known to be present in Brown, Douglas, Jewell, Lincoln and Smith counties; they are composed of fragments of local limestone beds and vary in color and texture depending upon the source rocks.

Distribution of sands and gravels in Kansas.—Kansas has unlimited reserves of sand and gravel, and deposits occur in almost all counties. In some areas the deposits may not be of great commercial value, but may be important for local purposes. The accompanying map (fig. 10) shows the general distribution of the more important sand and gravel deposits of the state. Sand and gravel, especially sand, may be found almost anywhere along the major stream courses in the state, such as those of the Arkansas, Big Blue, Cimarron, Kansas, Little Blue, Marais de Cygnes, Missouri, Ninnescah, Neosho, Republican, Saline, Smoky Hill, Solomon, and Verdigris.

The Tertiary sands and gravels are confined chiefly to the western part of the state in the region known as the High Plains. Quaternary sands and gravels are found chiefly in the same region as the Tertiary deposits. Glacial deposits are confined for the most part to northeastern Kansas.

Production of Kansas sand and gravel.—During 1940, Kansas produced 2,264,871 short tons of sand and gravel, valued at $893,962. Of this amount, 1,791,103 tons are classified as commercial and

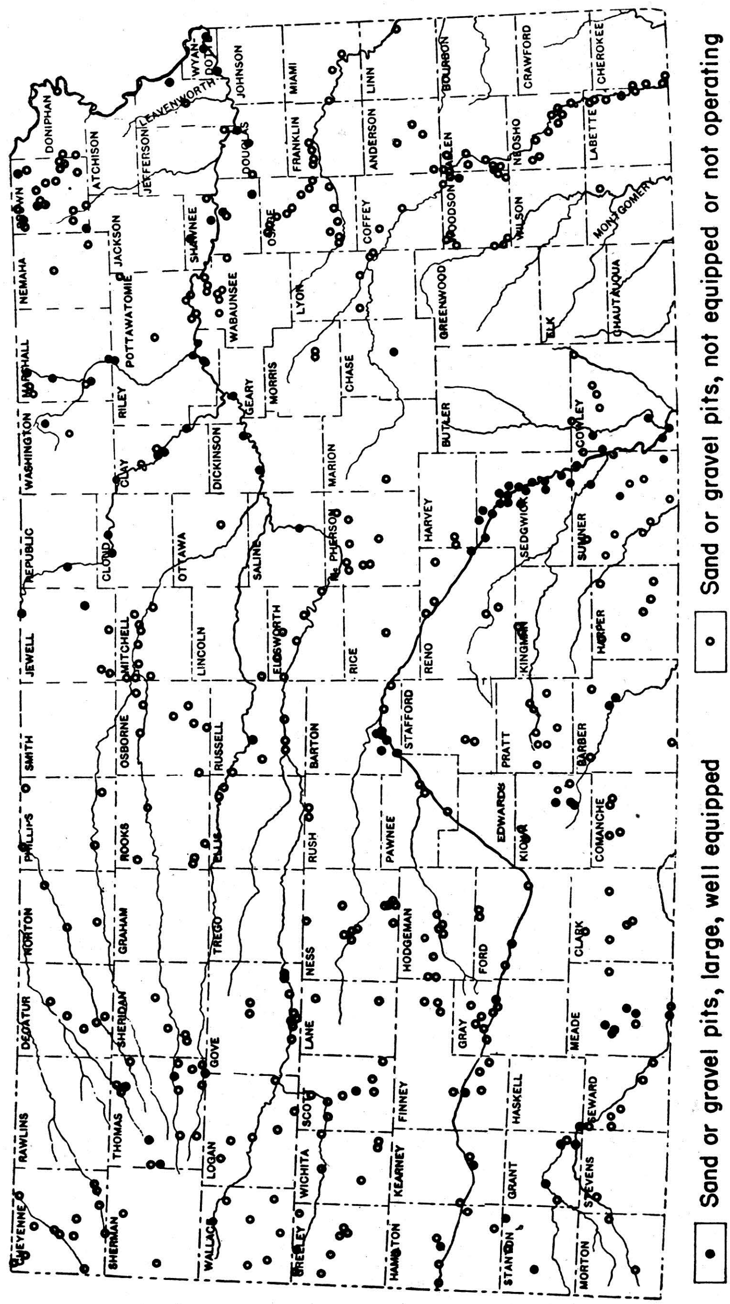

FIGURE 10. Map of Kansas showing distribution of sand and gravel pits.

the remaining 473,768 tons as government and contractor types. Wyandotte county leads in the annual production of sand in the state. The relative importance of the sand and gravel industry in Kansas is indicated in table 20, which gives statistics of the tonnage and value of the Kansas production from 1905 to 1940.

TABLE 20.—*Production of Kansas sand and gravel, 1905 to 1940*

Year	Production in short tons	Value in dollars	Year	Production in short tons	Value in dollars
1905	70,988	21,552	1923	1,950,411	1,039,064
1906	293,918	66,762	1924	1,882,968	1,223,016
1907	556,625	117,313	1925	2,198,870	1,303,060
1908	320,150	64,328	1926	2,489,343	1,491,492
1909	977,918	188,708	1927	2,254,648	1,456,130
1910	776,638	165,659	1928	2,760,277	1,532,399
1911	734,507	164,058	1929	3,389,783	1,879,899
1912	1,381,586	287,352	1930	3,232,858	1,649,476
1913	1,119,990	271,509	1931	2,893,249	1,333,175
1914	1,347,394	381,065	1932	1,851,211	878,733
1915	1,128,496	378,355	1933	2,015,799	734,343
1916	1,164,995	303,630	1934	1,681,619	698,461
1917	823,403	195,578	1935	1,570,975	666,529
1918	761,110	264,073	1936	2,454,017	920,730
1919	954,121	507,642	1937	2,495,196	1,017,053
1920	1,275,309	905,936	1938	2,962,831	1,117,053
1921	1,082,914	647,723	1939	1,934,759	822,305
1922	1,398,996	790,763	1940	2,264,871	893,962

Uses.—Sand and gravel are used chiefly in Kansas as structural and paving material. The material is used also as traction sand, filter sand, railroad ballast, grinding and polishing sand and molding sand. Studies made by the State Geological Survey during the past two years show that some Kansas sands are suitable for use as foundry sands. There are 41 plants in Kansas and 21 in Kansas City, Missouri, which use foundry sands. Many of these foundries are making castings, especially aluminum castings, for wartime industries. The greatest part of the molding sand used at these foundries is taken from glacial or Pleistocene hight-terrace deposits along the north side of the Kansas river in and near Kansas City, Kansas. A part, however, is taken from deposits formed by glacial outwash streams, and from deposits in the flood plain of the Kansas river.

Age and origin.—Sand and gravel deposits of the western part of the state, in the High Plains area, are either Tertiary or Quaternary in age and were deposited either by streams coming from the west or by wind action, the latter being in the form of sand dunes in the valleys of Arkansas and other rivers. The deposits in northeastern Kansas, on the other hand, are mostly of glacio-fluvial origin; that is, they were deposited by streams deriving sediment from a melting continental glacier or glaciers during the Great Ice Age some 750,000 years ago. Some of the sands, such as those near Atchison and Frankfort, were deposited in glacial lakes during the Great Ice Age. Much of the sand and gravel dredged up in our major stream courses represents older material reworked by the streams in modern times.

Work of the State Geological Survey.—Sand and gravel resources of Kansas have been studied by members of the State Geological Survey during the past two years. A report on these investigations is now being prepared and will be published in the near future as a bulletin of the Survey. Sand and gravel deposits in Kansas have been described in various publications of the State Geological Survey and in other publications; these are listed below.

References

BASS, N. W., *1926,* Geologic investigations in western Kansas: Kansas Geol. Survey, Bull. 11, pp. 1-96, pls. 1-9, figs. 1-27.

———, *1929,* The geology of Cowley county, Kansas: Kansas Geol. Survey, Bull. 12, pp. 1-203, figs. 1-23, pls. 1-12 (including map).

CHARLES, HOMER, *1927,* Oil and gas resources of Kansas, Anderson county: Kansas Geol. Survey, Bull. 6, pt. 7, pp. 1-95, pls. 1-10 (including map), figs. 1-13.

ELIAS, M. K., *1931,* The geology of Wallace county, Kansas: Kansas Geol. Survey, Bull. 18, pp. 1-254, pls. 1-42 (including map), figs. 1-7, tables 1-2.

FRYE, J. C. and HIBBARD, C. W., *1941,* Pliocene and Pleistocene stratigraphy and paleontology of the Meade basin, Kansas: Kansas Geol. Survey, Bull. 38, pt. 13, pp. 389-424, figs. 1-3, pls. 1-4.

HAWORTH, ERASMUS, *1896,* Surface gravels: Kansas Univ. Geol. Survey, vol. 1, pp. 246-255.

———, *1897,* Physical properties of the Tertiary: Kansas Univ. Geol. Survey, vol. 2, pp. 247-284, pls. 38-44.

———, *1897,* The McPherson Equus beds: Kansas Univ. Geol. Survey, vol. 2, pp. 287-296.

LANDES, KENNETH K., and OCKERMAN, J. W., *1930,* The geology of Mitchell and Osborne counties, Kansas: Kansas Geol. Survey, Bull. 16, pp. 1-55, pls. 1-15 (including map), fig. 1.

LANDES, KENNETH K., *1937,* Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110, maps.

LATTA, BRUCE F., *1941,* Geology and ground-water resources of Stanton county, Kansas Geol. Survey, Bull. 37, pp. 1-119, figs. 1-6, tables 1-5, pls. 1-9 (including maps).

LOHMAN, S. W., *and* FRYE, J. C., *1940,* Geology and ground-water resources of the "Equus beds" area in south-central Kansas: Economic Geology, vol. 35, pp. 839-866, figs. 1-5, tables 1-2.

MOORE, R. C., and LANDES, KENNETH K., *1927,* Underground resources of Kansas: Kansas Geol. Survey, Bull. 13, pp. 1-154, figs. 1-115 (including map), tables 1-2.

NEWELL, N. D., and JEWETT, J. M., *1935,* The geology of Johnson, Miami, and Wyandotte counties, Kansas: Kansas Geol. Survey, Bull. 21, pp. 1-205, pls. 1-23 (including map).

RUBEY, W. W., and BASS, N. W., *1925,* The geology of Russell county, Kansas: Kansas Geol. Survey, Bull. 10, pp. 1-104, pls. 1-7 (including map), figs. 1-11.

SCHOEWE, W. H., *1923,* Glacial geology of Kansas: Pan-Am. Geologist, vol. 40, pp. 102-110, pl. 11.

SEATON, R. A., and TAYLOR, I. I., *1916,* Tests of Kansas sands for use in mortar and concrete: Kansas State Agricultural College, Bull. 3, Eng. Experiment Station, vol. 42, no. 45, pp. 1-44, figs. 1-8, tables 1-5.

SMITH, H. T. U., *1938,* Preliminary notes on Pleistocene gravels in southwestern Kansas: Kansas Acad. Sci., Trans., vol. 40, pp. 283-291, fig. 1, table 1.

———, *1940,* Geologic studies in southwestern Kansas: Kansas Geol. Survey, Bull. 34, pp. 1-212, pls. 1-34, figs. 1-22.

THOENEN, J. R., *1937,* Sand and gravel: Industrial Minerals and Rocks (dept. 38), pp. 671-720.

TODD, J. E., *1918,* Kansas during the Ice Age: Kansas Acad. Sci., Trans., vol. 28, pp. 33-47, map.

TODD, J. E., *1918,* History of Kaw lake: Kansas Acad. Sci., Trans., vol. 28, pp. 187-199, maps.

WOOSTER, LYMAN C., *1934,* The chert gravels of Lyon county, Kansas: Kansas Acad. Sci., Trans., vol. 37, pp. 157-159.

STONE

Summary.—Several million tons of Kansas stone are used annually. The reserves of stone, including limestone, sandstone and hard shale, are extremely large.

This section of the report describes the economic aspects of firmly consolidated rocks that are used for purposes other than those discussed in other sections of this report. Limestone and sandstone have many uses; hard shale is useful as road metal. Locations of important quarries as shown in the Mineral Resources Map of Kansas (part 4, Bulletin 41); quarries from which various

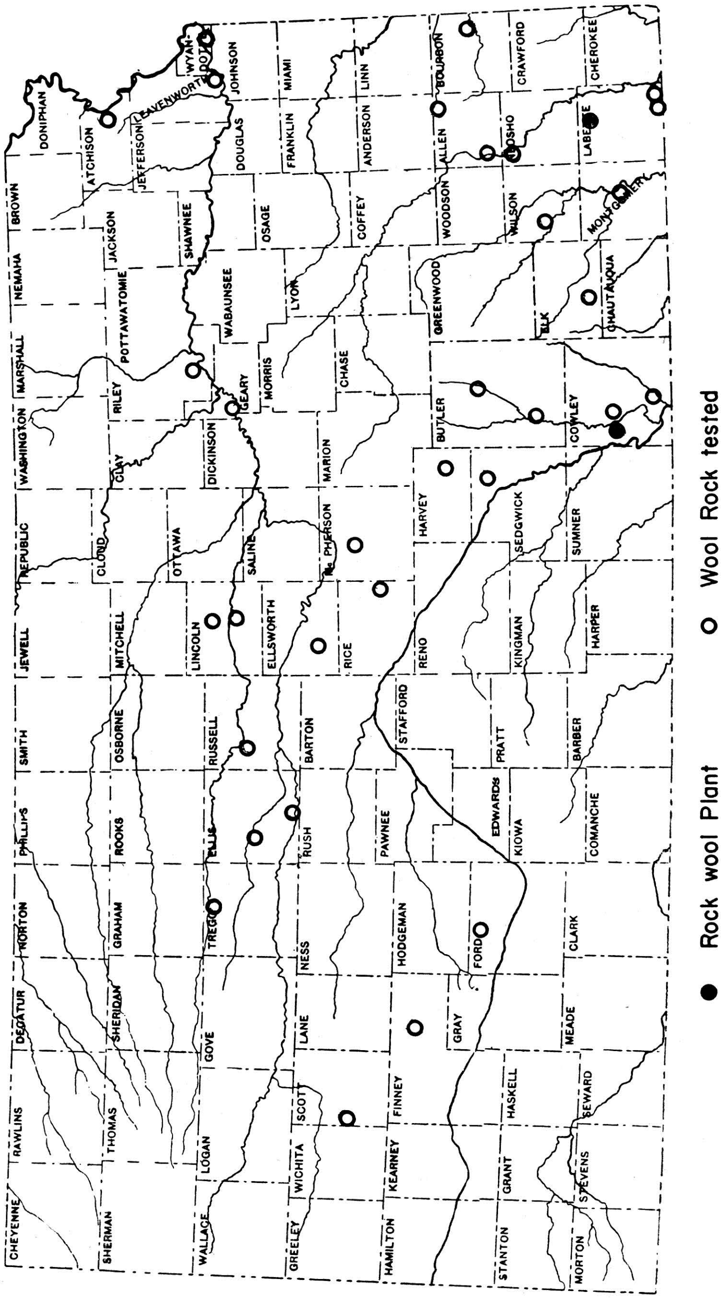

FIGURE 11. Map of Kansas showing location of rock wool plants and location of outcrops from which rock has been tested to determine suitability for use as rock wool material.

types of stone are taken are distributed throughout a majority of the counties in Kansas.

LIMESTONE

Limestone is a sedimentary rock composed primarily of calcium carbonate ($CaCO_3$), occurring in strata or beds. The normal color is white to light gray or buff. Limestones may pass by gradation into shales and sandstones, and it is customary to use adjectives in describing the intermediate varieties. Thus, one may speak of sandy or arenaceous limestone, calcareous sandstone. argillaceous limestone, calcareous shale, and so forth. In addition, there occur ferruginous, carbonaceous, magnesian, and phosphatic limestones, which are, respectively, those with a high percentage of iron, carbonaceous matter, magnesia, and phosphate. There are relatively few pure limestones, but a surprisingly large number consist of 90 per cent or more of calcium carbonate.

Limestones in Kansas.—The supply of limestone in Kansas is practically unlimited; areas having abundant reserves are shown in figure 12. All counties in the eastern third of tthe state and several of the north-central counties have large reserves. Limestone for various purposes has been quarried at one or more places in nearly every township in eastern Kansas.

Kansas limestones range in composition from nearly pure calcium carbonate to those composed of mixtures of calcium carbonate, silica, clay minerals, various iron compounds, and other impurities. Limestones composed of nearly pure calcium carbonate are rather abundant in the state. The rocks occur in beds ranging up to 50 feet thick. As a rule the purer material is found in the thicker beds, those which are 20 feet or more in thickness.

Table 21, below, presents analyses of samples taken from three

TABLE 21. *Analyses of calcined samples of eastern Kansas limestones*

Constituents	Drum limestone Montgomery county (per cent)	Iola limestone Allen county (per cent)	Iola limestone Neosho county (per cent)
SiO_2	11.50	4.76	1.76
Al_2O_3	3.02	0.46	2.08
Fe_2O_3	2.14	2.14	2.75
CaO	82.59	87.50	88.80
MgO	0.84	3.40	4.60

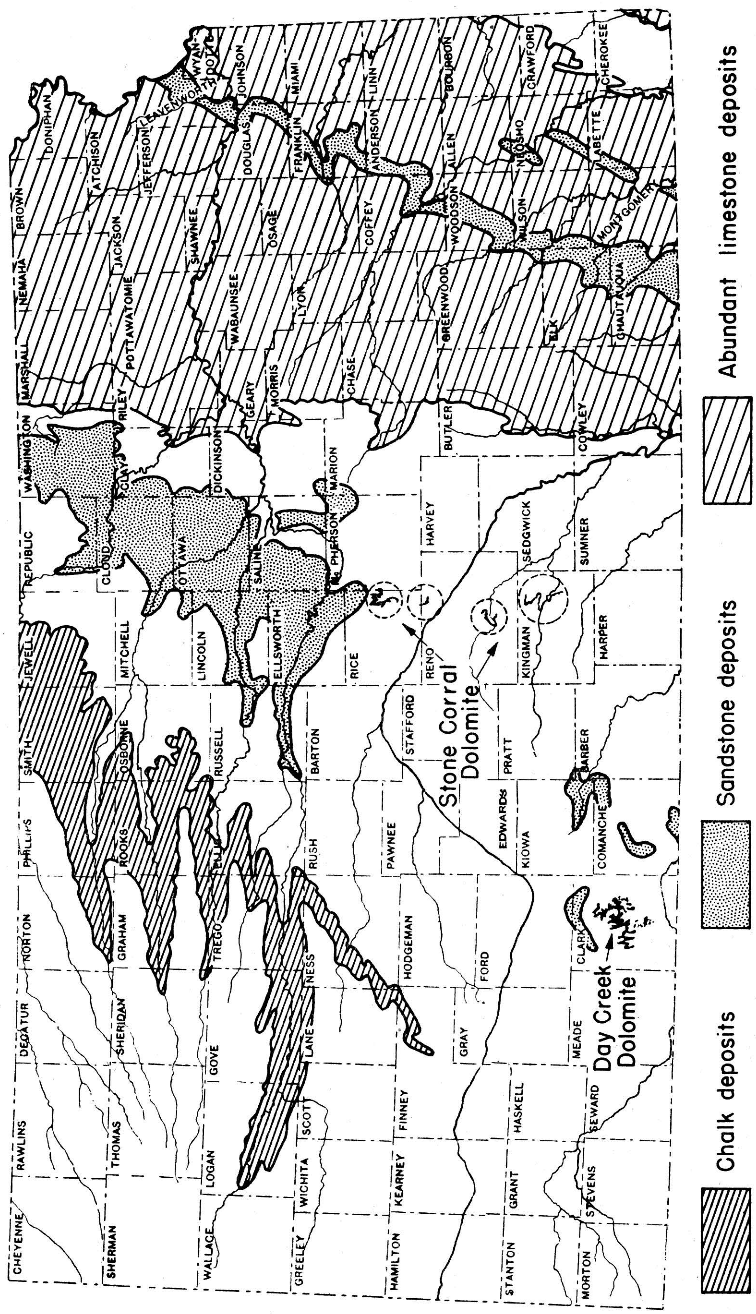

FIGURE 12. Map of Kansas showing location of areas of abundant limestone, sandstone, and chalk deposits.

quarries in eastern Kansas. The rocks from which the samples were taken are believed to be somewhat representative of many of the thicker limestone beds of eastern Kansas.

Limestones interbedded with shales and sandstones crop out in the eastern third of Kansas, forming narrow, tortuous bands of outcrop trending in a general north-south direction. The thicker limestones generally cap eastward facing escarpments, west of which they lie with little cover below "dip slopes" inclined gently to the west. The limestones are readily accessible for quarrying operations.

Limestone beds generally are less abundant in central and northern Kansas than in the eastern part of the state. Much of the limestone of central Kansas is in the form of chalk, a soft rock composed of the calcareous remains of minute organisms. Because of its physical properties and high degree of purity, chalk has uses that ordinary limestones do not have; it therefore is described in a separate section of this report.

Limestone production in Kansas.—Available quantitative figures on the production of limestone in Kansas are of little value because large quantities are quarried and used without being reported for incorporation in available records. Commercial quarries produce limestone in many places. Near each population center quarries have been established to supply local demands. The demand is variable, depending upon the extent of local concrete paving operations, building programs, and so forth. Railroad companies have quarried immense quantities that have been used largely as track ballast. The cement-manufacturing companies operate their own quarries. In the past few years a large amount of limestone has been quarried by W.P.A. workers, and the stone has been used in public works projects. It follows from the foregoing statements that a considerable portion of the product of lime-

TABLE 22. *Reported stone production in Kansas (chiefly limestone)*

YEARS	TONS
Yearly average for 10-year period (1927-36)	1,571,699
1937	3,540,860
1938	3,676,230
1939	3,405,640
1940	2,880,930

stone quarries does not enter the regular channels of trade; a large tonnage, nevertheless, is sold each year by quarry operators. Table 22 shows production figures as reported for the period from 1937 to 1940.

Uses of limestone.—Kansas limestone is used in large quantities as road metal, railroad ballast, rip-rap, concrete aggregate, in cement making, and to a considerable extent as building stone. In addition to these, limestone has many other uses. It is used as a flux in blast furnaces and in metallurgical work; it is used as agricultural limestone and in making lime; its products are used for refining sugar, manufacturing refractories, paper, and glass; with coke it is used in making calcium carbide from which aceteline gas is generated. Limestone is used as filter bed material and in making fillers and whiting.

When Kansas was being settled, limestone was used as building stone to a large extent. Some of the early settlers came directly from northern Europe, where wooden buildings are uncommon. They and others recognized the value of Kansas limestones and constructed many stone farm buildings. In certain areas, for example in the Flint Hills region, there are many farm buildings, rural schools and churches, constructed of limestone; some of these were built as early as the 1860's and still are in excellent condition. Some stone buldings built in territorial days still are in use.

From time to time a considerable amount of Kansas limestone has been used in public buildings. The athletic stadium of the Kansas State College at Manhattan, some of the University of Kansas buildings at Lawrence, and most of the permanent buildings at Fort Riley and at Fort Leavenworth have been constructed of limestone. In nearly every town in eastern Kansas there are churches and other buildings that have been built of limestone taken from local quarries. Farther west in the state limestone has been less extensively used.

In recent years limestone has been used extensively in public buildings constructed chiefly by W.P.A. workers. These buildings, of pleasing appearance, indicate that Kansas limestones may be used in masonry construction and that dimension blocks can be prepared without the use of highly skilled labor.

Space does not permit description here of individual limestone formations, but it should be noted that much of the best building stone occurs in thin regular beds and requires but little dressing.

Oolitic limestones represent a type of Kansas limestone that may be fashioned into beautiful building blocks. Such rock, quarried in eastern Kansas, was used recently in building the new Sweeney Gymnasium at the University of Kansas City, Missouri.

It is well to mention here that, although at the present time there are no lime kilns operating in Kansas, there is a great abundance of limestone suitable for use in lime manufacture. In the past, lime has been made at many places in eastern Kansas.

Kansas limestone reserves.—As indicated above, Kansas has unlimited reserves of various kinds of limestones adapted to numerous uses. The greatest reserves are in the eastern part of the state, but much limestone also is available in the central and northern parts.

Origin and age of Kansas limestones.—Most of the limestones of the world have been formed by the consolidation of calcareous mud that was deposited on the floors of shallow seas; this mud was derived largely from the accumulation of calcareous tests or shells of marine animals and hard parts of certain plants. Some limestone beds were formed largely by direct chemical precipitation of calcium carbonate from sea water, and perhaps nearly all limestone beds contain some precipitated material.

The limestones in eastern Kansas are Carboniferous and Permian in age. Those of central and northern Kansas are Cretaceous in age.

Work of the State Geological Survey.—Various members of the State Geological Survey of Kansas have carefully mapped and studied the limestone and other formations of the state. An abundance of data pertaining to thickness, lithologic character, and geographic distribution are at hand. The geologic map of Kansas, published by the Survey in 1937, shows the areal distribution of various formations. Bulletin 22 (Moore, 1936) presents general descriptions of limestone beds and other rock units of Pennsylvanian (Late Carboniferous age in Kansas. Numerous bulletins describing the rocks of individual counties have been published. Mineral Resources Circular 6 (Landes, 1937) describes briefly the limestone and other resources of every county in Kansas. The use of limestone and other rock in rock wool manufacture has been investigated and has been discussed in Mineral Resources Circular 5 (Plummer, 1937).

Limestone is one of Kansas' great mineral resources, on which additional research is needed. Studies of polished and thin sections of Kansas limestones have been initiated. These investigations are expected to yield valuable information pertaining to the use of limestone as building stone and for other purposes as well as information of important scientific value. Chemical analyses of Kansas limestones are being made in the Survey laboratories. Data obtained by these study methods will be of great value in determining potential economic uses of various limestones of the state.

SANDSTONE

Sandstone is a sedimentary rock occurring in strata or beds that is composed of sand grains cemented together so as to form a more or less solid mass. Most sandstones are composed largely of quartz grains held together by some natural cement, such as calcium carbonate, iron oxide, or clay. Sandstones may grade vertically or laterally into shales and limestones; intermediate rock types include sand limestones or calcareous sandstones, argillaceous sandstones or sandy shales.

Sandstone in Kansas.—The reserves of sandstone in Kansas are inexhaustibly great, but even so the rock is not as abundant as limestone. Sandstone occurs interbedded with shale and limestone in the eastern part of the state, and sandstone is present in the Smoky Hill region in north-central Kansas in a wide belt extending from Rice and McPherson counties to Washington county. Figure 12 shows the locations of principal sandstone outcrop areas in Kansas.

Sandstone production in Kansas.—The production (in tons) of sandstone marketed in Kansas are included in the figures given in table 22. There is a large deposit of "quartzite", a firmly cemented sandstone, in Lincoln county; the crushed "quartzite" has been taken from a quarry in sec. 7, T. 12 S., R. 7 E., Lincoln county. Pressed cement bricks are made from fine material derived from this quarry. For many years a unique flagstone type of sandstone has been produced in Bourbon county. This stone has been shipped to various points in Illinois, Missouri, Kansas, Oklahoma, and Texas, where it has been used chiefly as paving slabs in walks; more recently the rock has been used as building stone and as ornamental stone.

Uses of sandstone.—Sandstone has a variety of uses. Like other firmly cemented rocks it is used widely as aggregate in concrete. It is probable that some of the eastern Kansas sandstone could be employed as abrasives. As stated above, some of the Kansas rock is suitable for use as building stone and flagstone. Several years ago sandstone in southeastern Kansas was used as a source of quartz sand in glass manufacture. Cretaceous sandstones are being used as road metal material in central Kansas.

Age and origin of Kansas sandstones.—Sandstones in Kansas are chiefly nonmarine in origin and were formed largely as coastal plain deposits. Some are of marine origin and were deposited in deltaic or littoral environments. The deposits in eastern Kansas are Pennsylvanian (late Carboniferous) in age. Those in central Kansas are of Cretaceous age.

Work of the State Geological Survey.—Studies pertaining to potential uses of Kansas sandstones have been planned. The Survey has carefully mapped and studied the surface and subsurface distribution of Kansas sandstones and has carried out studies of the character of the various sandstone types.

SHALE

Shale is a stratified sedimentary rock made up of thin layers ordinarily composed of silt or clay particles; it tends to be softer than limestone and sandstone and therefore does not have the same uses as have harder rocks. Many shales consist chiefly of clay particles, and when subjected to weathering, the rock generally slakes. Certain shales in Kansas and elsewhere are an important source of clay used for ceramic purposes; such clay shales are discussed in another section of the present report.

Kansas shale used as road metal.—In general, shale is a relatively non-resistant rock; there occur, however, in Kansas two or three types of more resistant shale that are used as road metal material. These resistant shales provide road-surfacing material that is very easily obtained.

At many localities in eastern Kansas sandy shale, or very argillaceous sandstone, crops out and has been used for "sanding" roads. Another kind of shale that may be used as a road metal is a black, platy carbonaceous shale that occurs in several parts of the eastern Kansas stratigraphic section. This material has been used on roads for several years; in Labette county, especially, black shale has been used in large quantities, and farm-to-market roads, having a limited amount of traffic, have stood up well when surfaced with it. Black shale suitable for surfacing secondary or temporary roads is readily available in all counties in the eastern part of Kansas.

The Kansas shales discussed above occur interstratified with other shales, sandstones and limestones in the Pennsylvanian (Upper Carboniferous) rock section of eastern Kansas. It is probable that shales of Cretaceous age that are dark and somewhat similar to the black Pennsylvanian shale would be useful. Cretaceous shales of this type crop out in Kiowa, Comanche, Ellsworth and McPherson counties. Calcareous shale from the Greenhorn formation of Cretaceous age has been used as road metal material in Cloud and Republic counties, Kansas.

References

Bowles, Oliver, *1937*, Dimension stone: Industrial minerals and rocks, Am. Inst. Min. and Metall. Eng., New York, pp. 763-794.

Eardley, Wilmot, *1937*, Abrasives: Industrial minerals and rocks, Am. Inst. Min. and Metall. Eng., New York, pp. 1-58.

Landes, K. K., *1937*, Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110, maps.

Moore, R. C., *1936*, Stratigraphic classification of Pennsylvanian rocks of Kansas: Kansas Geol. Survey, Bull. 22, pp. 1-256, figs. 1-12.

Patterson, S. B., *1937*, Crushed and broken stone: Industrial minerals and rocks, Am. Inst. Min. and Metall. Eng., New York, pp. 795-836.

Plummer, Norman, *1937*, Rock-wool resources of Kansas: Kansas Geol. Survey, Mineral Resources Circ. 5, pp. 1-74, figs. 1-20.

Tripoli

Summary.—One tripoli processing plant is situated near Baxter Springs, Kansas. Tripoli occurs in Cherokee county; the reserves are inadequately known.

Tripoli consists essentially of silica (SiO_2), in a cryptocrystalline state, that can be ground to a fine abrasive of uniform texture. It occurs in limestones of Mississippian age in southeastern Kansas, northeastern Oklahoma, and southwestern Missouri, and probably is formed by ground water leaching of the calcium carbonate from a secondarily silicified limestone, leaving a siliceous residue. In some parts of the world the terms *tripoli* or *tripolite* are used to designate a siliceous deposit consisting almost entirely of the siliceous skeletons of diatoms; such deposits should be termed diatomite rather than tripoli. Diatomaceous marl deposits in Kansas are described in another part of this report.

Tripoli is a uniform-textured abrasive used mainly as a polishing and filtering material. It is used locally as an ingredient of drilling mud and can be used successfully in scouring powders and mechanics soap. A mill for the processing of tripoli is located near Baxter Springs, Kansas; according to H. W. Nesch this mill can process 6 tons an hour, the material being ground to a size of 300 mesh or smaller.

Tripoli deposits are known to occur in Cherokee county, Kansas, but it is impossible at the present time to make an accurate estimate of the known reserves, and the purity of the material is not adequately known.

Volcanic Ash

Summary.—Kansas is the leading state in the production of volcanic ash. Production in 1940 was 39,215 short tons valued at $129,959. Reserves, 10,000,000 short tons.

Description.—Volcanic ash consists essentially of very small, sharp and angular fragments of natural or rock glass. In addition, volcanic ash usually contains minor amounts of mineral feldspar, a small amount of quartz and occasionally muscovite mica. Impurities likely to be present are calcite, either in the form of a cement or concretions, sand and clay. Texturally, volcanic ash is very fine; mechanical analyses of Kansas deposits show that a very large percentage of the ash particles are finer than 0.147 mm in diameter, or will pass through a 100 mesh sieve. Much of the ash consists of particles smaller than 0.046 mm in diameter, or will pass through a 300 mesh sieve. As a general rule, the finer the ash the greater its commercial value. Kansas volcanic ash is white to light gray or bluish gray in color, the differences in color being due to differences in age. Volcanic ash is known also as pumicite, and erroneously as silica, feldspar, spar and geyserite.

The various deposits of volcanic ash in Kansas are widely separated and completely isolated from one another (fig. 13). Field observations indicate that individual deposits as seen in outcrop cover from a few square feet to more than a quarter of a section of

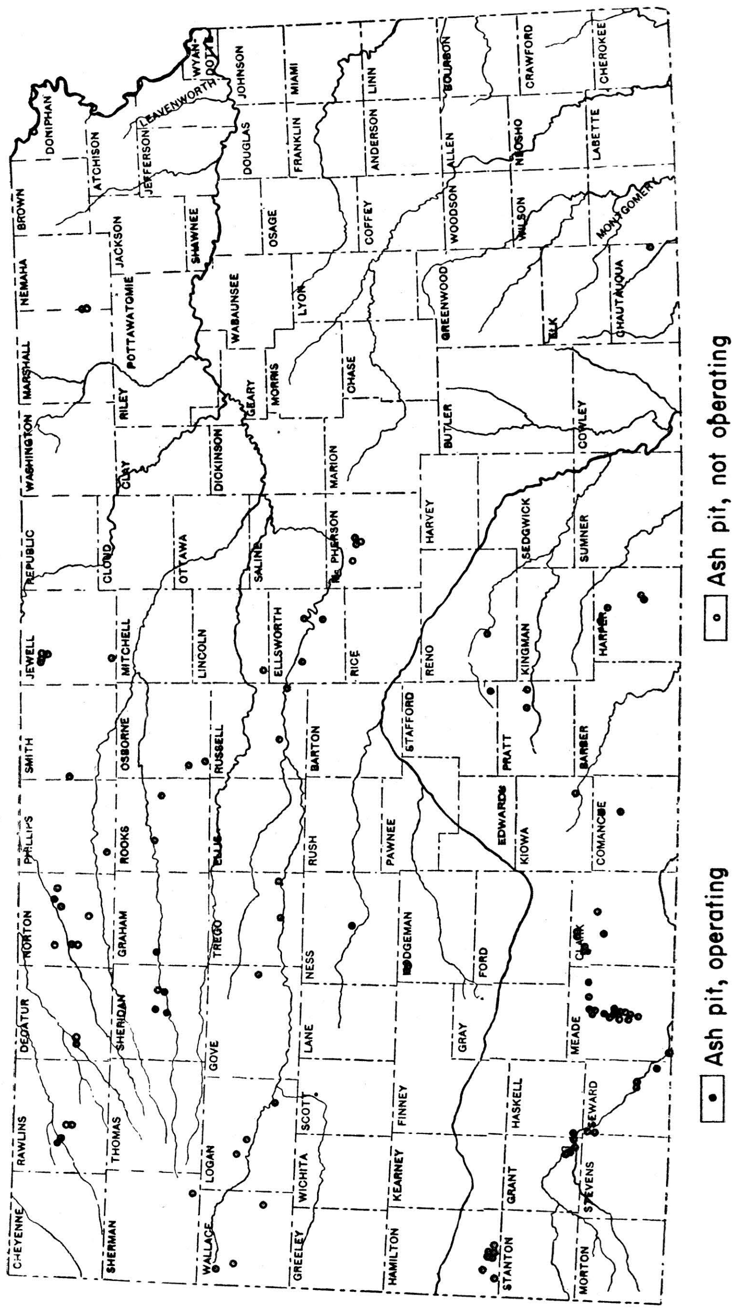

FIGURE 13. Map of Kansas showing distribution of volcanic ash deposits in Kansas.

land with an average areal extent of several acres. The ash beds are highly variable in thickness; at places they are but a few inches thick, whereas thicknesses of 20 to 30 feet or more have been reported from some localities. Thicknesses of 6 to 14 feet are common. The ash crops out at the surface at numerous places; at other places, however, it is overlain by soil, a veneer of stream-carried pebbles or by Pleistocene deposits. At no place is the known overburden greater than 20 feet in thickness. In general, the ash deposits are massive in structure; thin-bedded and cross-bedded deposits, however, are relatively common. In Norton county much of the ash shows distinct horizontal bedding, indicating deposition under quiet water conditions in lakes.

Chemically, volcanic ash is a solid solution of silicates, the combined constituents being alumina, soda, potash, magnesia, lime, and iron oxide. The feldspars found in Kansas ash thus far examined consist of the potash and soda aluminum silicates, the lime feldspars being absent. The chemical analyses shown in table 23 are typical of the Kansas deposits.

TABLE 23. *Chemical analyses of Kansas volcanic ash*

Constituents	McPherson Co. (per cent)	Lincoln Co. (per cent)	Meade Co. (per cent)	Satanta, Meade Co. (per cent)	McPherson Co. (per cent)
SiO_2	72.50	73.30	72.40	72.36	72.30
Al_2O_3	14.15	14.46	10.65	12.20	16.62
Fe_2O_3	1.65	1.54	2.65	1.40	2.33
CaO	0.70	1.00	1.68	trace	0.99
MgO	0.30	0.21	0.13	0.58	
K_2O	4.70	5.64	4.82	3.00	2.00
Na_2O				6.52	4.00
Ignition loss	5.00	4.60	9.60		
Total	99.00	100.75	96.93	100.00	98.24

Distribution.—In 1927 volcanic ash was known to occur in 13 counties, and at the present time 36 Kansas counties are known to contain volcanic ash deposits. At least 115 separate deposits are known in these counties. Table 24 shows the distribution of volcanic ash in Kansas by counties together with the number of deposits thus far reported; the geographic distribution of the deposits is shown also in figure 13.

Production.—Kansas is the leading volcanic ash producing state in the United States. In 1940, Kansas produced 39,215 tons of ash or 47.58 per cent of all the ash mined in the United States during that year. The value of the Kansas ash production for 1940 amounted to $129,959. Table 25 indicates that Kansas has led the states in the quantity and value of ash produced since 1916. The table shows also that although Kansas has ranked first in ash production since 1916, the percentage of ash mined in Kansas is gradually becoming less and is considerably less than it was in the early years of the industry. Meade county leads all other counties in the state in ash production.

TABLE 24. *Number of known volcanic ash deposits (by counties) in Kansas on February 1, 1942*

County	Number of deposits	County	Number of deposits
Chautauqua	1	Meade	12
Clark	8	Nemaha	2
Comanche	2	Ness	1
Decatur	2	Norton	20
Doniphan	1 (?)	Osborne	2
Ellsworth	3	Phillips	1
Gove	1	Pratt	2
Graham	1	Rawlins	4
Grant	4	Reno	1
Hamilton	7	Rooks	2
Harper	4	Russell	2
Haskell	1	Seward	5
Hodgeman	2	Sheridan	4
Jewell	4	Sherman	1
Kiowa	1	Smith	1
Lincoln	1	Stafford	1
Logan	2	Trego	2
McPherson	4	Wallace	3

Volcanic ash has been mined in Kansas since 1915 or earlier. During 1941, five companies were operating in six counties, namely Comanche, Grant, Meade, Norton, Osborne and Sheridan. At various times volcanic ash was mined by local individuals or owners. The names and home office locations of the most important volcanic ash or pumicite producers in Kansas are listed below.

The Cudahy Packing Co., Chicago, Illinois
Davidson Pumice Co., Norton, Kansas
Dodson Concrete Board Co., Wichita, Kansas

J. B. Ford Co., Wyandotte, Michigan
Mid-Co Products Co., Kansas City, Missouri
The Pumicite Co., St. Louis, Missouri

TABLE 25. *Volcanic ash production in Kansas*

Year	Production, short tons		Per cent of U.S. production from Kansas	Value of Kansas production, in dollars
	Kansas	United States		
1916	23,804	33,320	71.44	51,648
1917	*	35,293	*	*
1918	*	28,637	*	*
1919	*	34,051	*	*
1920	*	41,838	*	*
1921	34,172	37,108	92.09	125,642
1922	*	45,262	*	*
1923	51,907	56,575	91.75	170,459
1924	39,489	43,651	90.47	148,177
1925	35,385	40,380	87.63	122,349
1926	48,869	53,887	90.69	152,190
1927	45,439	53,298	85.26	152,748
1928	46,836	57,430	81.57	183,589
1929	49,768	67,013	74.26	195,784
1930	38,024	56,843	66.89	134,896
1931	47,783	69,819	69.43	152,520
1932	39,375	53,214	73.99	117,558
1933	42,355	61,220	69.18	109,454
1934	39,283	56,169	69.94	102,668
1935	41,111	57,116	71.98	108,349
1936	42,057	72,915	57.68	117,757
1937	38,438	71,007	54.13	111,655
1938	38,136	65,742	58.00	112,823
1939	41,643	89,159	46.70	123,163
1940	39,215	82,407	47.58	129,959

* *No data available.*

Kansas has produced more than 1,023,129 tons of volcanic ash since 1916, an amount valued at $2,613,399.

Uses.—The uses of Kansas volcanic ash are many and varied. It is used as an abrasive, especially as a polishing and cleansing agent. It is used in toothpastes and powders, as a high-grade silver polish, in making mechanics paste soaps, abrasive hand soaps, sweeping compounds, and rubber erasers. Because of its low heat conductivity and high porosity, volcanic ash can be utilized efficiently in heat-and-cold insulations and as a packing for water and steam pipes and lagging boilers. It may be used as a filler in paints and as an agent in filtering oils for purposes of purification and clarification. Experiments now being conducted by the State Geological Survey are designed to test its suitability as a filler in certain plastics. Volcanic ash has been used in the preparation of dynamite. It can be used in the making of puzzolan and trass or tufa cements. Puzzolan cement, because of its hydraulic properties, is especially valuable in seaworks; tufa cement has been used in the construction of aqueducts and dams. Recent experiments have shown that Kansas volcanic ash may be used by ceramic industries in the manufacture of glazes, enamels, glass, and vitreous pottery. The use of volcanic ash in a pottery body solved for a Kansas City firm the problem of manufacturing a container in March, 1942. The State Geological Survey recommended a mixture of 25 per cent volcanic ash and 75 per cent Kansas pottery clay, from which the firm is able to manufacture a container which is impervious to water and which can be fired at the relatively low temperature attained by their kiln.

Reserves.—The total volcanic ash reserves in Kansas are unknown. This is due to the fact that relatively few of the 115 known localities distributed throughout 36 counties in Kansas have been surveyed and only a few have been exploited. It is reasonably certain, however, that the Kansas reserves of volcanic ash are several times the total amount thus far mined. Table 26 gives estimates of the reserve tonnage of some of the larger known ash deposits.

TABLE 26. *Estimated reserves of volcanic ash in the larger known ash deposits*

County	Reserves, short tons
Grant	75,000
Gove	60,000
Jewell	4,000,000
McPherson	48,000
Meade	1,600,000
Norton	50,000
Phillips	500,000
Total	6,333,000

It is reasonable to assume that an additional 3 to 4 million tons of ash are present in the unsurveyed but known volcanic ash deposits in the remaining 29 counties not included in Table 26. It should be noted that undiscovered volcanic ash deposits undoubtedly exist not only in the counties known to have volcanic ash but also in counties in which volcanic ash has not as yet been reported. Recently (February, 1942), the State Geological Survey of Kansas received and examined volcanic ash from two hitherto unreported deposits in Hodgeman county. The total reserve tonnage of volcanic ash in Kansas may be estimated as approximating 10,000,000 short tons.

Origin and age.—Volcanic ash or pumicite is the finest material erupted from volcanoes. Inasmuch as no volcanoes are known to have existed in Kansas, it follows that the volcanic ash represents transported material brought to the state from volcanoes in other regions. The Kansas deposits are not continuous but occur in scattered and isolated patches in the counties cited above. A study of their distribution indicates that the area covered by the ash is fan-shaped with the apex of the fan pointing toward the southwest. In general, the coarser ash lies southwest of the finer ash. The fineness of the material, the absence in some places of horizontal bedding, and locally the characteristic eolian or wind-type of cross-bedding strongly indicate that wind was the transporting agent which brought the volcanic ash to Kansas. It has been suggested that the source of the Kansas volcanic ash was a group of now extinct volcanoes in the northeastern corner of New Mexico. These volcanoes, known as the Capulin group of volcanoes, lie to the southwest of the previously mentioned fan-shaped ash area in Kansas. The Capulin volcanoes are post-Tertiary or Pleistocene in age.

Not all of the ash deposits in Kansas are of Pleistocene age. In Norton, Decatur and Rawlins counties that ash is much more compact than elsewhere in the state and is bluish in color, in contrast with the white or light gray ash found in other counties. The compact and bluish ash occurs in the "mortar beds" of the Ogalalla formation which is considered to be of Pliocene (late Tertiary) age; this ash, therefore, is older than the white and more prevalent Pleistocene ash.

Work of the State Geological Survey.—The State Geological Survey has undertaken the work of examining samples of volcanic ash sent in by individuals for identification. Recent, intensive studies have been carried on by the Survey on the subject of the ceramic uses of Kansas volcanic ash and the control of iron oxide in the ash suitable for making glazes and low-cost glass. Bulletins published by the Survey dealing with volcanic ash are listed below.

REFERENCES

FRYE, J. C., and HIBBARD, C. W., Pliocene and Pleistocene stratigraphy and paleontology of the Meade basin, southwestern Kansas: Kansas Geol. Survey, Bull. 38, pt. 13, pp. 389-424, figs. 1-3, pls. 1-4.

LANDES, K. K., *1928,* Volcanic ash resources of Kansas: Kansas Geol. Survey, Bull. 14, pp. 1-58, figs. 1-3, pl. 1-4.

———, *1937,* Mineral resources of Kansas counties: Kansas Geol. Survey, Mineral Resources Circ. 6, pp. 1-110, maps.

———, *1938,* Distribution of volcanic ash: Am. Ceramic Soc., Bull., vol. 17, no. 8, pp. 323-325.

KINNEY, E. D.,*1941,* Control of iron oxide in volcanic ash: Am. Ceramic Soc., Bull., vol. 20, no. 4, pp. 118-121, fig. 1, tables 1-6.

MOORE, R. C., and LANDES, K. K., *1927,* Underground resources of Kansas: Kansas Geol. Survey, Bull. 13, pp. 1-154, figs. 1-115.

PLUMMER, NORMAN, *1939,* Ceramic uses of volcanic ash: Am. Ceramic Society., Bull., vol. 18, no. 1, pp. 8-11; also Kansas Geol. Survey, Mineral Resources Circ. 13, pp. 8-11.

SMITH, H. T. U., *1940,* Geologic studies in southwestern Kansas: Kansas Geol. Survey, Bull. 34, pp. 1-212, figs. 1-22, pls. 1-34.

WATER RESOURCES

GROUND WATER

Summary.—Industrial ground-water supplies in excess of 5 million gallons a day can be obtained at many places in Kansas, and at certain selected localities supplies in excess of 20 million gallons a day are available.

Every industrial establishment must have a water supply of adequate quantity and suitable quality to meet its specific requirements. In wartime, as in peace time, large water supplies are essential not only for industrial plants but also for public and agricultural uses. Although ground water is utilized extensively in eastern Kansas, it is in the south-central and western parts of the state that it is of paramount importance. In south-central and western Kansas stream flows are so small that they do not constitute an abundant or reliable water supply; on the other hand, large ground-water supplies generally are available in these regions.

The water supplies available for wartime industries in Kansas have been described in a report published recently by the State Geological Survey as part 2 of Bulletin 41. The ground-water supplies available in south-central Kansas were described in part 1 of Bulletin 41.

The rock materials that underlie the surface of Kansas yield water more freely in some parts of the state than in other parts. Beds of coarse gravel and sand that partially fill the large stream valleys yield large supplies of water to wells, whereas some of the fine-grained or tightly-cemented rocks that underlie large areas, particularly in the north-central and eastern parts of the state, yield relatively little water to wells. Supplies of from 10 million to more than 20 million gallons a day are available for continued use from groups of wells in the Missouri, Kansas, and Arkansas river valleys. Locally along these valleys larger supplies are available. Larger supplies probably would be available at most places along these valleys for a period of a few years during the present emergency.

Other areas, somewhat less prolific than those mentioned above, in which several million gallons of ground water a day could be obtained, include the valleys of the Big Blue, Republican and Smoky Hill rivers, and shallow-water areas in Kiowa, Scott, Finney, Grant and Stanton counties.

At many places in Kansas ground-water supplies are obtainable that are in excess of one million but, for the most part, less than 10 million gallons a day. The following areas in Kansas belong in this general classification: the valleys of Delaware, Solomon, Saline, lower Marais des Cygnes, and Pawnee rivers; the deep ground-water areas, including much of the High Plains of southwestern and northwestern Kansas and the extreme southeastern corner of the state; the area of sand dunes lying south of Great Bend, west of Hutchinson and east of Larned; the Meade county artesian basin; and areas in south-central Kansas underlain by Tertiary and Quaternary deposits.

The quantities of water available to wells in various parts of Kansas, discussed in the foregoing paragraphs, refer to continuous or permanent supplies from localized areas. It should be pointed out that at many places throughout the state it would be possible to pump much larger supplies of water for a relatively short period of time, in some cases 5 to 10 years. Water in excess of the safe yield described above would be taken from storage, that is, would be withdrawn from the pore spaces of the rock at a more rapid rate than it would be replenished by rainfall and seepage from streams. Such a procedure would result in a continual lowering of the water table and eventual diminution of the supply, but might be necessary locally during the present accelerated war production. Another method of increasing ground-water supplies is spacing of the wells over a wide area and connecting them by pipe lines. This method was recommended by the State and Federal Geological Surveys and has been used successfully by the City of Wichita in securing its new water supply.

Since 1937, the State Geological Survey and the Division of Ground Water of the United States Geological Survey, in cooperation with the Division of Water Resources of the State Board of Agriculture and the Division of Sanitation of the State Board of Health, have been making detailed investigations of the quantity and quality of ground water in various parts of the state. Of special importance in ground-water investigations are the periodic measurements of water levels in numerous observation wells in each of the areas being studied, in order to determine the magnitude and character of water level fluctuations and the rate at which the underground reservoirs are being replenished by rainfall, or depleted by natural processes or by heavy pumping. The cooperating State and Federal agencies now obtain accurate records of water level fluctuations in nearly 500 observation wells situated in 25 counties of central and western Kansas. These records are published annually in Water Supply Papers of the United States Geological Survey.

Published reports of detailed studies of the ground-water resources of specific areas in the state are listed below.

References

ABERNATHY, G. E., *1941*, Ground-water resources of Mississippian and older rocks in Bourbon, Crawford, Cherokee and Labette counties, southeastern Kansas: Kansas Geol. Survey, Bull. 38, pt. 8, pp. 221-236, fig. 1.

FRYE, JOHN C., *1940*, A preliminary report on the water supply of the Meade artesian basin, Meade county, Kansas: Kansas Geol. Survey, Bull. 35, pp. 1-39, figs. 1-7.

———, *1941*, Reconnaissance of ground-water resources in Atchison county, Kansas: Kansas Geol. Survey, Bull. 38, pt. 9, pp. 237-260, figs. 1-6, pls. 1-3.

LATTA, BRUCE F., *1941*, Geology and ground-water resources of Stanton county, Kansas: Kansas Geol. Survey, Bull. 37, pp. 1-119, figs. 1-6, pls. 1-9.

LOHMAN, S. W., *1938*, Water supplies from wells available for irrigation in the uplands of Ford county, Kansas: Kansas Geol. Survey, Mineral Resources Circ. 9, pp. 1-10, index map.

———, *1941*, Ground-water conditions in the vicinity of Lawrence, Kansas: Kansas Geol. Survey, Bull. 38, pt. 2, pp. 17-64, figs. 1-6, pls. 1-2.

———, *1942*, Ground-water supplies available for national defense industries in south-central Kansas: Kansas Geol. Survey, Bull. 41, pt. 1, pp. 1-20, figs. 1-3.

LOHMAN, S. W., FRYE, J. C., WAITE, H. A., FISHEL, V. C., MCLAUGHLIN, T. G. LATTA, B. F., and ABERNATHY, G. E., *1942*, Ground-water supplies in Kansas available for national defense industries; with a summary of stream flow in Kansas by George S. Knapp and J. B. Spiegel: Kansas Geol. Survey, Bull. 41, pt. 2, pp. 21-68, figs. 1-3, pls. 1-4.

MCLAUGHLIN, T. G., *1942*, Geology and ground-water resources of Morton county, Kansas: Kansas Geol. Survey, Bull. 40, pp. 1-126, figs. 1-6, pls. 1-9.

MOORE, R. C., *1940*, Ground-water resources of Kansas: Kansas Geol. Survey, Bull. 27, pp. 1-112, figs. 1-28, pls. 1-34.

SURFACE WATER

The Geological Survey, United States Department of the Interior, in cooperation with the Division of Water Resources of the State Board of Agriculture and the U.S. Army Engineers, maintains many gaging stations on the principal streams in Kansas. Detailed stream-flow records for Kansas streams are available in Water-Supply Papers of the U.S. Geological Survey and in state reports. Stream-flow records for the period 1895-1919 and for 1919-1924 are contained in reports on the surface waters of Kansas issued by the Kansas water commission. Records for 1924-1928, 1928-1935, and 1935-1939 are contained in reports of the Kansas State Board of Agriculture, Division of Water Resources. More recent information on the flow of Kansas streams may be obtained by writing to the U.S. Geological Survey, Division of Surface Water, Topeka, Kansas, or to the Kansas State Board of Agriculture, Division of Water Resources, Topeka, Kansas.

In general, supplies of surface water adequate for most purposes can be obtained from the major streams in eastern Kansas; supplies of surface water in western Kansas are inadequate for most industrial needs.

UNIVERSITY OF KANSAS PRESS
LAWRENCE

STATE GEOLOGICAL SURVEY OF KANSAS

Recent Publications

BULLETIN 22. Stratigraphic Classification of the Pennsylvanian Rocks of Kansas, by Raymond C. Moore, 256 pages, 1936. **Mailing charge, 20 cents.**

BULLETIN 23. Origin of the Shoestring Sands of Greenwood and Butler Counties, Kansas, by N. Wood Bass, 135 pages, 1936. **Mailing charge, 25 cents.**

BULLETIN 24. Geology and Coal Resources of the Southeastern Kansas Coal Field, by W. G. Pierce and W. H. Courtier, 122 pages, 1937. **Mailing charge, 25 cents.**

BULLETIN 25. Secondary Recovery of Petroleum, Part I, Bibliography, by John I. Moore, 103 pages, 1938. **Mailing charge, 20 cents.**

BULLETIN 26. Relation of Thickness of Mississippian Limestones in Central and Eastern Kansas to Oil and Gas Deposits, by Wallace Lee, 42 pages, 1939. **Mailing charge, 25 cents.**

BULLETIN 27. Ground-Water Resources of Kansas, by Raymond C. Moore with chapters by S. W. Lohman, J. C. Frye, H. A. Waite, T. G. McLaughlin, and Bruce Latta, 112 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 28. Exploration for Oil and Gas in Western Kansas during 1939, by Walter A. Ver Wiebe, 106 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 29. Asphalt Rock in Eastern Kansas, by John M. Jewett, 23 pages, 1940. **Mailing charge, 15 cents.**

BULLETIN 30. Oil and Gas in Linn County, Kansas, by John M. Jewett, with chapters by Wallace Lee and R. P. Keroher, 29 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 31. Oil and Gas in Montgomery County, Kansas, by G. E. Abernathy with chapters by R. P. Keroher and Wallace Lee, 29 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 32. Coal Resources of Kansas; Post-Cherokee Deposits, by R. E. Whitla, 64 pages, 1940. **Mailing charge 20 cents.**

BULLETIN 33. Subsurface Mississippian Rocks of Kansas, by Wallace Lee, 114 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 34. Geologic Studies in Southwestern Kansas, by H. T. U. Smith, 244 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 35. Preliminary Report on the Meade Artesian Basin, Meade County, Kansas, by John C. Frye, 39 pages, 1940. **Mailing charge, 25 cents.**

BULLETIN 36. Exploration for Oil and Gas in Western Kansas during 1940, by Walter A. Ver Wiebe, 109 pages, 1941. **Mailing charge, 25 cents.**

BULLETIN 37. Geology and Ground-Water Resources of Stanton County, Kansas, by Bruce F. Latta, 119 pages, 1941. **Mailing charge, 25 cents.**

BULLETIN 38. 1941 Reports of Studies (Parts issued separately). **Mailing charge, 10 cents each part.**

BULLETIN 39. The Geology of Riley and Geary Counties, Kansas, by J. M. Jewett, 164 pages, 1941. **Mailing charge, 25 cents.**

SCENIC KANSAS, Kenneth K. Landes, 51 pages, 24 pls. **Mailing charge, 5 cents.**

RESOURCE-FULL KANSAS, Kenneth K. Landes and Oren R. Bingham, 65 pages. **Mailing charge, 10 cents.**

STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 38

1941 REPORTS OF STUDIES

(parts available)

BULLETIN 41

1942 REPORTS OF STUDIES