MINERAL RESOURCES OF THE
TRINITY RIVER TRIBUTARY AREA
IN
TEXAS AND OKLAHOMA

Compiled by

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INTRODUCTION

A. E. Weissenborn, United States Geological Survey

History of the Project

Proposals for the improvement of navigation on the Trinity River in Texas have been under consideration for many years. A Federal project for the construction of a six-foot channel to Dallas, together with the necessary locks and dams was authorized in 1902. Under the terms of this act and subsequent legislation seven locks and dams and one auxiliary dam were constructed by the Corps of Engineers, U. S. Army, but the project was never completed. The River and Harbor Act of September 22, 1922, directed the abandonment of the project but provided for a six-foot channel from Liberty to the mouth of the Trinity River; the six-foot channel was maintained until 1930, when it was abandoned owing to lack of traffic. In 1945 Congress approved the construction by the Corps of Engineers, U. S. Army, of a number of reservoirs for flood control along the upper Trinity River. Congress also approved the excavation of a nine-foot channel from Liberty to the mouth of the Trinity River. It did not authorize the improvement of the Trinity River above Liberty, but the Corps of Engineers was authorized to investigate further the economic justification of a nine-foot channel from Liberty to Fort Worth.

In March 1945 Colonel George R. Goethels, Chief of the Civil Works Division of the Corps of Engineers, requested the Director of the Geological Survey, United States Department of the Interior, to prepare a report on the mineral resources of the area that, according to economic studies made by the Corps of Engineers, would be affected by the canalization of the Trinity River to Fort Worth. As a consequence, the staff of the Geological Survey's Regional Office at Rolla, Mo., was assigned the task of preparing the desired information. A. E. Weissenborn, acting Regional Geologist, called on Major H. R. Norman, Division Engineer of the Corps of Engineers, U. S. Army, and discussed with him the purpose, scope, and form of the proposed report. Following this discussion, Dr. John T. Lonsdale, Director of the Bureau of Economic Geology of the University of Texas, at Mr. Weissenborn's request, agreed that the Bureau of Economic Geology should participate in the preparation of the report. Mr. Weissenborn also called on Robert H. Dott, Director of the Oklahoma State Geological Survey at Norman, Oklahoma. The Oklahoma Geological Survey was unable to participate in writing the report, but was very helpful in supplying published and unpublished or out-of-print information on the mineral resources of Oklahoma.

Definition of Trinity River Tributary Area

Traffic studies by the U. S. Engineers indicate that, if the Trinity River were navigable from its mouth to Fort Worth, appreciable savings in freight rates would accrue in an area far beyond the limits of the Trinity River drainage basin. The area in which savings would accrue

Fig. 1

KEY MAP

SHOWING LOCATION OF TRINITY RIVER TRIBUTARY AREA

SCALE: 1 INCH = APPROX. 170 MILES

100 0 100 200 300

for the shipment of any commodity over the proposed waterway has been termed by the U. S. Engineers, "the Trinity River tributary area". The tributary areas vary for different commodities; the term "tributary area" as used in this report, comprises the tributary areas of all commodities considered to be potential tonnage for the proposed waterway, according to the studies made by the U. S. Engineers. The Trinity River tributary area, which is shown on the accompanying map (Fig. 1), includes a total of approximately 184,000 square miles and covers all or parts of 141 counties in Texas and 68 in Oklahoma. For convenience, the Trinity River tributary area will be referred to as the "Trinity tributary area", or more simply, as "the tributary area".

Purpose and Scope of the Report

Proponents of the canalization of the Trinity maintain that the mineral products of the tributary area would provide a considerable part of the traffic moving over the proposed waterway. They further argue that the opening of the Trinity River to navigation would result in the development of resources not now being used, or in increased output from existing mines and mineral-products processing plants, thus creating additional tonnage for the waterway.

The mineral resources found in the Trinity River tributary area are many and varied. A great deal is known about the fuels, as well as the non-metallic and metallic minerals found in the area, and much has been published on the subject; but the information is scattered through a vast volume of technical literature. The information relative to the Trinity River tributary area can be obtained only through a laborious and time-consuming culling of a great deal of irrelevant material from numerous publications, some of which are out of print and difficult to obtain. The purpose of the present report is to summarize all available information in a factual, concise account of the mineral resources of the Trinity River tributary area; thus presenting all the available, pertinent facts in convenient form, and assisting the U. S. Engineers in appraisal of the tonnage that mineral products would contribute to the proposed waterway. The report discusses each mineral commodity found in the area and gives a brief description of its uses in industry, methods of exploitation, economic factors involved, occurrences in the Trinity River tributary area, reserves, producing companies, and where available, records of output. A bibliography listing the significant references to the technical literature is included with each commodity.

At the suggestion of the U. S. Engineers, the occurrences of the various mineral commodities in the Trinity River tributary area have been classified into three groups which are:

(1) Those in the areas subject to periodic flooding by the Trinity River, for use in connection with economic studies of flood control projects.

(2) Those in the remainder of the Trinity River drainage basin where mineral commodities would be most directly affected by the canalization of the Trinity River.

(3) Those in the Trinity River tributary area, but outside of the drainage basin where mineral commodities would be less directly affected by canalization of the Trinity, but where appreciable savings in transportation costs would still accrue.

In describing the mineral resources of the tributary area, all the mineral commodities that are known to occur in the area are considered, whether they are being successfully exploited at present, or not. Because a given deposit is not now being worked, does not mean that it could not be profitably worked under changed economic conditions, or even under present conditions. Likewise, the fact that the known deposits of a given commodity are of too low grade to be worked, does not preclude the possibility that other, higher grade deposits might be found. The inclusion of a given commodity in the list of mineral resources of the Trinity River tributary does not necessarily mean, however, that deposits of these materials that cannot now be worked economically could be profitably worked if the Trinity were canalized. The general lowering of freight rates that is anticipated if the Trinity were opened to navigation would doubtless have a stimulating effect on the mineral industry in the Trinity River tributary area, but many other factors besides transportation costs are involved. Bulky, low-priced, non-perishable commodities such as sand and gravel, crushed stone for riprap and other purposes, building stone, and similar materials are the products that would benefit most directly from river transportation, and an increase in the production of these products in at least part of the Trinity River tributary area probably can be expected. Part of the crude oil and other petroleum products from the tributary area might move to markets through a canalized Trinity, and over the intercoastal waterway, with considerable saving in transportation charges; although this change in transportation does not necessarily mean that any actual increase in production would result from the opening of the Trinity waterway. Other commodities, such as salt, would benefit only indirectly, through a general increase in industrial activity in the tributary area. There are enormous deposits of salt in the area--enough to take care of the requirements of this country for many years to come--but salt can be produced just as cheaply in a number of other localities, and the market for salt from the Trinity tributary area, therefore, is limited by the location of the other producing centers. Development of some commodities may have been retarded by lack of transportation facilities, or by high cost of transportation, but transportation, or the lack of it, has had little influence on the development of other commodities; for example, the potash deposits of Texas, although large, are of too low grade to compete with higher grade deposits in New Mexico. Development of a potash industry in Texas depends on the finding of higher grade deposits than those already known, and would be influenced to only a comparatively slight degree by lower transportation charges. An appraisal of the effect of the proposed canalization of the Trinity River on the mineral industry of the tributary area would require thorough study of the existing and estimated future freight rates, and would involve the consideration of many factors that are outside the field of the geologist. The present report, therefore, attempts to describe adequately the actual and potential mineral resources of the region, but does not attempt to forecast in any detail the economic effect of the proposed canalization of the Trinity River on the mineral industry in the area.

The Federal Geological Survey was fortunate in obtaining the assistance of the Bureau of Economic Geology of the University of Texas in preparing the report. Dr. H. B. Stenzel and Mr. H. C. Fountain of this Bureau wrote the chapters on the following resources in Texas: Asphalt; coal, lignite and peat; building stone; celestite; burning clays; dolomite and magnesian limestone; limestone, caliche, and shell deposits; and iron. Each of these chapters has been supplemented by descriptions prepared by members of the United States Geological Survey of corresponding occurrences in the Oklahoma part of the area. The chapters on oil and gas in the entire Trinity River tributary area, and the descriptions of the occurrences of asphalt and coal in Oklahoma, were prepared by Mr. T. A. Hendricks, and Mr. R. L. Miller, of the Fuels Section of the United States Geological Survey. The remainder of the report was prepared by Mr. A. L. Jenke, Mr. D. M. Kinney, and Mr. A. E. Weissenborn of the Regional staff of the Central Region, United States Geological Survey.

Jenke, Kinney, and Weissenborn spent about two weeks in a reconnaissance of the Trinity River tributary area, in company with Mr. J. L. Cotton, engineer in charge of the Fort Worth office of the U. S. Engineers, and Mr. Forrest Park, of the Trinity Improvement Association; but aside from this, very little field work was done specifically for the report. Much of the report is based on information contained in the numerous publications of the Bureau of Economic Geology, the Oklahoma State Geological Survey, and the United States Geological Survey, although many other publications were also consulted. The report, however, is by no means based entirely on published information; the geologists of the Bureau of Economic Geology are thoroughly familiar with the geology and mineral deposits of the Texas part of the area, and Mr. Hendricks has done much field work in the Oklahoma part of the area over a period of many years. In addition, the individual sections of the report have been criticized by members of the Geological Survey in Washington, who are familiar with the different commodities discussed. As a final check, the entire part pertaining to the resources of the Texas part of the area has been read by geologists of the Bureau of Economic Geology, and the part dealing with the resources of the Oklahoma portion of the area by geologists of the Oklahoma State Geological Survey. It is believed, therefore, that the report gives an accurate summary of the mineral resources of the Trinity River tributary area, insofar as they are known at the present time, and that the information can be used with some confidence in making economic studies to assist in determining whether the canalization of the Trinity River is justified.

Transportation Facilities

Adequate transportation is essential to the proper development of the mineral resources of any region. The Trinity River tributary area is provided with excellent facilities for transportation, but, as the present report is a supplement to a more comprehensive report by the U. S. Engineers, only a brief resume is given here.

The Trinity River tributary area is traversed by eight major railroad lines: the Missouri, Kansas, and Texas; the St. Louis and San Francisco; the Missouri Pacific; the Chicago, Burlington, and Quincy; the Atchinson, Topeka, and Santa Fe; the Texas and New Orleans, the

Chicago, Rock Island and Pacific; and the St. Louis Southwestern. These lines, and branch lines from them, form a network that reaches into almost every part of the tributary area.

The main north-south highways in the Trinity River tributary area are U. S. Highways 59, 69, 75, 77, 81, and 87. The principal east-west highways are U. S. Highways 64, 66, 80, and 90. In addition to the above, many other improved Federal and State highways and a great number of secondary roads reach into almost every part of the tributary area. No part of the area is very far from good railroad or truck transportation. In addition to the railroads and highways, numerous oil, gasoline, and natural gas pipelines serve the tributary area. These exceptionally numerous, and conveniently located transportation facilities of the Trinity tributary area would permit the mineral products produced in the area to move cheaply and quickly to the proposed waterway.

Geology of the Trinity River Tributary Area

Rocks ranging in age from pre-Cambrian to Recent are found within the tributary area. Because of the size of the area, the diversity of the rocks that occur within it, and the complexities of the geologic structures, only a brief and superficial discussion of the geology can be included in this report.

The geologic structures and the stratigraphy are so diverse in different parts of the Trinity River tributary area that it is convenient in this report to divide the area into a number of smaller, more homogeneous divisions. Starting in the northeast corner of Oklahoma and working southward, the divisions chosen are: the Ozark dome; the Osage Plains, the Wichita, Arbuckle, and Ouachita Mountains; the High Plains and the Permian Basin; and the Gulf Coastal Plain. These will be described in the order given.

The Ozark Dome

The southern half of Missouri and part of northern Arkansas is geologically a structural high known as the Ozark dome or uplift. Sandstones and dolomites of Cambrian or Ordovician age form the present surface over much of the Ozark region and dip gently away from the core of pre-Cambrian granite which is exposed in the St. Francis Mountains in southeastern Missouri. On the southwest flank of the dome Mississippian limestone and shale, which once covered most of the Ozark area, but have been largely stripped away by erosion, still are exposed in the northwestern corner of the tributary area in Mayes, Cherokee, and Sequoyah Counties, Oklahoma. About 550 feet of Mississippian rock is present, most of which is limestone belonging to the Boone formation. Isolated remnants of a former covering of Pennsylvanian rocks overlie the Mississippian in a few places on the lower flanks of the dome, and Devonian, Silurian, and Ordovician rocks, which underlie the Mississippian, are exposed in the deeper stream valleys. To the west and south the Mississippian disappears under a cover of Pennsylvanian rocks.

Osage Plains

The Osage Plains region is here considered to be the large area extending from the Llano uplift in Central Texas northward through Oklahoma. In Texas it lies between the High Plains on the west and the Gulf Coastal Plain on the east; in Oklahoma it lies between the High Plains and the Ouachita Mountains and Ozark dome. As here defined, it does not include the Arbuckle and Wichita Mountains in southern Oklahoma, which for convenience are discussed under a separate heading.

In the Osage Plains area the surface formations are almost entirely of Pennsylvanian and Permian age. Except in the region bordering the Wichita, Arbuckle, and Ouachita Mountains, they are almost horizontally bedded, but have a gentle regional dip slightly west of north over most of the area. The regional dip is disturbed in places by flexures over buried granite ridges. These major flexures, together with local, minor flexures and the local thickening and thinning of the beds, are structures favorable for the accumulation of oil and gas.

The Pennsylvanian rocks vary considerably in different parts of the area, but throughout the region consists essentially of a thick series of marine shales, sandstones, limestones, and some conglomerates. Workable coal beds are found in both the Texas and Oklahoma parts of the area. In central and northeastern Oklahoma red shales, sandstones, and conglomerates are found near the top of the Pennsylvanian, and mark the first stages of the change from the marine deposits of the Pennsylvanian to the continental deposits of the Permian.

The Permian deposits are radically different in their lithologic character from the underlying Pennsylvanian, but despite this the division between the two is transitional. Three distinct facies are recognized in the Permian deposits of the Osage Plains area. These are: (1) a marine facies composed of normal marine limestones, shales, and sandstones; (2) a massive "reef" limestone facies; and (3) a lagoonal or "red bed" facies with thin-bedded limestones, gypsum, salt and other evaporites, and "red beds" of continental origin. In the Permian of central Texas, shales and limestones typical of the marine facies predominate; as the beds are traced northward there is a gradual change to the "red bed" facies, and in the vicinity of the Red River, the entire Permian consists of shales, clays, and sandstones with thick gypsum beds in the upper part of the system. In northern Oklahoma interbedded marine limestones appear, but the "red bed" facies is prevalent northward into Kansas and Nebraska where marine sediments again predominate. To the west the Permian disappears under Triassic rocks or under the Tertiary deposits of the High Plains.

In the Osage Plains area many of the interstream divides are capped by beds of sand and gravel as much as 50 feet thick. These deposits are somewhat doubtfully regarded as of early Pleistocene age.

Although Mississippian rocks do not crop out in the Osage Plains area, they underlie the Pennsylvanian rocks throughout much of the region and come to the surface in the Llano uplift, south of the Trinity River tributary area. In Texas the Mississippian is thin and may be missing from geologic highs, such as the Red River uplift.

Wichita, Arbuckle, and Ouachita Mountains

The Arbuckle Mountains in south-central Oklahoma consist of a central core of pre-Cambrian granite and granite porphyry cut by numerous dikes, chiefly of diabase. A thick series of marine sedimentary rocks, mostly limestones and shales which range in age from Cambrian to Pennsylvanian, was laid down over the eroded pre-Cambrian surface. Owing to subsequent uplift and to folding and faulting associated with the orogeny, the beds dip steeply and in places are overturned. Pennsylvanian beds were involved in the folding, but the orogeny had been essentially completed by Permian time, as the Permian beds that lap around the western flank of the Arbuckles are undisturbed.

In the Wichita Mountains in southwestern Oklahoma the central mass of the mountains consists of pre-Cambrian granite, rhyolite, gabbro, and anorthosite intruded into still older quartzite and sandstone. The granite masses have been cut by numerous dikes. The Paleozoic beds that were deposited over this eroded pre-Cambrian surface are similar to those in the Arbuckles and have been correlated with them; but the Mississippian sediments, which attain a thickness of 1,500 feet in the Arbuckles, are absent in the Wichitas, and some of the formations that crop out in the Arbuckles, though probably also present in the Wichita area, are buried under younger rocks. Folding in the Wichita Mountains was more gentle than in the Arbuckles and, except locally, dips do not exceed 25 degrees. The Wichita Mountains are entirely surrounded and partly buried by undisturbed Permian beds, and no Pennsylvanian rocks crop out in the area.

South of the Arbuckle Mountains a section of tightly folded Pennsylvanian rocks, about 20,000 feet thick, is exposed in the Ardmore basin. These rocks, which rest on the Mississippian Caney shale, differ in lithologic character and nomenclature from the Pennsylvanian rocks of the Arbuckle Mountains, but have been correlated with them by means of fossils.

The Ouachita Mountains are in southeastern Oklahoma and southwestern Arkansas. They consist of a tightly folded and overthrust, exceptionally thick, series of marine strata which include formations of all ages from Cambrian to Pennsylvanian. No igneous rocks are known except for a few dikes that cut the Paleozoic rocks. The geologic structure is similar to that in the Appalachian Mountains and is believed by many geologists to be a continuation of the same belt of folding and overthrusting. The main mass of the Ouachita Mountains is made up of a thick series of shales, sandstones, and novaculite ranging in age from Cambrian to Devonian. Overlying the Devonian are some 18,000 to 20,000 feet of Pennsylvanian shales and sandstones, which are distinct from rocks of the same age in the Arbuckle Mountains, and cannot be precisely correlated with them. North and west of the main mass of the Ouachita Mountains, and separated from it by overthrust faults of large proportions, is a belt of Pennsylvanian limestones and shales 8,000 to 9,000 feet thick, resting on the Mississippian, or on the Devonian where the Mississippian is absent. These rocks are very similar to those of the Arbuckle Mountains and have been correlated with them.

To the south the Paleozoic strata of the Ouachita Mountains are covered by Cretaceous deposits of the Gulf Coastal Plain, but a belt of similar rocks has been traced in drill holes across Central Texas.

The High Plains and the Permian Basin

Occupying the part of the Trinity River tributary area west of the Osage Plains, and separated from this physiographic province by an eastward-facing escarpment known as the "break of the plains", is a flat, featureless upland termed the High Plains which lies at an altitude of about 2,500 to 3000 feet. In Texas and New Mexico this upland area is known also as the Llano Estacado. The upland owes its phenomenal flatness, which is broken only by the deep valley of the Canadian River, to a deep mantle of Tertiary gravel and silt derived from the erosion of the Rocky Mountains to the northwest.

During much of the Paleozoic era the region of the present Gulf Coast was occupied by a landmass known to geologists as Llanoria; during Permian time this landmass was bordered by a shallow sea that covered west Texas and eastern New Mexico and extended far to the north. Sediments derived from the Llanoria landmass and from uplands to the west were deposited in the subsiding basin occupied by this sea and gradually filled it. Since most of the sediments so deposited are of Permian age, the region containing them is commonly known as the Permian basin. The first deposits within the basin consisted of an alternating series of marine limestones and shales. As the seas became shallower, natural barriers were formed obstructing the connection to the open sea. Continued evaporation in the partially confined basins or lagoons thus formed resulted in the precipitation of beds of anhydrite, common salt, potash salts, and other evaporites interspaced with beds of clay. Overlying these, non-marine "red beds" of continental origin were deposited. During the entire period deposition was very irregular and marine deposits fingered out laterally into typical "red bed" deposits within short distances. The total thickness of the Permian beds in the Permian basin approaches 14,000 feet. Drill holes near Ochoa in the center of the basin have penetrated 4,000 feet of "red beds", salt, and anhydrite before reaching the underlying marine beds..

Triassic deposits crop out along the eastern edge of the High Plains south of the Panhandle and are known to underlie the High Plains at least as far north as the valley of the Canadian River. They are entirely of non-marine origin and range in thickness from a few hundred feet along the eastern edge of the High Plains to more than 1,200 feet near the center of the Llano Estacado.

In Dallam County, Texas, in the extreme northwest corner of the Trinity River tributary area there are a few scattered outcrops of rocks that are believed to be of Jurassic age and which are correlated with the more extensive Jurassic rocks of Colorado and New Mexico.

Cretaceous beds once covered most of Texas but in the High Plains area they have been mostly stripped away by erosion. The Cretaceous cover still remains in parts of Midland, Glasscock, Sterling, Tom Green, and adjacent counties in the southwestern part of the Trinity tributary area, and isolated patches of Cretaceous sediments occur in the High Plains area.

Gulf Coastal Plain

The Gulf Coastal Plain division of the Trinity River tributary area is a more or less gently undulating plain bordering the Gulf of Mexico; it lies south of the Arbuckle and Ouachita Mountains and east of the Osage Plains. It is composed of strata that dip at a slightly steeper angle than the present land surface, and its gentle seaward slope is, therefore, interrupted by low, landward-facing escarpments which mark the outcrops of the more resistant beds.

The formations exposed in the Gulf Coastal Plain are entirely of Cretaceous, Tertiary, and Quaternary ages. During early Cretaceous time the Llanoria landmass sank below sea level and Cretaceous seas, which extended far to the north, covered almost all of Texas and part of Oklahoma. The Cretaceous strata of the Gulf Coast were deposited in these seas and probably once were continuous with the Cretaceous deposits of the Rocky Mountain area. Cretaceous rocks of the Gulf Coastal Plain rest unconformably on the older rocks and dip under Tertiary strata. They extend down dip for an unknown distance under the younger beds, and come to the surface in many of the salt domes which are prominent geologic features of the Gulf Coastal Plain.

In the Trinity River tributary area the Lower Cretaceous series is composed of calcareous shales, sandstones, thin-bedded limestones, with a bed of anhydrite near its base. The Upper Cretaceous consists mainly of shales, sandstones, chalk, and marls. In northeast Texas some volcanic ash is interbedded with the shales and marls.

One of the most complete sections of Tertiary sedimentary rocks found anywhere in the world is exposed along the Texas Gulf Coast. In the Trinity River tributary area these Tertiary rocks occupy a belt from 140 to 225 miles wide. Marine, shallow water, deltaic, and continental deposits are all present and there is much interfingering and intergrading between the several facies. Beds of volcanic ash, now largely altered to fuller's earth and bentonitic clay, are found at several places in the section, particularly in the Eocene and Miocene deposits. The Eocene deposits contain beds of lignite also.

Overlying the Tertiary beds and bordering the Gulf Coast is a narrow belt of sands and clays of Quaternary age which, except for the stream gravels, are the youngest deposits of the Coastal Plain.

Quaternary Gravels

Quaternary stream and terrace gravels are found along most of the major rivers in both the Texas and Oklahoma parts of the Trinity River tributary area. The gravels that cap the interstream divide in the Osage Plains area have already been described.

Acknowledgments

This report is based largely on information published by the Bureau of Economic Geology, University of Texas, the Oklahoma State Geological Survey and the United States Geological Survey, but many other technical publications were also consulted. The various publications consulted will be found in the bibliography following each chapter.

In the preparation of this report the information was drawn from so many sources that it is difficult to acknowledge them all. Dr. John T. Lonsdale, Director, of the Bureau of Economic Geology, University of Texas, arranged for the collaboration of the Bureau in writing the report, supplied unpublished information on the mineral resources of Texas, and furnished a proof copy of a map of the mineral resources of that State in advance of publication. Dr. H. B. Stenzel and Mr. H. C. Fountain of the same bureau, not only prepared many of the chapters on the mineral resources of the Texas part of the area but Dr. Stenzel also critically reviewed all parts of the manuscript dealing with the geology and resources of Texas. Mr. Robert H. Dott, Director of the Oklahoma State Geological Survey, supplied a number of out-of-print publications of the Oklahoma State Geological Survey and read the parts of the manuscript dealing with the mineral resources and geology of Oklahoma. Mr. John R. Fouts, Manager of the Trinity Imporvement Association and Mr. Forrest L. Park, Engineer for the same organization, provided factual material and out-of-print literature on the area. Mr. Park also accompanied members of the United States Geological Survey on a tour of the southern part of the Trinity River tributary area and his intimate knowledge of the area was very valuable.

Most of the production statistics have been obtained from the Minerals Yearbooks published by the Bureau of Mines, United States Department of the Interior. Published information by the Bureau of Mines is not broken down into smaller units than states. For those minerals in part from the Trinity tributary area and in part from outside the area, the Bureau of Mines has furnished production statistics for the tributary area.

The assistance of Messrs. R. A. Cattell, H. P. Wheeler and H. S. Kennedy of the Bureau of Mines in preparing the chapter in Helium, is gratefully acknowledged.

Bibliography

The literature on the geology of the Trinity River tributary area is voluminous; however, the bulk of the publications discuss in great detail small areas or geologic problems of limited scope, and only a few discuss the area as a whole. The better references on the regional stratigraphy and structure of the Trinity River tributary area are given in the following bibliography.

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SUMMARY OF MINERAL RESOURCES OF THE TRINITY RIVER TRIBUTARY AREA

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The following is a summary of the mineral resources which are found in the three area divisions into which the Trinity tributary area has been divided in this report. Where one or more of the three divisions is omitted for any commodity, it is implied that the commodity is not found in the division omitted. A detailed description of the various mineral occurrences will be found in the main body of the report.

Fuels and Other Hydrocarbons

Asphalt and related bitumens

Trinity River drainage basin -

Found in asphaltic sand stratum of Trinity age (Lower Cretaceous) in Cooke and Montague Counties. Reported from oil seep in Tarrant Clunty. No present production.

Tributary area outside of Trinity drainage basin -

In Texas from oil seeps and impregnated sands in Permian rocks in Coke County; from Pennsylvanian rocks in Stevens County; from oil seeps and impregnated Eocene strata in Anderson and Nacagdoches Counties. In Oklahoma from Permian beds east of the Wichita Mountains in Comanche County; in strata ranging from Ordovician to Cretaceous on north, west, and south flanks of the Arbuckle Mountains; from tar sands of Cretaceous age in Love, Marshal, Johnston, and McCurtain Counties. Also as vein-like deposits of grahamite and impsonite in the Ouachita Mountain area, in Stephens County and in a few other places in the state. Production from Murray County, Oklahoma (Arbuckle Mountain area).

Coal, lignite, and peat

Area subject to periodic flood -

Lignite - Lignite in Yegua formation (Eocene) crops out along Trinity River in Houston and Madison Counties. Lignite belt in Wilcox group (Eocene) crosses river in Henderson, Anderson, Navarro, and Freestone Counties.

Trinity River drainage basin -

Coal - Bituminous coal of Pennsylvanian age found in Archer, Jack, Montague, Wise, and Young Counties.

Lignite - Found in Anderson, Freestone, Henderson, Houston, Leon, Limestone, Navarro, and Van Zandt Counties in Eocene strata.

Peat - Extensive undeveloped peat bogs in Houston and adjacent Counties.

Coal, lignite, and peat (continued)

Tributary area outside of Trinity drainage basin -

Coal - In Texas bituminous coal is found in Archer*, Brown, Coleman, Eastland, Erath, Jack*, Montague*, Palo Pinto, Parker, Stephens, and Young* Counties. Abundant in Pennsylvanian strata in east-central and northeastern Oklahoma where it has been mined from ten different beds. Some of the beds are of mineable thickness beneath hundreds of square miles.

Lignite - From Eocene strata in Bowie, Camp, Cass, Cherokee, Franklin, Freestone*, Gregg, Harrison, Henderson*, Hopkins, Houston*, Leon*, Limestone*, Marion, Morris, Nacogdoches, Panola, Rains, Robertson, Rusk, Smith, Titus, Van Zandt*, and Woods Counties, Texas.

Peat - Peat bogs occur in Houston* County and in a number of other localities in the Texas part of the tributary area, but there is no commercial production from within the area.

Natural Gas

Area subject to periodic flood -

Some natural gas fields are found in the flood plains of the lower part of the Trinity River.

Trinity River drainage basin -

A number of natural gas fields are found within the Trinity drainage basin, particularly in the lower part.

Tributary area outside of Trinity drainage basin -

Natural gas fields are found in almost all parts of tributary area but are most abundant in central Oklahoma and north-central and central Texas. Amarillo field is the largest discovered to date.

Petroleum

Area subject to periodic flood -

A number of fields in the lower part of the Trinity drainage basin are in the area subject to periodic flood.

Trinity River drainage basin -

Comparatively few in the upper part of the basin; considerable number in the lower part.

Tributary area outside of the Trinity drainage basin -

From almost all parts of the tributary area except extreme eastern Oklahoma. Tributary area is one of the richest petroleum regions of the world.

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* Also occurs in the same county in the Trinity drainage basin

Non-metalliferous deposits

Abrasives

Area subject to periodic flood -

Material suitable for grinding pebbles and sand suitable for abrasive use are found in sand and gravel deposits along the Trinity River. Volcanic ash is found in the belt of Jackson and Catahoula strata of Tertiary age which crosses the river in Polk, Trinity and Walker Counties. The Catahoula also contains deposits of rice sand some of which may be in the area subject to periodic flood.

Trinity River drainage basin -

All the abrasives listed above are found in the Trinity basin outside the area subject to flood. In addition, deposits of chalk are found in Upper Cretaceous rocks in the northern part of the basin, but the deposits have not been developed.

Tributary area outside of the Trinity drainage basin -

Grinding pebbles have not been produced commercially in the tributary area although suitable material probably occurs along many of the major streams in the area. A small production of abrasive sand has been recorded from the Texas part of the area; there is no record of it having been produced in Oklahoma although suitable material probably could be obtained from a number of sand deposits in the state. Volcanic ash is found in the Jackson and Catahoula strata in the tributary area east of the Trinity drainage basin. Deposits of volcanic ash are extensive in Oklahoma, the larger deposits being concentrated in the northwest, north-central and east-central parts of the state. Similar deposits are found in several localities in western Texas. There are several producers in Oklahoma, and a small production has recently been recorded from the Texas part of the area. Although there has been no production, deposits of diatomite are known in several widely scattered localities in the High Plains area of Texas, Material suitable for the manufacture of millstones, whetstones and oilstones is reported in Oklahoma but has not been utilized for this purpose to any considerable extent.

Barite

Tributary area outside of the Trinity drainage basin -

Occurs in many places in Permian rocks and western Texas and western Oklahoma but has not been produced commerically in the tributary area.

Building stone

Trinity River drainage basin -

Limestones are abundant in the Cretaceous deposits in the upper part of the basin, but generally are scarce or of poor quality

Building stone (continued)

in the Tertiary rocks in the southern part of the basin. Sandstones are abundant in the Tertiary rocks of the basin but are not everywhere sufficiently consolidated to be used for building stone. Tertiary rocks in the basin also contain beds of glauconitic rock and silicified wood which have been used to some extent as building stone.

Tributary area outside of the Trinity drainage basin -
Limestones are abundant in the Pennsylvanian, Permian, and Cretaceous strata in Oklahoma. Sandstones are present in the tributary area in beds ranging in age from Cambrian to Quaternary. Granite is quarried in the Wichita and Arbuckle Mountains area in Oklahoma. Marble has been quarried in Sequoyah County, Oklahoma and silicified wood in Erath County, Texas. Building stone of one sort or another can be obtained in most parts of the tributary area except the lower part of the Trinity basin and in some of the counties in the High Plains area.

Celestite

Tributary area outside of the Trinity drainage basin -
Production centered in Nolan and Brown Counties, Texas. Reported also from Oklahoma but deposits have not been developed.

Clays

Area subject to periodic flood -
Bleaching clays - Belts of sedimentary rocks containing bentonite and fullers earth cross Trinity River in Houston, Leon, Madison, Polk, San Jacinto, and Walker Counties.

Burning clays - Found in various places in the Trinity basin and some of these deposits may extend into the area subject to flood.

Drilling clays - Some of bentonitic clays listed under bleaching clays probably could be used for drilling clays.

Trinity River drainage basin -
Bleaching clays - Bentonite and fullers earth found in Cook Mountain, Jackson and Catahoula formations in Houston, Leon, Madison, Polk, San Jacinto, Trinity, and Walker Counties.

Burning clays - Abundant in Cretaceous and Eocene formations in the basin.

Drilling clays - Most of production is from outside basin but part of bentonite output is used for drilling clay.

Clays (continued)

Tributary area outside of Trinity drainage basin -
Bleaching clays - Produced from Angelina, Scurry and Briscoe Counties, Texas. Formerly produced in Woodward County, Oklahoma.

Burning clays - Clays suitable at least for the manufacture of common brick and tile are found in almost every part of the tributary area.

Drilling clays - Produced in Angelina, Howard, and Terry Counties, Texas. Suitable material is found also at a number of other places in tributary area, chiefly in northwestern Texas and western Oklahoma.

Dolomite and magnesian limestone

Tributary area outside of Trinity drainage basin -
Best deposits are found in Arbuckle and Wichita Mountains in Oklahoma, but have not been utilized to any great extent. Elsewhere beds are thin and have been used only locally as building stone and for crushed rock.

Gypsum and anhydrite

Trinity River drainage basin -
Reported in drill holes in Cretaceous beds in Freestone, Hill, and Parker Counties, but there has been no production from this source.

Tributary area outside of Trinity drainage basin -
Large reserves in Permian strata in both Texas and Oklahoma parts of area. Operating companies in Blaine County, Oklahoma, and Fisher, Hardeman and Nolan Counties, Texas.

Helium

Trinity River drainage basin -
Some natural gas fields in extreme upper part of basin contain a small proportion of helium but there has been no production from within the basin.

Tributary area outside of Trinity drainage basin -
Most of world production is obtained from Hartley, Moore, Potter, and Oldham Counties, Texas. Other gas fields in tributary area which contain appreciable quantities of helium are in central Texas and north-central Oklahoma.

Limestone, caliche and shell deposits

Trinity River drainage basin -
Limestone - Abundant in Cretaceous rocks in upper part of basin. Generally scarce in lower part of basin.

Limestone, caliche and shell deposits (continued)

Shell deposits - From Galveston bay near mouth of Trinity River.

Tributary area outside of Trinity drainage basin -

Limestone - Abundant in eastern Oklahoma and in Texas east of the High Plains and west of the Coastal Plain. Generally scarce on the Coastal Plain, although some of the older Tertiary formations contain limestone beds. Generally scarce in western Oklahoma and in the High Plains area of Texas.

Caliche - Found as surficial deposits in the High Plains.

Phosphate Rock

Area subject to periodic flood -

Phosphate-bearing beds in Cretaceous and Eocene rocks cross the Trinity River at several places but phosphate deposits are not commercially important.

Trinity River drainage basin -

In Eocene and Cretaceous rocks at many places in the basin, but the deposits are of no present commercial importance.

Tributary area outside of Trinity drainage basin -

In Cretaceous and Eocene rocks both within and without basin. Also in Pennsylvanian and Permian strata at various places in Oklahoma and in Permian rocks in Texas. Deposits are of no present commercial importance.

Portland cement materials.

Trinity River drainage basin -

Raw materials for manufacture of Portland cement abundant in Trinity River basin. Two cement plants are at Dallas; a third at Fort Worth. A cement plant at Houston (outside tributary area) uses kaolinitic clay from Freestone County and oyster shells from Galveston bay.

Tributary area outside of Trinity drainage basin -

Raw materials for manufacture of Portland cement abundant in both Texas and Oklahoma parts of tributary area. In addition to those mentioned above, cement plants are at Waco, Texas, and Ada, Oklahoma.

Sand and gravel

Area subject to periodic flood -

Abundant in flood plain of Trinity River. Principal production is in Fort Worth - Dallas area. Proportion of sand to gravel is high below Dallas but sand and gravel is produced from flood plain near Romayor in Liberty County.

Trinity River drainage basin -

Stream and river terrace sand and gravel deposits are abundant in Trinity basin. Chief production is from Tarrant, Dallas, Sand and gravel (continued)

Kaufman, Ellis, Henderson, and Liberty Counties. Deposits suitable for producing concrete aggregate are scarce below Dallas.

Tributary area outside of Trinity drainage basin -
Occurs as stream and terrace gravels along major rivers. Sand and gravel deposits cap many of the interstream divides in western Texas and western Oklahoma.

lass sand and other specialized sands

Trinity River drainage basin -
From sands in the Eocene Claiborne group in lower part of the basin and from Cretaceous Trinity sand in the upper part. These formations cross the Trinity River and in places may crop out in the area subject to periodic flood.

Tributary area outside of Trinity drainage area -
Eocene and Cretaceous sands mentioned above occur also outside of the drainage basin. Best glass sands in tributary area, however, are found in the Simpson formation and the Arbuckle Mountain area and in the Burgen sand near Tahlequah. Both these f formations are of Ordovicien age.

Soluble salts

Trinity River drainage basin -
Common salt - Found in salt domes in Anderson, Freestone, Leon, Liberty and Chambers Counties. No present production from within the Trinity basin.

Calcium chloride - Probably present in oil field brines from the Trinity basin, but no production has been recorded.

Tributary area outside of the Trinity drainage basin -
Potash - Large reserves in the Permian basin in west Texas but the known deposits are too low grade to compete with the New Mexico deposits.

Common salt - Abundant in salt domes on the Coastal Plain, in bedded deposits in Permian strata in west Texas and Oklahoma, and in saline lakes in western Texas and western Oklahoma. Principal production is from Van Zandt County, Texas, and from Woods, Harmon and Beckham Counties, Oklahoma.

Calcium chloride - Some calcium chloride was produced near Tulsa, Oklahoma, from oil field brines, but no production has been reported since 1936. Permian salt beds in western Texas and Oklahoma also contain calcium chloride but none has been produced from this source.

Soluble salts (continued)

Magnesium chloride - Associated with common salt in Permian strata in western Texas and western Oklahoma. Reported in brines in Permian strata in Borden County, Texas. No present production.

Bromine -- Occurs in alkaline lakes in High Plains area, probably as magnesium bromide. Also in various oil field brines. Small production reported from plant at West Tulsa, Oklahoma, prior to 1936.

Magnesium sulfate - Recovered from shallow well brine in an alkaline lake bed near O'Donnel, Lynn County, Texas.

Sodium sulfate - Produced from alkaline lakes brines in Lynn, and Terry Counties, Texas, and has been reported in alkaline lake brines in several other counties in the High Plains area of Texas.

Sulfur

Trinity River drainage basin -
Development of a sulfur deposit in the Moss Bluff salt dome in Liberty and Chambers Counties is reported being considered by a nationally-known sulfur producer.

Tributary area outside of the Trinity drainage basin -
Although there are a number of salt domes in the tributary area, only the Moss Bluff dome is known to contain commercial quantities of sulfur.

Metalliferous Deposits

Copper

Tributary area outside the Trinity drainage basin -
Found mostly in Permian "red beds" in western Texas and Oklahoma. Several attempts have been made to mine the deposits but all to date have been unsuccessful.

Iron Ore

Trinity River drainage basin -
The east Texas iron ores are derived from the weathering of Weches strata of Eocene age. The iron ore belt crosses the Trinity basin in Robertson, Leon, Houston, and Anderson Counties; but the principal deposits are east of the drainage basin.

Iron Ore (continued)

Tributary area outside of the Trinity drainage basin -
The principal deposits of iron ores are in the belt of Weches strata east of the Trinity drainage basin. In 1944 there were three producing mines in the east Texas area. There are iron ore deposits in the Wichita and Arbuckle Mountains areas in Oklahoma, but the deposits are either too small or too low grade to be an important source of iron ore.

Manganese

Tributary area outside of the Trinity drainage basin -
Found in the Arbuckle and Ouachita Mountains in Oklahoma. There has been a small production from the Ouachita area but the deposits are small and are of marginal grade.

Zinc and lead

Tributary area outside of the Trinity drainage basin -
Some zinc and lead deposits are known in the Wichita, Arbuckle and Ouachita Mountains in Oklahoma and several attempts have been made to mine them but to date all have been unsuccessful.

MINERAL RESOURCES

OF THE

TRINITY RIVER TRIBUTARY AREA IN

TEXAS AND OKLAHOMA

FUELS AND RELATED PRODUCTS

ASPHALT AND RELATED BITUMENS

E. B. Stenzel and K. C. Fountain, Bureau of Economic Geology, University of Texas and T. A. Hendricks, United States Geological Survey.

Bitumens are generally fusible substances of variable color, hardness, and volatility composed principally of complex organic compounds. They are naturally-occurring saturated hydrocarbons substantially free of oxygenated bodies and include all petroleums, natural asphalts, natural waxes, and asphaltites. Petroleum is discussed in a separate chapter.

Asphalt is a species of bitumen of dark color and variable hardness, that is comparatively non-volatile. It is composed principally of hydrocarbons, is essentially free of oxygenated bodies and crystallizable paraffins, is fusible, and is largely soluble in carbon disulfide, yielding water-insoluble sulfuration products. Asphalt may occur in nature in a relatively pure state or may be associated with mineral matter. When the content of mineral matter is great or the amount of asphalt in a rock matrix so small that separation of the asphalt is impracticable the material is called rock asphalt or bituminous rock. A common type of bituminous rock is the bituminous sands or tar sands, which are sands impregnated with bitumen or tar.

Several related substances such as grahamite, glance pitch, and gilsonite are grouped together as asphaltite, which differs from asphalt in that it is a hard non-volatile coal-like solid, static at ordinary temperatures and fusible with difficulty. The asphaltic pyrobitumens differ from asphaltite in that they are infusible and are largely insoluble in carbon disulfide. This group of materials includes elaterite, wurzilite, albertite, and impsonite.

Asphalt, asphaltite, asphaltic pyrobitumens, and bituminous rock occur in natural deposits. They are believed to be the product of metamorphism of asphaltic petroleum. Common asphalt, such as that constituting the organic portion of tar sands, has undergone little change from the original petroleum other than the loss of volatile fractions. However, grahamite, glance pitch, and gilsonite appear to be products of polymerization in which simple molecules of t original petroleum have become rearranged into more complex molecules of higher molecular weight, under the influence of time, heat, pressure, and catalytic agents. These processes are believed to have progressed further to form the asphaltic pyrobitumens.

Asphalt is also manufactured from residual fractions and distillates in the refining of petroleum. Such asphalt is called manufactured or petroleum asphalt, About 88 percent of the total annual production of asphalt and related bitumens in the United States is from petroleum refineries. About 2/3 of one percent of the total domestic production is of gilsonite from Utah, and the remaining production is almost entirely of bituminous rock, more than 2/3 of which comes from Texas and Oklahoma.

The principal use of asphalt is in paving, which consumes between 55 and 75 percent of all asphalt produced as well as virtually all bituminous rock produced. Between 18 and 30 percent of the production of asphalt is used for roofing. Other uses, in the approximate order of their importance, are for waterproofing; emulsified asphalts and fluxes; molding compounds; paints, enamels, japans and lacquers; mastic and mastic cake; pipe coatings; and blending with rubber. In addition there are very many minor uses which together represent a significant consumption.

The physical characteristics that determine the suitability of asphalt for most uses are related to its combined function as a binder and as a water- and weather-proofing material. Principal factors are: uniformity; viscosity and softening or fusing point; solidifying point and hardness or plasticity; adhesiveness; and resistance to moisture and weathering. Purity is important for most uses except paving, and many characteristics are of primary importance to one or more of the numerous special uses. Blending to produce a material to meet specifications is common practice. The high fusing point and low plasticity of grahamite restrict its suitability for many purposes. It is used principally in combination with asphalt and other materials in special products such as bituminous rubber substitutes; small molded articles such as push-buttons, electrical fittings, handles, etc.; automobile battery cases, etc.

Most bituminous rock is mined in open cuts by blasting, and then loading with steam shovel, drag-line, or other mechanical equipment. The asphaltites are generally mined in shafts or tunnels by normal stoping, room and pillar, or longwall mining methods depending on the local conditions of occurrence of the material.

The discussion of methods of processing asphalts and related bitumens will be confined to bituminous rock and grahamite, which are the only two materials of significant commercial possibility in the Trinity River tributary area. Rock asphalts are generally broken down in a jaw crusher, toothed-roller crusher, or a disintegrator, screened to the required size, and blended to the required asphalt content; the material is then treated in a revolving fire-heated cylinder to expel moisture, usually at a temperature of 260 to 300° F. Paving asphalt generally is processed locally and the product transported to the job while still hot. Asphalt has been extracted from asphaltic rock at several plants by boiling the rock in water. In order for this method to be successful, the contained asphalt should have a fusing point not exceeding 90° F. and the mineral matter should be unconsolidated and coarse-grained to permit separation of the asphalt and mineral matter, rapid settling of the mineral matter, and rise of the released asphalt to the surface of the water. The asphalt must be dehydrated later by heating, for which a number of different processes have been used. A number of other processes of separating asphalt from sands and of separating various fractions from asphalt have been considered. Most of these processes are based on extraction with solvents and are not in general commercial use.

Because asphalt and the related bitumens are liquid, semi-solid, and solid, they are transported in a variety of ways. The liquid varieties and others with low melting point are transported in tank cars, tank trucks, metal drums, wooden barrels, and fiber barrels. The more solid varities are shipped as cakes or molded blocks. Some asphalt is melted and run into paper bags which serve as containers and some is shipped as "shot" after granulation by running a stream of molten asphalt into water to chill the drops. Large containers in which semi-liquid asphalt is shipped, such a tank cars or trucks, are generally equipped with heating devices to permit removal of the material at its destination.

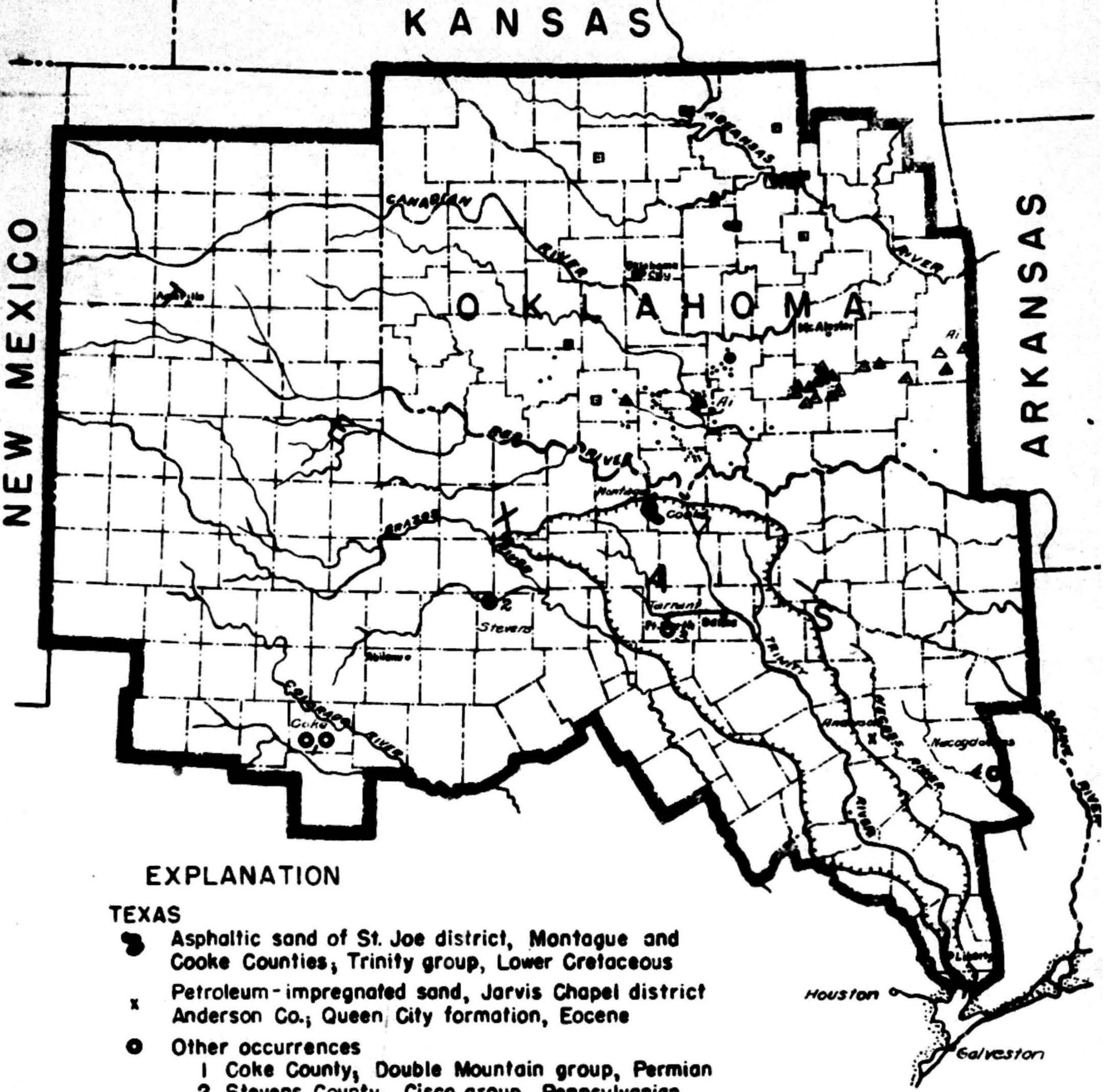
The asphaltic deposits of the Trinity River tributary area in Texas are not being exploited now but some asphalt was produced prior to 1900 in north Texas and east Texas. It was mined by crude methods in open quarries or dug wells and was used locally in paving streets and sidewalks. The oil-impregnated sands of Jarvis Chapel, Anderson County, were used for pavement of small areas in Palestine, Texas. In the town of St. Jo, Montague County, local asphalt has also been used for paving and has stood up well under traffic.

The commercial value of the asphalt deposits of the St. Jo district in Cooke and Montague counties is difficult to evaluate. Its position high on the slopes of natural ridges is ideal for mining with gravity methods, letting the filled cars pull up the empty ones. This is the cheapest form of loading. The character of the rock may present difficulties. The deposit is not thick and the asphalt is in some places irregularly distributed around larger masses or boulders of unimpregnated rock. The overburden too is a problem. Exploitation should in any case be preceded by careful exploration for favorable local deposits.

The commercial value of the oil-impregnated sands from Jarvis Chapel is enhanced by their fairly uniform character which would insure a uniform product.

The asphaltic deposits of the Trinity tributary area in Oklahoma are being exploited. Bituminous rock is blended at an asphalt plant near Dougherty in Murray County, Oklahoma, and is marketed for road-surfacing material. Similar material has been prepared at plants at Ada in Pontotoc County and near Stroud in Lincoln County. There are no plants in Oklahoma engaged in processing relatively pure asphalt or in the fabrication of any of the products that utilize asphalt. The presence of numerous petroleum refineries in Oklahoma and Texas and the large petroleum resources of the tributary area insure a substantial source of supply of manufactured asphalt for many years. An excess of manufactured asphalt for paving purposes is now produced in Oklahoma and Texas, and is shipped to other areas.

The post-war construction program, which is expected to include extensive road construction and repair work as well as construction of buildings should provide an excellent market for asphalt products. Considering all factors of supply of raw materials and potential markets the area appears to be one in which an industry of moderate size engaged in the preparation of roofing materials, water-proofing, weather-proofing, and asphalt paints and cements, might prosper.



EXPLANATION

TEXAS

- Asphaltic sand of St. Joe district, Montague and Cooke Counties; Trinity group, Lower Cretaceous
- x Petroleum-impregnated sand, Jarvis Chapel district Anderson Co.; Queen City formation, Eocene
- ⊙ Other occurrences
  1 Coke County; Double Mountain group, Permian
  2 Stevens County; Cisco group, Pennsylvanian
  3 Tarrant County; Washita group, Lower Cretaceous
  4 Nacogdoches County; Mt. Selman group, Eocene

OKLAHOMA

- · Bituminous rock
- ▲ Grahamite
- Ai △ Impsonite
- ● Asphalt plant
- ▣ Petroleum refinery with aphalt production

DISTRIBUTION OF ASPHALT AND RELATED BITUMENS IN THE TRINITY RIVER TRIBUTARY AREA

Occurrence of natural asphalt and related bitumens in the Trinity River tributary area

Texas

The bituminous sand deposits known in 1902 were investigated by W. B. Phillips (13) 1/. At the present time the following deposits are known:

Cooke County: (1) Four miles southwest of Muenster; (2) 1½ miles west of Muenster: (3) 6½ miles southeast of St. JO.

Montague County: (1) northern extremity of Sampson Ridge east of Devil's Backbone, 3 miles north-northeast of St. Jo; (2) extreme northern point of Gordon Mountain, 4 miles north-northwest of St. Jo; (3) southwest side of Gordon Mountain, 1½ miles north of St. Jo.

The deposits of Cooke and Montague counties apparently form an extensive district in which the asphaltic sand stratum averages locally 3 feet in thickness. Some of the exposed deposits are traceable for about 1 mile on the surface. This stratum is in the upper part of the Trinity sand of the Lower Cretaceous.

Coke County: (1) along Pecan Creek at some distance above its confluence with Brazos River, sporadic oil seepages from the San Angelo and lower Blaine (Flower Pot) sands of the Permian; (2) near Edith post office on Pecan Creek just east of Robert Lee. These seeps and impregnated sands have not been utilized.

Tarrant County: a small spring or seepage of nearly pure asphalt is reported from a small basin 7 miles south of Fort Worth. The pool is 10 to 12 feet in diameter.

Anderson County: vicinity of Jarvis Chapel, about 10 to 12½ miles east of Palestine. The deposits consist of sands impregnated with heavy petroleum and are in the Queen City formation of the Eocene. Following the original discovery of a seepage of heavy oil near Jarvis Chapel a well was put down to a depth of 300 feet, encountering quantities of oil and a small amount of gas. This well is about 300 yards north-northeast of the present Jarvis Chapel, and is within a mile of most of the known occurrences of the asphaltic material, either at the surface or in test holes. The oil-impregnated sands make up three distinct and neighboring deposits extending over a distance of 1.8 miles. The eastern deposit occupies about 20 acres, the central one about 144 acres, and the western one 34 acres, making a total of about 200 acres. The oil-impregnated sands crop out at the surface in the eastern deposit, but elsewhere they lie under a cover of 5 to 40 feet thickness. Their thickness varies from 0.5 to over 10 feet.

Nacogdoches County: oil seeps have long been known and utilized near Chireno. The petroleum occurrence of these seeps and wells dug in

1/ Literature references are given in the bibliography to this paper.

the area of the seeps is more in the nature of a shallow oil field than of minable bituminous sands.

Analyses

	A	B	C	D
Asphaltene - - - - -	1.35	0.45	trace	11.25
Petrolene- - - - - -	9.00	5.31	10.10	12.09
Total bitumen- - - -	10.35	5.76	10.10	23.34
$CaCO_3$- - - - - - - -	trace	0.56	trace	0.00
S - - - - - - - - - -	0.20	0.14	0.50	0.43
SiO_2 - - - - - - - - -	89.65	93.68	89.90	76.71
Total- - - - - - - - -	100.20	100.14	100.50	100.48

	E	F
Total bitumen- - -	8.91	8.56
Sp. gr.- - - - - -	2.06	1.52
Penetration- - - -	very soft	very soft
Ductility - - - -	0	0
Percentage through	#30--100	100
Percentage through	#50--44.7	60.3
Percentage through	#100--2.7	21.5

(A) Sampson Ridge, 3½ miles northeast of St. Jo, Montague County.
(B) Thomas Hoover's place, Cooke County
(C) One and one-half miles west of Muenster, Cooke County
(D) Chapel well, Anderson County
(E) St. Jo. district, Montague and Cooke counties, average.
(F) Jarvis Chapel district, Anderson County, average.
Analyses (A) to (D) from W. B. Phillips (13); (E) and (F) from W. M. Terry (19).

Oklahoma

The natural asphalt deposits of Oklahoma fall into two general groups; tar sands or bituminous rock deposits scattered throughout the east one-half of the extreme southern part of the state; and grahamite deposits in the Ouachita Mountains. In addition, impsonite occurs in two small deposits near Page in LeFlore County within a few miles of the Arkansas state line and near Dougherty in Murray County in the south-central part of the state, and grahamite is reported in a small deposit near Alma in Stephens County.

The bituminous rock deposits are in three general groups. One group of deposits is in sediments of Permian age a short distance east of the Wichita Mountains in Comanche County, Oklahoma. The second group of deposits occurs in limestones, sandstones, and shales of Ordovician to Cretaceous age on the north, west, and south flanks of the Arbuckle Mountains in south-central Oklahoma. The third group of deposits are tar sands in rocks of Cretaceous age in Love, Marshall, Johnson, and McCurtain Counties near the Texas state line in eastern Oklahoma. Two of the principal deposits have recently been studied in detail by the Geological Survey, United States Department of the Interior (7 and 8). One of these, the Sulphur deposit in secs. 15, 21, and 22 T. 1 S., R. 3 E., Murray County, occurs principally in faulted sandstone beds of the Simpson group of Ordovician age. The rock that has been mined has ranged between 6 and 12 percent of bituminous material and has averaged 7 to 8 percent. The second deposit is near Dougherty in sec. 25, T. 1 S., R. 2 E., and sec. 30, T. 1 S., R. 3 E., in Murray County. In this deposit asphalt impregnates beds in the Viola limestone of Ordovician age. The asphalt content of the rock varies but slightly from 3 percent by weight. Rock from these two deposits is mixed together with some pure asphalt to make a paving material. The other deposits are either less extensive or have a lower asphalt content.

The grahamite deposits of the Ouachita Mountain area occur in veins. Most of the veins are in shale and sandstone beds of Carboniferous age, but a few are in limestone, shale, and novaculite of Ordovician, Silurian, and Devonian age. About half of the veins lie parallel to the bedding of the surrounding rock and the remainder occur in fault zones. Most of the veins are less than one foot thick but thicknesses as great as 6 feet have been observed locally. Visible impurities are few.

Reserves

No accurate estimate of the total reserves of the asphalts in the Texas part of the area is possible at this time, though from the extent and thickness reported for the deposits in Cooke and Montague counties, in north Texas, they must be considerable in that region. They are assumed to be present in a more or less continuous stratum about 3 feet thick under the entire extent of the Trinity Cretaceous strata in that part of Texas. The three deposits at Jarvis Chapel in Anderson County contain about 3,700,000 cubic yards of oil-impregnated sands underlying about 200 acres, according to estimate made by the Bureau of Economic Geology of The University of Texas. However, it is not known how much of the deposits is recoverable.

The tonnage of reserves of bituminous rock in Oklahoma cannot be computed because of lack of data on their thickness in some deposits and lateral extent in others. However, it may be stated that the aggregate tonnage is large in relation to past production. The tonnage of grahamite reserves cannot be computed because they have not been prospected or mined sufficiently to supply data on their extent. The total tonnage that could be considered proved on the basis of the scant available data should not exceed 1000 tons, but should an attractive market exist for grahamite from these deposits, it is believed that adequate prospecting of known deposits would reveal many times this amount. The supply of manufactured asphalt to be expected from petroleum refineries in the future is dependent on the oil reserves and is large, but cannot be estimated accurately because of possible modifications of refinery practice, which might change the asphalt output materially.

Producing companies and production

The only company mining asphalt or bituminous material in the Trinity River tributary area at present is the Southern Rock Asphalt Co., Sulphur, Oklahoma, which operates the mines in the Sulphur and Dougherty deposits in Murray County, and produces bituminous rock for road and street surfacing. Production of bituminous rock in Oklahoma and Texas from 1934 through 1943 is given in the following table. The figures include production in Texas outside of the Trinity River tributary area.

	Tons	Value		Tons	Value
1934* - -	290,940	$1,152,331	1939 - -	221,497	$ 684,808
1935* - -	185,013	726,801	1940 - -	282,250	833,248
1936* - -	333,243	1,245,442	1941 - -	446,432	1,197,319
1937* - -	265,895	1,075,832	1942 - -	699,572	2,018,822
1939* - -	206,443	727,032	1943 - -	600,545	1,673,689

* Includes minor production from New Mexico.

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COAL, LIGNITE, AND PEAT

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Coal is a type of combustible rock formed from vegetal matter by heat and pressure operating over a long period of time. It contains varying amounts of mineral matter, but when the content of mineral matter becomes so great that the material is not useable as a fuel the rock is called bone, carbonaceous shale, or some similar term, rather than coal. Coal supplies more than half of the total energy requirements of the world. As the principal source of heat and power it plays a dominant part in industrial development of all countries.

Coals are formed by geologic processes acting on the remains of plants. The nature and composition of a coal is dependent on the composition of the original raw material, that is, the plant remains, and the duration and character of the geologic processes which shaped the plant remains into those sedimentary rock bodies that are called coal seams.

Using the duration and intensity of the geologic processes as a guide, the coals are classified into a continuous series which begins with coals that were affected by geologic processes of short duration and low intensity only, and ends with those that were affected for a long time and with high intensity. That series is roughly represented by the following classes of coal:

Peat---→ Lignite (or Brown Coal)---→ Bituminous Coal----→ Anthracite---→ Graphite

Among these the peat is least affected by geologic processes. In it the plant remains can be separated readily into individual strands and identified as their botanical nature. Peat is of very low specific gravity and has high primary porosity. On the other end of the series, graphite is a material so thoroughly altered that it does not contain any plant structures; it is rather a mineralogical material composed of crystals of carbon, and its organic origin can be surmised only from data other than organic plant structures.

Peat is composed of partly decayed and disintegrated brown to black vegetal matter, the decompositon of which has been greatly retarded by immersion in water. Remains of numerous plant species are identifiable in peat, but its chief component is usually one plant species only, the nature of which differs from deposit to deposit. Peat freshly removed from its bog usually contains 85 to 90 percent moisture, has an apparent specific gravity of up to 1.06, and weighs about 7 to 65 pounds per cubic foot, varying with the moisture content.

Lignite is near the beginning of this series of the classes of coal. It contains more or less clearly separable pieces of plant material identifiable as lignitized roots, leaves, twigs, and tree trunks; but besides this material there is a considerable amount of earthy to dense, more or less friable, material that cannot be identified as a botanical entity without the aid of a microscope. The color of lignite is usually a very dark brown, and the color of the very finely divided material, obtainable on a mineralogical streak plate, is characteristically dark chocolate-brown. For that reason it is perhaps better to call this kind of coal "brown coal", as the word "lignite" implies derivation from wood (lignum)--a derivation which is only partially consistent with the nature of the plant remains that went into the making of lignite. Most lignites are soft, friable or crumbly, have low specific gravity, and comparatively high primary porosity. The large amount of moisture present in mine-fresh lignite is due to its high primary porosity. The specific gravity of lignites is variable and ranges from 1.16 to 1.46; the average is about 1.33.

Bituminous coal is usually brownish-black to black, and the mineralogic streak is brownish to grayish black. Plant structures are only rarely visible to the naked eye but can be detected under the microscope after preparation. The bituminous coals have a glassy or greasy luster on fresh crossbreaks. They are considerably harder than lignites and more coherent. The natural porosity is low and they average about 1.40 in specific gravity.

The principal use of coal is as a domestic fuel and for steam generation, both in stationary engines such as power plants, and in mobile engines such as railroad locomotives. The by-products resulting from special treatment are very many and have manifold uses. Coke is a residue obtained by distillation of certain types of bituminous coals whereby most of the volatile materials are driven off as gases and the fixed carbon, or coke, left behind. This residue is then used directly as a fuel, in the manufacture of water gas, in blast furnaces in the making of steels and in a great variety of metallurgical processes. The volatile fractions obtained by the distillation of coals contain many valuable hydrocarbons and other substances that can be recovered and used. Among the many by-products are volatile fuels and tars which can be further processed and made to yield dyes, solvents, drugs, and other chemicals. Only the coals with a high fixed carbon ratio are suitable for making coke.

Lignite can be burned as it comes from the mine, but its efficiency is much less than that of the harder coals. Special types of grates and methods of stoking are necessary to achieve the complete burning of lignite. However, when fashioned into briquettes, lignite can be made to approach some of the other coals in utility and efficiency. Both lignite and coal have been used in the finely ground or powdered form for injection into furnaces or boilers somewhat after the manner of a gaseous or liquid fuel. This method achieves a nearly complete consumption of the fuel.

In the United States, peat has never been burned on a commercial scale as in some European countries, and its principal employment is in soil improvement. About 93 percent of the peat sold in the United States in 1940 was used for soil conditioning, the remainder being used in mixed fertilizers, litter for barns and poultry yards, and as packing material for eggs, shrubs, fruits, vegetables, and fragile articles. None was reported as used for fuel.

Coal is mined in open pits by stripping off the overburden and in underground mines. Underground mining in general is by the room and pillar method or the longwall method, either of which may be used in a shaft mine or a drift or slope mine. The coal may be undercut by machine and broken down by explosives, or may be shot down from solid faces. The mined coal is hauled to the mine tipple where it is loaded directly to cars for transportation if it is to be used as "run-of-mine" coal. Most coal, however, is classified into size grades by screening. If the coal has a high ash content the finer sizes are cleaned by washing. For coking, coal with suitable coking properties from two or more mines are commonly blended in definite proportions to supply a raw material with the best possible coking properties.

Most coal is transported by railroad but some coal for local markets is hauled by truck. Much coal is shipped by barge in Europe and in some parts of the eastern United States. Bituminous coal is generally shipped in open cars and may be stored in the open. The tendency of lignite to slack and to burn by spontaneous combustion requires that it be protected from the weather, both in shipping and in storage.

Coal, Lignite, and Peat in Texas

Extensive coal-bearing strata occur in the Trinity River tributary area of Texas and contain deposits both of bituminous coal and lignite; the former is the belt of Pennsylvanian rocks that crop out near the headwaters of the Trinity River and the latter in the Eocene beds in the southeastern part of the area. In addition to coal and lignite, deposits of the related substance, peat, are present in areas adjacent to the lower reaches of the Trinity River. However, the introduction of more desirable or cheaper fuels, largely products of the petroleum and gas industry, has made serious inroads in the production and utilization of the coal resources of the Trinity River area. Large scale production of the bituminous coals has ceased, along with a severe decline in that of lignite.

In Texas, processing of the coals, especially lignite, for enhancing the fuel value, has met with little success. The natural adaptation of certain European brown coals to the manufacture of briquettes led to the early inference that the Texas material also might be treated with similar success, but experimentation has so far not been successful, although the feasibility of manufacturing certain dehydrated products is indicated.

A small amount of lignite is now being used in the manufacture of activated carbon (8) 1/, chiefly for use as a filtering material.

Tests and analyses have shown that some of the bituminous coals would make fairly good coke but that their sulfur content is too high to make them desirable for blast furnace use (19). The Thurber coal, according to Baker (22), will coke. Its B.T.U. value ranges from 11,800 to 13,750; the fixed carbon from 40.8 to 52 percent.

1/ Literature references are given in the bibliography.

The annual report of the mining industry of Texas for the year 1928, some ten years after the beginning of the sharp decline in coal mining operations, summarizes the mining methods as follows:

> "The majority of the bituminous mines of Texas are operated by the long-wall method and single entry plan. The lignite mines are all room and pillar with double entries. All bituminous mines are shaft mines. Of the lignite, about two-thirds are shaft mines, the other third using slopes.
>
> "Steam hoists are used at practically all of the mines. The majority use mule haulage, a few use electric and gasoline motors and rope haulage.
>
> "The majority of the mines are ventilated by fans, a few are ventilated by furnace. Of Texas' output, approximately 74% is mined by hand, 1% by machines, and 25% is shot off solid. None of the lignite tonnage is mined by machines except the strip mining, which is mined by steam shovels. There are two different companies of this kind operating in the state at this time."

Later statistical reports of the United States Bureau of Mines indicate a progressive increase in stripping operations, the details of which are concealed by including the Texas data with those of other states

Underground mining by hand had always obtained in the bituminous fields until in 1940, when a small tonnage was reported as cut by machines.

Future production of Texas coals depends on very many economic factors. Coal as a fuel for home use has probably only a very limited future. At present this field is served by natural gas wherever the market is a concentrated one; such as in the most populous settlements. These settlements will probably continue to be served by natural gas as long as this fuel is so abundant. This condition would tend to restrict the home fuel market considerably.

The most promising outlet for the coals as fuel is in the industrial field and in the fuel supply of power plants in such areas where natural gas is not easily available, but where the coals are conveniently located. The successful operation of the University of Texas power plant in Austin with lignite is an example of this sort. Another possible future use of the coals is in conjunction with chemical extraction plants where the coals could be used not merely as fuel but as a raw material for chemical extraction.

However, should in the future the production of petroleum and natural gas not keep pace with the continuously rising demand for these products, then conditions for production of coals might change so much that a new era of economic exploitation of the coals might arise. Under such conditions coals might be produced again in quantities equal to, or greater than, were taken from the ground in the years 1917 to 1920.

The outlook for future uses of some of the Pennsylvanian coals of Texas is not bright. Seams that are only 20 to 24 inches thick and have a high sulfur content cannot be mined cheaply, nor can they find many uses.

Peat produced in the Trinity River area might find uses as soil conditioner in nearby situated plant nurseries and for commercial florists. Such uses would by their nature have to be small and locally restricted so that the peat would not have to be shipped for long distances. In normal times high quality peat from European countries can be delivered cheaply by ship to the sea coast of the United States and is in competition with locally produced peat.

Occurrences Within the Trinity River Tributary Area in Texas

Bituminous Coals--Workable deposits of bituminous coals in the Trinity tributary area are found in strata of Pennsylvanian age in a number of north-central Texas counties: Archer, Brown, Coleman, Eastland, Erath, Jack, McCulloch, Montague, Palo Pinto, Parker, Stephens, Wise, and Young. (Fig. 3) The various beds range from Lower to Upper Pennsylvanian in age, and the three most important of them represent all three divisions of Pennsylvanian strata outcropping in the area, namely, the Strawn, Canyon, and Cisco divisions.

The Thurber coal, of Strawn age, occurs in the base of the Mineral Wells formation and has been mined at Thurber in Erath County, at Gordon and Strawn in Palo Pinto County, and at Rock Creek in Parker County. The average thickness of the Thurber seam is about 2 feet.

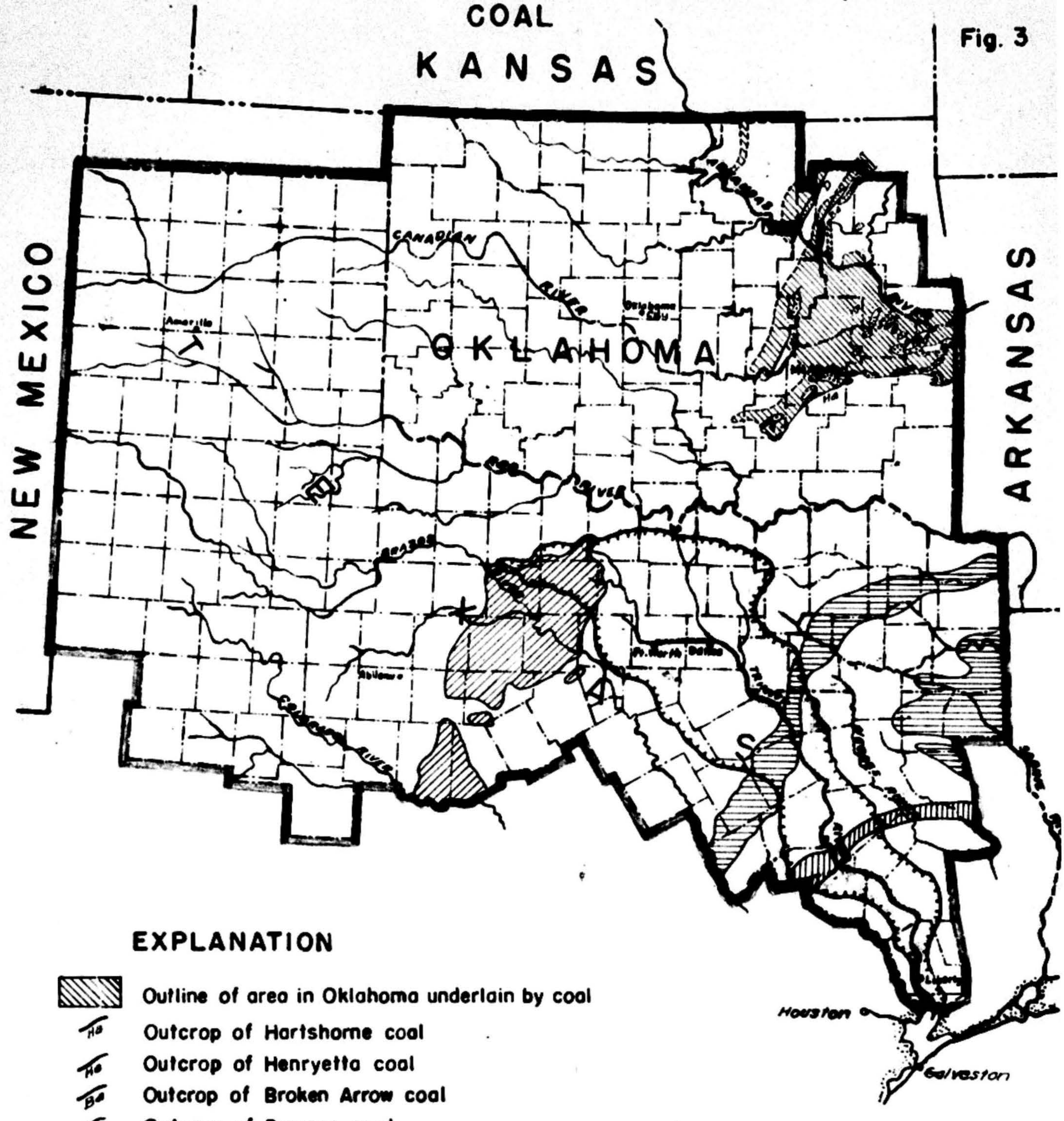
The Bridgeport coal, at Bridgeport, Wise County, averaging about 20 inches in thickness, is in the upper part of the Palo Pinto formation, Canyon group. Mining operations in this bed were the last to close down in the state.

The Chaffin coal, in the Thrifty formation of the Cisco group, occurs only in the Chaffin mine near Waldrip in McCulloch County, and is about the same thickness as the Bridgeport seam and, like the latter, is associated with limestone.

In addition to the above well-known seams, which have been more or less accurately traced over considerable areas, other beds of less certain relationships are known and others continue to be discovered from time to time. Several thin coals in the stratigraphic vicinity of the Chaffin seam are ordinarily encountered over a wide area in bore holes. These center about Young County and can be traced down dip to the west where they are replaced by oil sands occupying a similar stratigraphic position. One or more of these coals has been mined in the past at Newcastle, Young County, and near Jermyn, in Jack County.

In the report on Palo Pinto County, Plummer and Hornberger (20) name three coals in addition to the Thurber and give information as to their extent, thickness, and possibilities of commercial development. These are the: (1) Dalton coal, between 9 and 10 feet thick, occurring in the Graford formation; (2) Abbott coal, $2\frac{1}{2}$ feet thick and occurring in the Brazos River sandstone, Mineral Wells formation of the Strawn group; and (3) Sunday Creek coal, 65 feet below the upper Santo limestone

Fig. 3



EXPLANATION

- Outline of area in Oklahoma underlain by coal
- Outcrop of Hartshorne coal
- Outcrop of Henryetta coal
- Outcrop of Broken Arrow coal
- Outcrop of Dawson coal
- Areas in Oklahoma in which coal has been mined

- Outcrop area of Pennsylvanian strata containing bituminous coals in Texas
- Outcrop area of Eocene - Wilcox strata containing lignites in Texas
- Outcrop area of Eocene - Yegua strata containing lignites in Texas

DISTRIBUTION OF
COAL AND LIGNITE IN THE TRINITY RIVER TRIBUTARY AREA

of the Millsap Lake formation, Strawn group. This seam is said to be like the Thurber coal but somewhat thinner. It is a little less than 2 feet thick. The Dalton seam, it will be noted, is much thicker than other known coals in the area.

Lignites - Deposits of lignite are widespread in Eocene strata in the southeastern part of the Trinity tributary area, particularly in the Wilcox group of sediments (Fig. 3). Some deposits of less extent and importance occur higher in the section in the Yegua formation of Claiborne age. Counties in the area crossed by the lignitic belts are as follows: (*Indicates past or present commercial production.)

Anderson*	Franklin	Hopkins*	Morris	Robertson*
Bowie	Freestone	Houston*	Nacogdoches*	Rusk
Camp	Gregg	Leon*	Navarro	Smith
Cass	Harrison*	Limestone	Panola	Titus*
Cherokee	Henderson*	Marion	Rains*	Van Zandt*
				Wood*

The Rockdale member of the Wilcox formation contains large deposits of lignite in the western part of Anderson County and has been mined at the Palestine salt dome.

In Bowie, Camp, Cass, Cherokee, and Franklin Counties, the known lignite deposits have received little or no development. The same is true of Freestone County, where a 25-foot seam occurs near Turlington. Many lignite exposures in the county show evidence of having burned in place through natural causes (14), after the manner of the porcellanites of Trinidad and the burned rocks of northern-central United States. The Gregg County lignite resources also lack development.

Harrison County has been an important producer of lignite in the past from mines near Marshall, and there is some production at present. Lignite from mines about 12 miles to the southwest are utilized by a plant in that city in the manufacture of activated carbon.

Most of the central and western parts of Henderson County are underlain by lignite, which crops out in places near Athens. The county has been a large producer, and mines are now in operation at Malakoff.

Lignite mines near Como in Hopkins County were in operation from sometime before 1909 to about 1928, according to annual reports of state mine inspectors, whose duties and functions expired near the latter date.

Yegua lignite crops out in southern and southwestern Houston County and along Trinity River. A 6-foot bed near Lovelady was mined from 1907 to 1930. During the same period a seam about 9 feet thick in the Wilcox was worked near Boar Grass and Evansville in Leon County. Information about these mines is given by H. B. Stenzel (25).

Wilcox lignites also occur in the southeast part of Limestone County and along Sulphur Fork in Morris County. Similar beds of less than commercial thickness are found in Marion County on Big Cypress Creek and on the north side of Caddo Lake. No development of any of these occurrences has been reported.

Nacogdoches County was listed among the producers in the report of the state inspector for 1928, with mines near Garrison; and a mine at Ginger, in Rains County, was listed in the report of 1909. Dumble (6) mentioned outcrops near Emory in the same county, in what is now called the Wilcox group.

Kennedy (13), in 1893, reported on the lignite occurrences in Robertson County, particularly at Calvert Bluff, which deposits were being developed in 1909.

Non-commercial deposits are widespread in the Yegua of Rusk County. Smith and Van Zandt Counties have numerous exposures of Wilcox lignites.

Important Wilcox lignite beds near Alba, in western Wood County, have been in intermittent production since 1890 to the present.

Peat - Peat bogs are found in the Trinity River tributary area in the outcrop area of the Carrizo sand and the Sparta sand of the Claiborne group. Extensive bogs occur in eastern Houston County. These bogs have not been investigated from the point of view of commercial production of peat, and peat is not produced in the area, although there has been a small production from Lee County, outside the tributary area.

Reserves

Estimates on reserves of Texas coal and lignite, most of which are located in the Trinity River tributary area, have long pointed to a prodigious supply. The north Texas bituminous coal beds underlie an area in excess of 8,000 square miles, with a total reserve estimated at 3 billion tons. Texas lignite areas cover an estimated extent of 60,000 square miles, of which about 63 percent are in the Trinity River tributary area. The total Texas lignite reserve has been placed at 30 billion tons.

Accumulated total production to the end of 1943 for the entire state of Texas was 60,499,000 tons, a total less than 2/100 of 1 percent of the estimated reserves of coal and lignite. When it is considered that it has required more than 60 years to reduce the reserves by this small amount, their enormity is at once evident.

Production

Bituminous Coal in Texas Portion of Trinity River Tributary Area

Year	Production (Net Tons)	Value	Per Ton	Producing Counties	Mines	Remarks
1934	15,502 a/	$42,000 a/	$2.70	Brewster*, Palo Pinto	3	a/ Includes Brewster County*
1935	17,112 a/	46,000 a/	2.70	Same	3	
1936	21,507 a/	--	--	Brewster* Palo Pinto, Wise, Young	-	
1937	44,060 b/	--	--	Palo Pinto, Webb*, Wise, Young	-	b/ Includes Webb* County
1938	33,781 (?)	--	--		-	
1939	8,000	26,000	3.23	Palo Pinto, Wise	4	
1940	14,137 b/	48,000 b/	3.42	Palo Pinto, Wise, Webb*	3	
1941	15,482	53,000	3.41	Palo Pinto, Wise	3	
1942	13,210	55,000	4.17	Same	3	
1943	9,097	39,000	4.32	Palo Pinto	-	
Total	191,838					

*Indicates counties not in Trinity tributary area.
All data from publications of United States Bureau of Mines

Lignite in Texas Portion of Trinity River Tributary Area

Year	Production (Net Tons)	Value	Ton	Producing Counties	Mines	Remarks
1934	561,566	$939,000	$1.69	Anderson, Harrison, Henderson, Titus, Wood	9	
1935	562,129	460,000	1.22	Same	9	
1936	651,952	509,000	0.78	Harrison, Henderson, Titus, Wood	8	
1937	707,788	559,000	0.79	Same	8	
1938	846,219	679,000	0.80	Same	8	
1939	727,547	809,000	1.11	Henderson, Titus, Wood	8	
1940	532,471	589,000	1.11	Same	8	
1941	258,135	245,000	0.95	Henderson, Titus	6	
1942	290,969 a/	246,000 a/	0.85	Henderson, Milam*, Wood	5	a/ Includes Milam* County
1943	144,144 a/	127,000 a/	0.88	Same	3	
Totals	5,282,920	5,162,000				

*Indicates county not in Trinity River tributary area.
All data from publications of United States Bureau of Mines.

Coal in Oklahoma

Bituminous coal is abundant in east-central and northeastern Oklahoma (Fig. 3). It has been mined in considerable quantities from ten different coal beds, which are from oldest to youngest: Lower Hartshorne, Upper Hartshorne, McAlester, Stisler, Cavanal, Lower Witteville, Upper Witteville, Henryetta, Broken Arrow, and Dawson. Some of the beds, such as the Lower Hartshorne and McAlester coals, are known to be of mineable thickness beneath hundreds of square miles. Others, such as the Henryetta and Cavanal coals, are somewhat less extensive, and still others, such as the Broken Arrow and Dawson coals, are generally thin but are mineable near the surface in limited areas. Most of the coal produced from the Broken Arrow and Dawson beds has been mined from open cuts, whereas most of that produced from other beds has come from underground mines. All of these coal beds occur in rocks of Carboniferous

(Pennsylvanian) age. In the southern and extreme eastern part of the Oklahoma coal field, the strata have been folded rather intensely; so that at most places coal near the surface dips 20 degrees or more, and gently dipping coal generally lies a thousand feet or more beneath the surface. In the northern part of Oklahoma the rocks are less folded and the Henryetta, Broken Arrow, and Dawson coal beds are nearly horizontal.

Much of the coal produced in the Trinity tributary region of Oklahoma is used in steam power plants, for minor industrial purposes, and for the heating of buildings. The majority of the railroads now use diesel engines for major hauls, with the result that coal-burning engines are used only for switching and on branch lines. Coal from the eastern part of the Oklahoma field was coked in considerable quantities about 1900, but the only recent use of these coals for coking has been in steel plants in Texas that have been operated principally as war industrie. Most of the coal of eastern Oklahoma is suitable for coking, particularly if the various coals are properly blended. Both fuel oil and natural gas are abundant in this area and have supplanted coal in places. In most industries, except such specialized ones as glass manufacture, coal is a satisfactory fuel and the existence of adequate coal resources assures a supply of fuels in case petroleum and natural gas resources diminish greatly.

The reserves of bituminous coal in Oklahoma were estimated at 54,755,853,000 net tons, as of 1937. Production and mining losses since that time, and deduction of the amount of coal in areas outside the Trinity tributary area would still leave more than 50 billion tons of unmined bituminous coal within the Trinity tributary area in Oklahoma.

There were 98 mines in Oklahoma, from each of which more than 1,000 tons of coal was produced in 1942, and there were 66 wagon mines with a production of less than 1,000 tons each. Eleven of the mines with more than 1,000-ton production were strip mines that produced 1,100,800 tons of coal, employed 423 men, and worked an average of 231 days during the year. The production of bituminous coal in Oklahoma from 1934 through 1943 is given in the following table. The production from Craig County which is outside the tributary area is included.

All data from publications of the United States Bureau of Mines

Year	Net Tons	Value
1935	1,229,000	2,879,000
1936	1,540,000	---
1937	1,600,000	---
1938	1,245,000	---
1939	1,188,000	2,507,000
1940	1,646,000	4,016,000
1941	1,771,000	4,693,000
1942	2,387,000	6,779,000
1943	2,838,000	8,968,000
1944	3,209,000	---
Total	17,653,000	

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NATURAL GAS

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Natural gas in the broad sense is any naturally occurring gas that is present beneath the surface of the ground. In normal usage, however, natural gas is restricted to naturally occurring inflammable gases consisting principally of hydrocarbons and occurring beneath the surface of the ground. Most natural gas is made up of a mixture of pure gases, principally methane (CH_4), ethane (C_2H_6), propane (C_3H_8), and butane (C_4H_{10}), with minor amounts of nitrogen, carbon dioxide, and oxygen. Helium occurs as a minor constituent of natural gas in some areas.

Natural gas is inflammable, is usually lighter than air, is color less, generally has a slight, sweet odor, and generally is under considerable pressure underground. When impurities are present in considerable amount, these properties may change. If hydrogen sulfide is present in appreciable quantities, the gas is called "sour gas" and is unsatisfactory for many uses unless the hydrogen sulfide is removed. Gases containing a relatively small proportion of gasoline vapors are termed dry gases and those with relatively large amounts are wet gases. Wet gases are commonly associated with oil underground, though the two may not be produced from the same well. Gas which is collected and utilized from a producing oil well is known as "casing-head" gas. The extraction of natural gasoline and other liquid hydrocarbons by collecting the vapors from "casing-head" gas is an important by-product of the oil production in some oil fields.

In many parts of the country vast quantities of natural gas have been allowed to escape into the atmosphere because oil was the only product sought by well drillers. The gas accompanying the oil in the reservoir was only considered desirable insofar as it assisted in bringing the oil to the surface. Some gas wells have been allowed to blow free for years, not only wasting a highly valuable fuel, but also lowering the reservoir pressure and the ultimate recovery of oil from the reservoir. Laws have been passed in many states, however, forbidding or restricting this practice. In addition many pipelines have been built in recent years to convey natural gas from the producing fields to the markets. The search for sources of natural gas now proceeds hand in hand with the search for oil, and annual production and consumption of natural gas is still on the increase.

Natural gas is used almost entirely for heating purposes, both in industry and for domestic use. It constitutes one of the most satisfactory fuels because of the cleanness, efficiency and convenience of its use, and it is superior to manufactured gas because of its higher heating value. Natural gas is becoming more and more popular in the heating of homes with the result that consumption of gas shows a strong fluctuation between the summer and winter months.

In addition to its use as a fuel, natural gas is also utilized in the manufacture of carbon black. The flame from a gas jet is thrown against a chilled surface on which the carbon collects and from which it is removed at periodic intervals. Natural gas is also used in the manufacture of some organic chemicals such as plastics, and great expansion may be expected in this industry as additional methods of breaking down and recombining the constituents of the gases are developed. Some natural gas contains sufficient percentages of helium to be valuable in the production of that rare and strategic element. Carbon-dioxide gas from wells has been used in the manufacture of dry ice, but no important carbon-dioxide wells are present in the Trinity River area.

Natural gas is transported almost entirely by pipeline, although butane gas for use in isolated homes is transported in pressure cylinders by truck. It may be used directly as it comes from the pipes, or it may be stored for short periods of time in large cylindrical tanks from which it is distributed by numerous small pipes to local consumers. The usual practice is to control the flow of gas from the wells to conform to the demand. Where gas is collected as a by-product of oil production, this cannot be done, however, and gas in excess of the immediate demand must either be stored or wasted. Storage above ground in large quantities is prohibitively expensive; so that in some fields the gas is pumped back into the underground reservoir from which it came. It thus helps to maintain reservoir pressure, and is also available for future use as needed. In places gas has also been stored underground in exhausted reservoirs, to be withdrawn at a later date. Thus the seasonal variations in natural gas consumption can be met, by storing excess gas produced during the summer months and withdrawing it during the winter months when demand exceeds supply.

Natural gasoline and other liquid hydrocarbons are normally collected from "casing-head gas" or wet gas near the sites of the wells. Transportation of these liquids to markets is then by pipeline, tank car or tank ship. Where the haulage to waterways connecting with the ocean is not excessively long, ocean-going tankers normally afford the cheapest means of transportation to distant coastal markets.

Nearness to markets was for many years the chief factor in determining whether natural gas would be utilized when found. In recent years, however, longer and longer pipelines have been built to carry natural gas to larger cities and to other industrial areas. A network of gas pipelines now crisscrosses the southwest, midwest and northeast parts of the country and some pipelines have been built in other sections. New England, the south Atlantic coastal region, the Pacific Northwest, and Nevada are the only large areas of the country which as yet have no natural gas pipelines.

Natural gas occurs abundantly in the Trinity River tributary area, especially in north-central and northwest Texas and central and eastern Oklahoma (Fig. 4). It is found in commercial quantities, principally in rocks of Pennsylvanian, Permian, Cretaceous and Tertiary age, but has also been found in older rocks. Along the Gulf Coast it occurs in salt domes, and further inland it has been trapped in folded and faulted structures and in stratigraphic traps.

The Amarillo gas field in the Panhandle of Texas is the largest gas field in the world. A considerable part of the gas is, however, sour and has not been utilized. The gas occurs in rocks of Permian age along a broad east-west trending arch. Other important gas fields are the Carthage field in Panola County, Texas, where the gas occurs in Lower Cretaceous rocks, and the fields of the Arkansas Valley of east-central Oklahoma, where the gas occurs in Pennsylvanian rocks. In the Carthage field the gas is of the wet type; whereas in the Arkansas Valley fields the gas is dry, and no oil is found with it, nor does oil occur in other stratigraphic horizons in the region. Numerous other gas fields are found in almost all parts of the Trinity River tributary area, but they are most abundant in central Oklahoma and north-central and central Texas. Some of the gas has oil associated with it and some is of the dry type.

The reserves of natural gas in the Trinity River area are large, but figures for gas reserves are not as meaningful as with petroleum because some of the gas which is produced in the future will continue to be wasted, and much of it will be used in repressuring oil reservoirs to increase the production of oil rather than being utilized directly. The Petroleum Administration for War estimates the proved reserves of natural gas in Texas on January 1, 1945 to be 64 trillion cubic feet, and in Oklahoma to be 6 trillion cubic feet. About half of the Texas reserves lie in the Trinity River tributary basin, with the Amarillo field in the Panhandle region accounting for the major share. Almost all of the proved Oklahoma reserves are within the Trinity tributary area.

With natural gas, as with oil, the producing companies are extremely numerous and include most of the major oil and gas companies of the country and many of the smaller ones. Production figures of marketed gas for the states of Oklahoma and Texas for 1934 to 1943 are given below. Almost all of the Oklahoma production comes from the Trinity River tributary area, but only about half of the Texas production is within the Trinity area. Figures are given in millions of cubic feet.

	Oklahoma	Texas
1934	254,457	602,976
1935	274,313	642,366
1936	280,481	734,561
1937	296,260	854,561
1938	263,164	882,473
1939	250,875	979,427
1940	257,626	1,063,538
1941	234,054	1,086,312
1942	269,704	1,170,345
1943	285,045	1,323,885

The table shows that production and marketing of gas in Oklahoma has been relatively stable over the 10-year period; whereas the production from Texas has shown a steady increase with the volume marketed in 1943, being slightly more than twice that of the 1934 volume. This has been due in part to the building of many new pipelines in Texas to tap older fields whose gas had not previously been utilized, and partly to the discovery of more new fields with larger gas production in Texas than in Oklahoma.

Production of gasoline and other associated liquid hydrocarbons from natural gas also increased steadily in Texas over the 10-year period 1934-1943, but in Oklahoma a peak was reached in 1937, and there has been a marked decline since that time. The production figures in thousands of gallons for the two states are given below.

	Oklahoma	Texas
1934	355,438	466,570
1935	379,913	516,748
1936	418,591	520,547
1937	492,290	615,281
1938	468,499	685,920
1939	436,123	770,047
1940	399,369	932,040
1941	362,247	1,180,221
1942	336,707	1,207,901
1943	307,384	1,192,526

A list of the companies producing carbon black in the Trinity River tributary area is given in the following table. Most of the plants are located in the Panhandle district of Texas:

Name of Company	County	State
Cabot Carbon Co.	Texas	Oklahoma
General Atlas Carbon Div. of General Properties Co., Inc.	Texas	"
Charles Eneu Johnson & Co.	Pontotoc	"
United Carbon Co.	Beckham	"
Cabot Carbon Co.	Carson, Gray, and Hutchinson	Texas
Carbon Blacks, Inc.	Gray	"
Coltexo Corporation	Gray	"
Columbian Carbon Co.	Carson, Gray, Hutchinson, Moore	"
Columbian-Phillips Co.	Moore	"
Combined Carbon Co.	Hutchinson	"
Continental Carbon Co.	Moore	"
Crescent Carbon Co.	Hutchinson	"
Crown Carbon Co.	Moore	"
General Atlas Carbon Div. of General Properties, Co., Inc.	Gray	"
J. M. Huber Corporation	Hutchinson	"
Moore County Carbon Co.	Moore	"
Panhandle Carbon Co.	Hutchinson	"
Peerless Carbon Black Co.	Gray	"
Texas Elf Carbon Co.	Gray, Stephens	"
United Carbon Co.	Hutchinson, Moore	"

Most of the carbon black produced from natural gas in the Trinity River tributary area comes from the Amarillo gas field in the Panhandle of Texas, and two of the three Oklahoma counties in which carbon black plants are located are adjacent to the Texas Panhandle. The production

of carbon black from natrual gas in Oklahoma and Texas, 1934-1943, is shown in the following table. Figures are in thousands of pounds.

	Oklahoma	Texas
1934		262,290 1/
1935		287,847 1/
1936	18,238 2/	333,906
1937	23,157 3/	421,068
1938	20,401 3/	417,104
1939	20,258 4/	453,174
1940	33,287 4/	479,895
1941		480,212
1942	24,318	434,889
1943	31,411	407,345

1/ Includes Oklahoma and Wyoming production.
2/ Includes Wyoming production.
3/ Includes Wyoming and Kansas production.
4/ Includes Kansas production.

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PETROLEUM

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Petroleum is an inflammable oily mixture of natural hydrocarbons. In general petroleum is divided into two types: those with a high ratio of hydrogen to carbon which are classed as having a paraffin base, and those with a lower ratio of hydrogen to carbon which are classed as having an asphaltic base.

Petroleum varies greatly in exact composition from dark heavy oils with few volatile constituents to green and amber light oils consisting mainly of easily volatile constituents. The density of petroleum is generally expressed as its Baume or A.P.I. gravity. As petroleum occurs underground it is almost invariably associated with hydrocarbon gases. When the petroleum is brought to the surface the gaseous constituents leave the liquid and carry some of the lighter liquid constituents with them. The liquid fraction that can be recovered from the gases is generally called "casinghead gasoline".

Films of iron oxide and other inorganic materials on water are often confused with petroleum, but are easily distinguishable because they are insoluble in chloroform, carbon tetrachloride and other standard solvents for organic compounds.

Petroleum is used principally as a raw material for the production of gasoline, kerosene, diesel oil, lubricating oil, fuel oil, asphalt, and organic chemicals for medical use, use in paints and varnishes, and in making synthetic rubber. Asphaltic crude oils generally yield gasoline with a high octane rating and low volatility on distillation, with the reverse being true of gasolines from paraffinic crude oils. Refinery practice can, however, be adjusted to control the nature of the gasoline from most crude oils. Highly paraffinic oils yield kerosene of high quality, whereas the reverse is true of kerosene fractions from asphaltic crude oils. Diesel oil fractions from the more paraffinic crude oils, as they become higher in boiling range, are wax-containing, so that their inclusion into diesel oil is limited because they reduce the tendency of the oil to flow. Paraffinic crude oils generally yield good lubricating oils but generally require dewaxing or solvent extraction to remove napthenic fractions. Improvements in processing have greatly increased the range of crude oils suitable for the production of high quality lubricants. Fluidity is the most essential quality of fuel oil, which is a residue or mixture of residues from distillation or cracking of crude oil. The straight run residues of asphaltic crudes are generally more fluid than those of paraffinic crudes. Asphalt, as would be expected is produced from the crude oils with an asphalt base.

Petroleum is produced almost entirely from underground reservoirs by drilling. When oil-bearing strata are penetrated by a drill hole the oil flows to the surface if it is under considerable pressure underground or requires pumping if the pressure is low. After a field has been in production for some time the pressure generally declines and wells that flowed originally may require pumping. When an oil field nears its final production much oil is still underground. Repressuring of oil fields by pumping excess gas or water back underground serves to maintain pressure and to increase the total recovery of oil from the field. Some petroleum is produced from oil-saturated rocks and from oil shale, particularly in Europe where domestic supplies of liquid petroleum are small.

Petroleum is refined after it is brought to the surface. Distillation constitutes the principal part of refining, and the principal equipment is a "pipe still" or "tubular still". These are stills in which the heating of the oil is done in tubes instead of tanks. The tubes are arranged in a furnace in a manner to provide maximum efficiency of heating and heat transfer between crude oil being heated and distillation products being cooled and also to provide proper ratio of rise in temperature. The principles are the same for (1) simple distillation, usually called "skimming" or "topping"; (2) vacuum distillation at subnormal distilling temperatures to avoid damaging the distillates, as for lubricating oils; and (3) distillation under high temperatures and pressures to accomplish destructive distillation or "cracking" in the making of gasoline from heavier by-products of crude oil. Catalysts, substances that promote and accelerate chemical reactions between other substances without being affected themselves, are used extensively in refining processes. This is particularly true in hydrogenation and polymerization. Hydrogenation is a combination of cracking with the introduction of hydrogen to be added to the compounds produced. Polymerization is a process combining molecules of one or more compounds to produce a compound that is more desired. In general it is used to produce liquids from simple hydrocarbon gases. Excess of sulfur in crude oil is troublesome and requires special technique in the refining process. Waxes are also removed in the preparation of lubricating oils by one of several methods such as: (1) passing the oil through filter presses, (2) chilling a solution of the oil in naphtha to 20° to 40° F. below the desired congealing temperature of the finished oil and separating the wax in high speed centrifuges; (3) processes similar to solution in naphtha but using other solvents.

Petroleum and petroleum products are transported by three general methods: pipelines, tank cars and tankers or tank ships. In 1941, there were in service in the United States more than 125,000 miles of petroleum pipe lines; over 2,000 tank ships with a gross tonnage of more than 3⅓ million tons and a cargo capacity of more than 42 million barrels; more than 165,000 railroad tank cars; and a sufficient number of tank trucks to transport more than half as much petroleum as the pipe lines, with transportation computed on a ton-mile basis. Wartime conditions have naturally changed the conditions of petroleum transportation materially and further changes can be expected in the post-war period. Where the geography permits, transportation by tank ships is generally the lowest cost method.

There are numerous petroleum refineries in the Trinity tributary area and the Trinity drainage basin, as most petroleum is refined comparatively close to the places of production and the refined products shipped. Some crude oil is, however, transported outside the area for refining. The refineries in this region range from simple casinghead gasoline plants to complete refineries capable of preparing any type of petroleum products. In addition there are innumerable wholesale and retail distribution agencies for petroleum products. In all phases of the petroleum industry, including production, refining, transportation, and distribution, there are opportunities for new business developments with capital requirements ranging from a few thousand dollars to several million dollars.

Geographically, petroleum occurs in almost all parts of the Trinity River basin and tributary area except extreme eastern Oklahoma (fig. 4). Geologically, it occurs under a wide range of conditions. It is produced from rocks of all ages from Cambrian to Tertiary except Triassic and Jurassic and from every known type of structural or stratigraphic trap except upturned beds adjacent to igneous intrusions. However, it should be pointed out that, in spite of the wide geographic and geologic range in the occurrence of petroleum in this region, many areas that are structurally favorable have been drilled and have failed to yeild petroleum from rocks that are productive in other areas. The search for new oil fields in this region is conducted continuously by many oil companies with large staffs of technical personnel, and although a number of new fields or extensions of old fields are discovered each year, many other apparently favorable areas are drilled without success. Wells are being drilled to increasingly greater depths and the effort and cost required to discover and develop new fields is increasing.

The distribution of the principal oil fields of the Trinity tributary area, the Trinity Basin, and the area subject to periodic flood are shown on fig. 4. In general, it may be stated that comparatively few fields are situated in the upper part of the Trinity basin, a considerable number are situated in the lower part of the basin, most of which lie within areas subject to periodic flood, and that the tributary area is one of the richest petroleum regions of the world.

Proved reserves of petroleum in the Trinity River tributary area were estimated on January 1, 1945, to be 5,618,519,000 barrels. Of this, nearly half is concentrated in the East Texas oil field. Oklahoma accounts for somewhat over one billion barrels and the remainder is scattered over a large area of Texas. The reserves of the Trinity tributary area constitute 27 percent of the proved reserves of the entire United States. The discovery of new fields, the extension of known fields, the discovery of new producing horizons in known fields, and the upward revision of previous estimates of reserves combine to add substantial quantities of petroleum to the proved reserves annually, but in recent years there has been a marked decline in the ratio of new reserves to annual production. The proved reserves of the state of Texas have increased at an average rate of 100,000,000 barrels per year from 1941 to 1945 but over the same period Oklahoma's proved reserves have declined slightly. The time has apparently passed when the discovery of new sources of oil in the Trinity River area can be counted on to far exceed the depletion of the known supply.

Most of the major oil companies of the United States and numerous smaller ones are included in the list of producers from the Trinity

PETROLEUM AND NATURAL GAS

Fig. 4

EXPLANATION

• Oil field

∘ Gas field

DISTRIBUTION OF PRINCIPAL OIL AND GAS FIELDS IN THE TRINITY RIVER TRIBUTARY AREA

Adapted from maps by Texas Bureau of Economic Geology and Oklahoma State Geological Survey.

River area. Annual production figures for Oklahoma and for the part of Texas included in the Trinity River tributary area are given in the table below. All of Oklahoma's production lies within the Trinity tributary area except a relatively insignificant amount in Nowata, Rogers, and Washington Counties in the northeastern corner of the state. In 1944 this totalled only 3.6 percent of Oklahoma's production. The production of oil from the Trinity tributary area in 1944 was 17 percent of the production for the entire United States.

Annual Production of Petroleum in Oklahoma and in the part of Texas tributary to the Trinity River in thousands of barrels, 1934-1943

Year	Oklahoma	Trinity tributary area of Texas
1934	178,652	263,040
1935	182,597	261,265
1936	200,881	258,862
1937	223,107	293,109
1938	169,307	262,000
1939	152,400	256,488
1940	149,629	258,492
1941	153,167	250,631
1942	137,792	247,347
1943	120,559	272,571

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MINERAL RESOURCES

OF THE

TRINITY RIVER TRIBUTARY AREA IN

TEXAS AND OKLAHOMA

NON-METALLIC RESOURCES

NATURAL ABRASIVES

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Many manufacturing processes are based on the use of abrasives in cutting, sawing, grinding, and polishing. Hence may diverse abrasives, some natural and some artificial, are in use today. The natural abrasives range from diamond, the hardest, down to such soft and mild materials as chalk, which is used for polishing.

Natural abrasives are known to occur in the Trinity River tributary area, but their variety is small and they comprise mostly cheap materials obtainable in large quantities and not restricted in their geographic distribution. Grinding pebbles, diatomite, sand and sandstone, volcanic ash, and pulverulent limestone and chalk, millstone and novaculite occur in the area.

Grinding Pebbles

Grinding pebbles are pebbles of hard siliceous material, usually flint or chert. Flint or chert is silica (SiO_2) with minor impurities, the silica being in the form of the mineral chalcedony. Chalcedony is made up of microscopic and closely packed fibers that build up the flint rock. This microscopic structure is responsible for the toughness of the flint and gives it its strength and coherence. Although the mineral quartz has the same composition (SiO_2) and hardness (Mohs scale, 7) as chalcedony it lacks the microscopically fibrous structure of chalcedony. Therefore, quartz pebbles do not have the same toughness and coherence as flint pebbles. Because silica is a chemically inert substance flint makes desirable grinding pebbles, since in the grinding process the pebbles do not contaminate the material being ground.

Grinding pebbles are used in porcelain or flint-lined mills for the grinding of mineral substances. Steel balls are used also and have replaced the once widely used flint pebbles in many ordinary grinding operations. However, steel balls add appreciable quantities of iron to the ground mineral. Hence they can be used only where iron contamination is not objectionable, for instance, in grinding ores and portland cement materials. Flint pebbles are used in preference to steel balls where iron contamination is objectionable, for instance, in the grinding of ceramic materials used in the making of porcelain, china, and pottery. In 1941 and 1943 inclusive, a yearly average of 13,766 short tons of grinding pebbles, domestic or imported, was used in the United States; the average value of this tonnage was $218,913.

In peacetime many flint pebbles are imported from Denmark and France. In those countries the Upper Cretaceous chalk forms high cliffs along the sea, where the erosive action of the surf breaks down the chalk rock and frees the enclosed flint concretions. Wave action rolls these flints about, cleaning and rounding them in the process. The clean round pebbles are picked up by hand on the beach. Hence no machinery is needed and transportation to coastal shipping points is very short. Essentially, wave action does the mining and processing of the pebbles.

In Texas, wartime demands have resulted in the development of local flint pebble resources which are found in stream gravel deposits. Most of these deposits are ancient and the flints have a weathered surface skin. Such flint pebbles if used directly without processing would wear rapidly at first until the weathered surface skin is rubbed off. To produce milled flint pebbles, that is, pebbles without soft surface skin, one processing plant tumbles the raw material wet in a conical flint-lined pebble mill until the pebbles are clean and rounded. This milling removes the soft surface skin and sorts out weak pebbles or those that crack under impact. The pebbles pass over a sorting belt where broken pebbles and foreign material are removed by hand. Raw pebbles are obtained from large stock piles of material screened to size. Another plant processes the pebbles dry in a granite-lined cylinder mill which holds a charge of 5 tons. A collector is used to draw off dust and fine fragments. After a run of 3½ hours the pebbles pass over a screen designed to remove flat pebbles and are then hand-sorted on a moving belt. The raw material is obtained from oversize material stock-piled from local gravel operations by hand-picking on a belt.

It will be noted that these domestic operations require considerable processing by machines. Therefore, they are more expensive than the simple European gathering methods and f.o.b. prices of domestic pebbles are higher than for foreign pebbles. However, locally produced pebbles do not have to be shipped by rail from the coast to local inland users.

Occurrence of grinding pebbles in the Trinity River tributary area

Grinding pebbles occur in the gravel deposits of the major stream valleys. Some of the gravel deposits are ancient river terraces flanking the stream channel at various elevations above the flood plain. Others are gravel bars in the stream channel. The gravel deposits in the stream channels are usually composed of a mixture of all the types of resistant rocks crossed by the streams and are not purely flint gravels. In such deposits material found a short distance upstream predominates over that derived from greater distances. In the older terrace weathering has been in progress for some time and rock types subject to weathering have been gradually eliminated, leaving the more weather-resistant types somewhat concentrated. In such terrace gravels flint predominates. The size of the gravel decreases downstream in all deposit hence, only the deposits in the upper reaches of the streams have a gravel size large enough for use as grinding pebbles. Gravel deposits of the Trinity River tributary area are described in the chapter on sand and gravel.

Reserves

Due to the number of gravel deposits in the Trinity River tributary area the reserves of pebbles of possible use as grinding pebbles are very large. However, in many cases selection of suitable material may be beset with difficulties on account of the admixture of softer material in the gravel.

Production

There is no production of grinding pebbles in the Trinity tributary area. Texas producers are located in San Antonio, Austin, and Columbus, Texas.

Grinding pebbles produced in the United States

Year	Short tons	Value
1941	13,561	$ 221,826
1942	15,487	245,794
1943	9,924	157,778
1944	8,012	172,418

Diatomite

Diatomite, also known as diatomaceous earth, infusorial earth, and kieselguhr, is a light, earthy, sedimentary rock composed of the microscopic skeletons of acquatic algae, the so-called diatoms. These microscopic skeletons are highly ornamented fragile, hollow, box-like, and composed of silica (SiO_2). No less than 40,000,000 skeletons of diatoms are necessary to form one cubic inch of diatomite. Diatomite is highly porous and absorbent and is a very light weight (15 to 40 lbs. per cubic foot) sedimentary rock, usually whitish in color. It is a chemically inert and has fineness and uniformity of grain size. It can be identified under the microscope by the characteristic algal skeletons.

Diatomite has a very great number of uses, most of which are nonabrasive. The principal nonabrasive uses are as filler in synthetic plastics, rubber compounds, in insulating materials, in filtering, in light weight concrete aggregates, and as chicken litter. The use of diatomite in synthetic plastics is comparatively new and appears to be increasing. The material mixes readily with plastic compositions, and the mixture can be molded satisfactorily. Its high resistance to heat, chemical inertness, low moisture absorption, excellent electrical insulating properties and surface finish characteristics make it suitable as a filler for many products, including battery boxes, electrical parts, and phonograph records, which require a durable surface finish. Insulating materials composed in part of diatomite are used for heat and sound insulation. Filters containing diatomite are used in paper pulp manufacture, for cyanide precipitate, and other processes. Diatomite is used to minor extent as a mild abrasive in metal, glass, furniture, enamel, and other polishes, in scouring and cleansing soaps, in dentifrices, and in nail polishing powders. Approximately one-half of the diatomite production is used for filtration, one-quarter for insulation, and one-sixth for fillers, and the remainder for other uses including abrasives.

Diatomite prices per ton in 1943 were (on f.o.b. mill, Nevada, basis): crude in bulk, dried $7.00 nominal; 98 to 100 mesh, $20.00; low temperature insulation, $19.00; high temperature insulation, $30.00; diatomite for fine abrasives was quoted at 2 cents per pound.

Occurrence of diatomite in the Trinity River Tributary area

Diatomite occurs in several widely separated localities in the High Plains in Armstrong, Crosby, Dickens, and Hartley Counties, Texas.

In Armstrong County deposits are known in Mulberry Canyon, 7.4 miles southwest of Goodnight. The deposits extend for at least 2 miles, are from less than 2 to 7 feet thick, and average about 4 feet. The diatomite lies between or below soft sands and fresh-water lime-stones.

In Crosby County deposits occur in two horizons about 25 and 42 feet above the base of the Blanco beds, 10 miles north of Crosbyton. The diatomite beds are up to 6 feet thick and lenticular. Overburden is up to 20 feet thick for the upper bed and up to 40 feet for the lower bed. Associated beds consist of calcareous sands and clays.

In Dickens County diatomite, in two beds, occurs about 4 miles north of old Dockum. The beds are reported to be 3 to 4 feet thick and the overburden 6 to 12 feet respectively.

In Hartley County diatomite is found 3½ miles southeast of Channing. The diatomite is 3 to 3.8 feet thick and has at least 10½ feet overburden. It contains about 20 percent CaO.

No diatomite deposits of importance are known in Oklahoma.

Reserves of diatomite

Detailed estimates of the reserves available in the High Plains are not given by Evans (7). However, it is apparent that only small quantities are recoverable from the deposits so far discovered.

Production

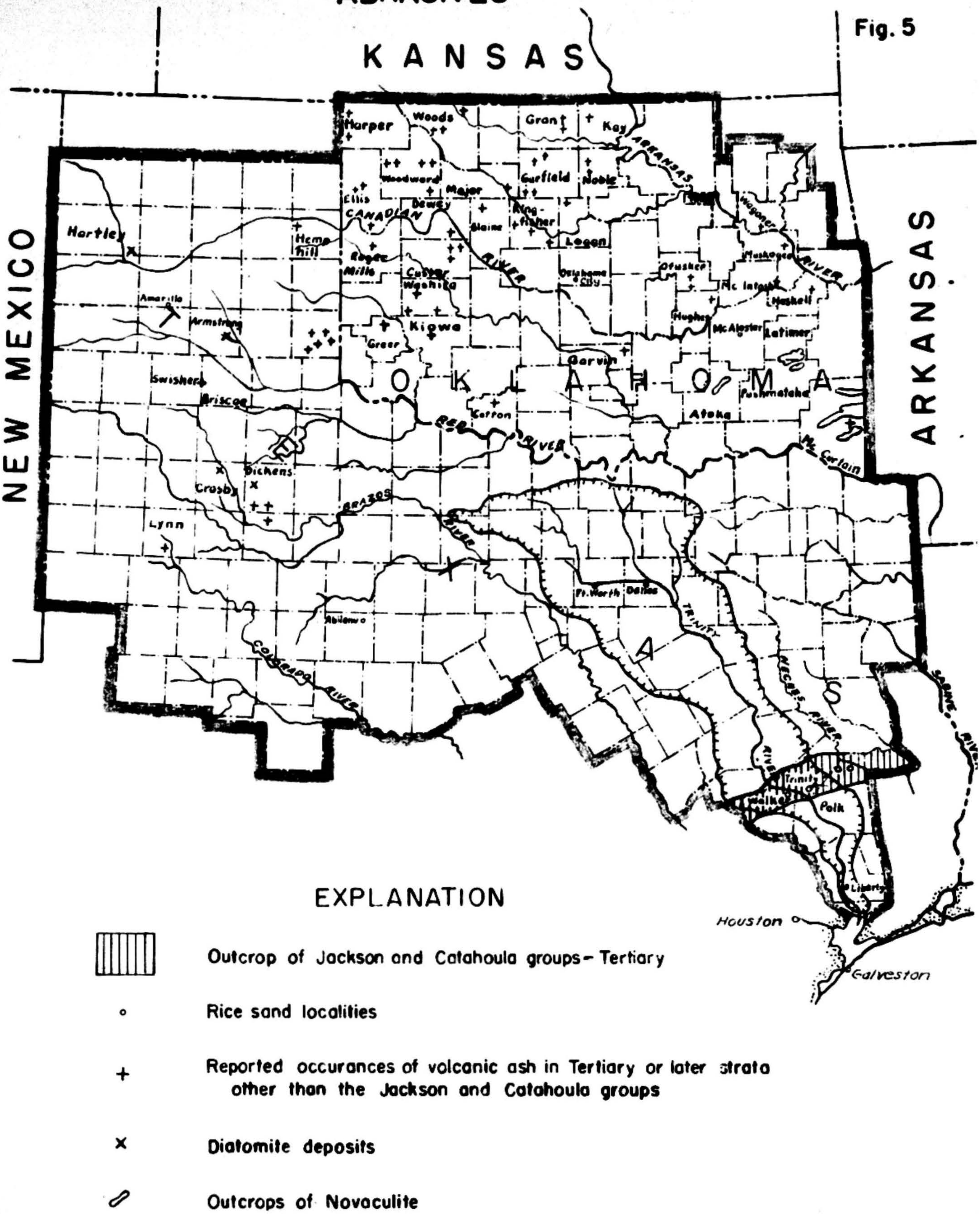
Diatomite is not being produced in Texas.

Diatomite production in the United States

Period	Short tons	Value
1933-35	244,342	$ 3,618,428
1936-38	279,645	4,377,353
1939-41	360,502	5,746,216
1942-44	524,872	9,894,534

ABRASIVES

Fig. 5



DISTRIBUTION OF ABRASIVES IN TRINITY RIVER TRIBUTARY AREA

Abrasive Sand and Sandstone

Sand and sandstone used for abrasives are composed of nearly pure quartz sand, and their abrasive qualities are derived from the mineral quartz. This mineral is hard (Mohs scale, 7), fractures irregularly with a nearly conchoidal or uneven splintery fracture producing sharp edges and points, and is composed of silica (SiO_2), which is chemically inert.

Sand and sandstone are used in two forms for abrasive purposes: as crushed sand and sandstone and as uncrushed sand. The latter is used extensively in sawing and rubbing of such building stones as granite, limestone, marble, slate, and soapstone, in removing surface irregularities in crude-rolled plate glass before grinding, and for sand blasting. The demand for this type of grinding or polishing sand depends largely on activity in the dimension-stone and plate-glass industries. Thus in 1929, 1,636,464 short tons were used in the United States; in 1932 only 419,691 tons, in 1935, 816,540 short tons; in 1938, only 502,328 short tons, in 1941 1,001,814, and in 1943 only 837,662 short tons. The average value in 1943 was $1.71 per short ton. This value compares as follows with average values of sand used in other industries: glass, $1.86; molding, $1.36; building $0.60; paving, $0.61; fire or furnace, $1.37; engine, $0.69; filter, $1.63; and railroad ballast, $0.31.

Occurrence of abrasive sand and sandstone in the Trinity River tributary area

The main occurrences of sand and sandstone in the Trinity River tributary area have been taken up in other chapters. However, a particular variety known as "rice sand" has received some development and may have future possibilites. Rice sand deposits are coarse-grained quartz sands occurring in lenticular bodies near the base of the Catahoula formation. Several of these deposits were described and studied by Shafer (20). Among them are the following:

(1) Chita deposit, 12 miles south of Groveton, Trinity County
(2) Chester deposit, 10 miles north of Chester, Tyler County
(3) Harmon Creek deposit, 2 miles southwest of Riverside, Walker County
(4) Texas Silica Sand Company deposit, 5 miles east of Corrigan Polk County

The last deposit has been worked for several years and the product used as a water filter and as blast sand. The sands are also suited for molding sands.

There is no record of abrasive sand having been produced in Oklahoma in the last 10 years, although possibly some of the river sand deposits might be suitable for this purpose.

Reserves of abrasive sand and sandstone

Although accurate figures for the reserves of such sand bodies as the rice sands are not available, it seems evident from their geologic occurrence that the supply is large.

Companies producing sand used as abrasive

Texas Silica Sand Company, Houston, Texas. Pits in Polk County, Texas.

Volcanic Ash

Volcanic ash or pumicite is a sedimentary rock derived from the ejectamenta of volcanoes of the explosive type. The finer material, or ash, is often carried long distances by the wind and falls to earth in the form of microscopic glassy particles. These small fragments, or shards, are natural volcanic glass derived from the lavas by the bursting of the countless bubbles or vesicles formed by expanding gas during eruption. Hence many fragments are very sharp and concavely curved. The abrasive qualities of the ash are due to the shape and hardness of the shards and the high porosity of the rock composed of them. It has a gritty feel and does not adhere to the fingers like clay.

Volcanic ash is used in cleansing and scouring compounds, abrasive hand soaps, metal polishes, acoustic plaster, concrete mixtures, absorbent or oiled road surfaces, insulating materials, filter cells, and in fillers for paints, sweeping compounds, and fertilizers.

The use of pumicite for abrasive purposes expanded 17 percent in 1943 in the United States as compared with 1942 and accounted for 75 percent of total sales. Consumption in the building industries dropped decisively and reflected the curtailment of private construction due to war time restrictions. With the return of peace and the attendant expected increase in building, this trend is apt to be reversed as pumicite begins to participate in the new demand for light weight concrete aggregate and insulating materials.

Ash deposits accessible to centers of population and industry through cheap transportation facilities should bear some promise of profitable development.

Occurrences of volcanic ash in the Trinity River tributary area

Texas - Most of the known occurrences of volcanic ash in the tributary area in Texas are confined to two geologic provinces: (1) the Jackson-Catahoula belt of outcrop of Tertiary age in the southeastern part of the area; and (2) the continental Cenozoic in the western and northwestern parts.

Some of the known ash deposits in the Catahoula belt are:

(1) An 8-foot bed at Chalk Bluff in northeastern Polk County
(2) Near Corrigan in Polk County
(3) An 8-foot bed just north of milepost 16 on the I. & G. N. railroad, southern Trinity County
(4) Exposures on White Rock Creek east of the town of Trinity, in Trinity County
(5) Deposits in northern Walker County

Doubtless other commercial deposits of volcanic ash may be found in the Catahoula strata in the area. In the same general area, but a few miles to the west, beds of Jackson age outcrop across Trinity and Polk counties. These beds also contain strata of ash, but thinner, more indurated, and less pure than the ash beds of the Catahoula.

In the continental Tertiary and Cenozoic rocks of the western part of the area occurrences have been reported as follows and their age given as Pleistocene:

(1) Seven localities in a 20-mile wide belt across Collingsworth County (2). Thickness from 4 to 34 feet is recorded, with but little overburden, and the ash is stated to be nearly pure.

(2) A seven-foot bed on the north side of Tule Canyon at the Swisher-Briscoe County line

(3) An extensive 10-foot bed along Duck Creek southeast of Spur, in Dickens County

(4) A 4-foot bed along Spring Creek 4½ to 5 miles southwest of Spur, Dickens County

(5) A 2- to 15-foot deposit over an area of 350 acres 1 mile from Skeen station in Lynn County

(6) A deposit 18 feet thick along Duck Creek in Kent County

A Pliocene deposit of volcanic ash is described by Reed and Longnecker in Hemphill County (16). It is located in section 58, block A-2, south of the Canadian River in the northwestern part of the county and consists of a 7-foot bed estimated to contain 46,500 cubic yards of ash.

Other ash deposits are thought to be present in the Pliocene beds of the plains area, for the ash is a normal constituent of those beds.

<u>Oklahoma</u> - Volcanic ash deposits in the tributary area in Oklahoma are quite extensive, but most of the larger deposits are concentrated in the northwest, north-central and east-central parts of the state. Deposits of possible economic grade and size are known in Blaine, Custer, Dewey, Ellis, Garfield, Garvin, Grant, Greer, Harper, Haskell, Hughes, Hay, Kingfisher, Okfuskee, Roger Mills, Wagoner, Washita, Woods, and Woodward Counties. Lower grade and smaller deposits are found in

Cotton, McIntosh, and Muskogee Counties. The exact age of the ash deposits has not been determined but they appear to be Miocene or younger.

Production of volcanic ash in the Trinity River tributary area

Only small beginnings have been made in the development of the volcanic ash deposits in the Texas part of the tributary area, and production statistics are not available. One producer, Kelly Products, Lubbock, Texas, operating deposits in Dickens and Scurry Counties, is credited with a total production in 1941-42 of 250 tons of unknown value.

Producers in the Oklahoma part of the tributary area in 1941 include the Muskogee Silica Company with a quarry near Tullahassee, the Tulsa Earth Products Company which also operates a quarry in the same locality, and the Sol H. William Company which operates a quarry near Dustin. The Muskogee Silica Company, produces ash used in topping asphalt pavements, the Tulsa Earth Products Company produces ash for use in concrete admixture and the Sol H. Williams Company produces ash used in the manufacture of cleansing materials.

Reserves of volcanic ash

The reserves of volcanic ash in the Texas part of the area are extensive, but no estimates of the total amount available have been made. Total reserves in the Oklahoma part of the area are believed to be in excess of 17,000,000 cubic yards. A number of individual deposits are known containing more than 1,000,000 cubic yards of volcanic ash.

Pulverulent Limestone and Chalk

Pulverulent limestone, ground limestone, and chalk are used in minor quantities as polishing materials. These rocks are varieties of limestone, which is a sedimentary rock composed chiefly of the soft (Mohs scale, 3) mineral calcite ($CaCO_3$). Freedom from grit is a requisite in these materials if they are to be used for polishing.

The quantities used are small and the uses are in polishing cutlery, surgical instruments, and plated ware, and in window cleaning compounds. A use important for the region is as polishing agent for rice.

Occurrence of pulverulent limestone and chalk in the Trinity River tributary area

Pulverulent limestone is known to occur in the Edwards formation of Williamson and Bell Counties, Texas, which are outside of the tributary area. It is possible that small deposits of this type occur also in the Trinity River tributary area in the Edwards or Goodland formations. Deposits of this rock are difficult to discover, because the material is soft and is usually covered by soil and vegetation.

Chalk deposits occur in the Trinity River tributary area in the outcrop belts of the following geologic formations: Austin, Ector, Gober, Pecan Gap, and Cooledge. These formations are part of the Upper Cretaceous and are widely distributed through northeastern Texas from the Red River to Limestone and Falls Counties in the south.

No tests of their possible use as polishing materials and no attempt at exploitation have been made so far.

Millstones

According to V. L. Eardley-Wilmot (6) "the term 'millstone', which includes the true burrstone and the chaser stone, is somewhat loosely applied to include circular stones revolved on a horizontal plane as well as those run on edge. They may be made from any hard and suitable rock varying from a sandstone, basalt, granite to a quartz conglomerate...."

Forty or fifty years ago the production of millstones of various types was a moderately important industry, but millstones are used to only a minor extent at the present time. Rocks suitable for the manufacture of millstones are found in the Trinity tributary area in the Ouachita Mountain region in Oklahoma. Regarding these rocks Honess (11) states as follows: "There is no doubt whatever, but that many of the fine grained quartzites and quartzitic sandstones of the Stanley (Pennsylvanian) and Jackfork (Pennsylvanian) formations would make excellent millstones and burrstones. So far as known to the writer these formations have never been considered of any value in this connection. The demand for millstones is not large, but it is possible that sometime there may be a wider field of application of this type of abrasive and it well to call attention to this possible source of raw material."

Novaculite

Novaculite is an aphanitic granulose or cryptocrystalline rock essentially composed of quartz, sometimes containing other forms of silica and generally containing accessory feldspar and garnet. Novaculite from the Ouachita Mountains region of Arkansas has had considerable use for the manufacture of high quality whetstones and oilstones. Novaculite, from the neighboring Ouachita Mountains area of Oklahoma, is reported to be equally suitable for this purpose, but as far as can be determined the Oklahoma deposits have never been exploited on a commerical basis.

The Oklahoma novaculite occurs chiefly in central McCurtain County. Smaller exposures are known in the Potato Hills area in southeastern Latimer and northern Pushmataha Counties and near Atoka and Stringtown in Atoka County.

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BARITE

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Barite, barium sulphate, ($BaSO_4$), also known as barytes, baryta, or heavy spar, is a heavy (sp. gr. 4.3-4.6) brittle mineral with a pearly to vitreous luster and a hardness ranging from 2.5 to 3.5. It crystallizes in the orthorhombic system and commonly is found in tabular crystals. When pure, the color is white or gray, but barite may be tinted various shades of blue, pink or yellow from impurities. Colorless transparent crystals are sometimes found. Most of the barite mined in the United States is obtained from residual deposits derived from the weathering of barium-bearing rocks. Barite is also obtained from bedded replacement deposits in sedimentary rocks, from breccia deposits, mostly in limestones and dolomites, or from veins in which barite is essentially the only mineral present. Barite is a common gangue mineral in many metalliferous deposits, but in only rare instances has it been produced commercially from deposits of this type.

According to the United States Bureau of Mines, of the total of 434,774 short tons of crude barite produced in the United States in 1943, 225,154 short tons was used in the manufacture of ground barite (including some crushed barite), 128,073 tons was manufactured into lithopone, and 81,547 tons was employed in the manufacture of barium chemicals.

The greater part of the ground barite produced in this country in 1943 was used in the petroleum industry where it is mixed with bentonite and other ingredients to form a heavy mud which is employed as a drilling medium in drilling deep oil wells. For this use color and extreme purity are not important provided the specific gravity is 4.2 or higher. An increase in the use of barite in oil well drilling can be expected due to the expiration of the patent covering the process. Barite is also used as a flux in glass making, because of its property of forming a surface froth which protects the melt from the furnace gases and slows heat transfer. Barite added to the glass mix in small amounts imparts desirable properties to some grades of glass, especially moulded forms. Coarsely crushed barite was formerly thought necessary for use in glass manufacturing but recent experiments have demonstrated that ground barite can be used equally well. Ground barite is used as an inert filler in rubber, paper, printer's ink, oilcloth, linoleum, phonograph records and similar articles, as a paint pigment or paint extender, and to weight textiles and leather goods. All grades are used, from an off-color product to white acid-bleached barite depending on how the color will affect the finished article. According to the Minerals Yearbook, in 1943, 69 percent of the ground barite produced in this country was used in drilling muds, 12 percent was employed in the glass industry, 7 percent in the manufacture of paints, 4 percent was used as a filler in rubber, and 8 percent went into various miscellaneous uses.

One of the principal uses of barite is in the manufacture of lithopone which is employed mainly as a white paint pigment but which also finds considerable use as a filler. Lithopone is an intimate mixture of barium sulphate and zinc sulphide obtained from the co-precipitation of the two constituents and contains approximately 70 percent $BaSO_4$ and 30 percent ZnS. Lithopone paint pigments were used extensively during the war in place of titanium, lead and zinc oxide pigments, but these pigments will probably again replace lithopone to a considerable extent when conditions become normal.

Barium chemicals are used for a variety of purposes in industry. Blance fixe (precipitated barium sulphate) is used in white paint and as a filler for products which require a whiter and finer material than can be obtained from ground barite.

Barium chloride is used indirectly in the manufacture of chlorine and sodium hydroxide, in coatings for photographic paper, for finishing white leather, and as a flux in the fabrication of magnesium alloys. Barium hydroxide is employed in beet-sugar refining and in purifying animal and vegetable oils. Barium nitrate imparts a green color to signal flares, barium oxide is useful in case-hardening steel, barium carbonate is also used for this same purpose, as well as for retarding efflorescence in bricks, and barium peroxide is used in making hydrogen peroxide.

Specifications for barite vary considerably according to the use. Common specifications call for 95 percent $BaSO_4$ and less than 1 percent Fe_2O_3. For use in the glass trade barite containing less than 0.1 percent Fe_2O_3 and a minimum of 96 percent $BaSO_4$ is demanded. Prices of crude barite were frozen in March 1942. Ceilings for crude chemical-grade barite approved by the Office of Price Administration in April 1944 for Georgia and Alabama producers ranged from $9.50 to $11.00 a ton. Prices for Missouri producers for the same grade material were frozen at $7.00 a ton f.o.b. rail points. According to the Minerals Yearbook, in 1943 the price of ground barite delivered to oil wells in the Houston, Texas area was $23 to $27 a short ton; ground, bleached barite was quoted at $25.35 a short ton in the St. Louis area, and ground, unbleached barite at $17.50 a short ton f.o.b. producing plants. Because for many of its uses it competes with other low-priced minerals which can be used equally as well, barite has been, and is likely to remain, a low-priced commodity. Prices at the producing centers are governed largely by the cost of transportation to markets.

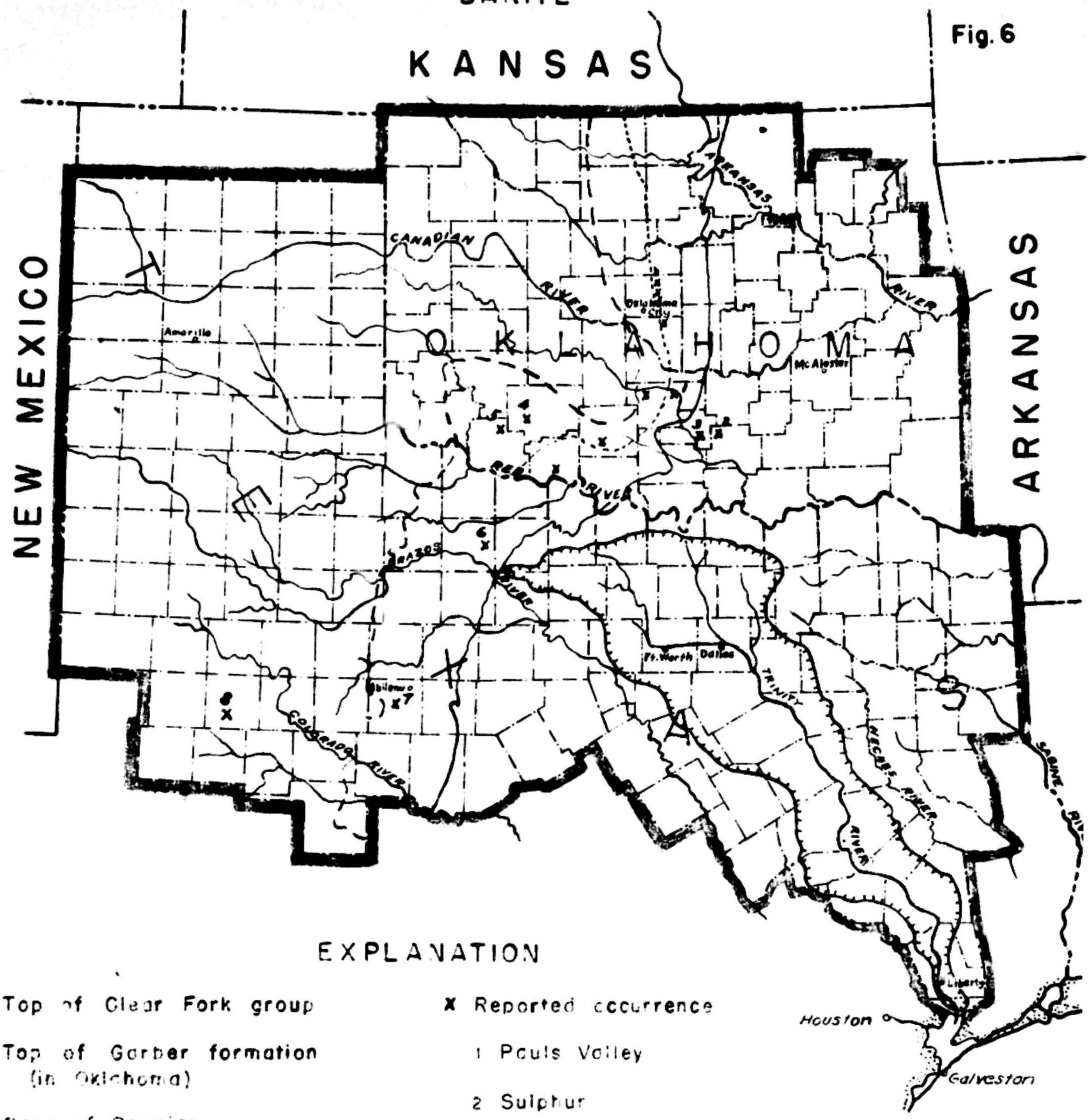
Occurrence

Barite is not known to occur anywhere within the Trinity River drainage basin. It is found, however, at a number of localities within the Trinity River tributary area in both Texas and Oklahoma. In neither state has there been any significant production, although a number of attempts have been made to mine barite. The total production of the entire state of Texas probably amounts to less than 500 tons and Oklahoma has produced even less. The Milwhite Company, Inc. produced ground barite at a plant at Houston, Texas but the plant processes crude barite imported from outside the state.

Thin irregular veins or scattered nodules of barite are found in shale beds of Lower Permian age throughout central and southwestern Oklahoma, especially in McClaine, Garvin, Comanche, Tillman, Stephens, Cotton and Kiowa Counties. A similar occurrence is reported from beds of about the same age 22 miles southwest of Abilene, Taylor County, Texas. In Baylor County, Texas barite nodules have been reported in red shales of the Permain Belle Plains formation in an escarpment east and northeast of Rendham, and discontinuous barite veins and joint fillings are found in

BARITE

Fig. 6



EXPLANATION

Top of Clear Fork group

Top of Garber formation (in Oklahoma)

Base of Permian

Oklahoma part of area adapted from map by W.E. Ham and C.A. Merritt in Circular 23, Oklahoma Geological Survey.

X Reported occurrence

1 Pauls Valley

2 Sulphur

3 Mill Creek

4 Cache

5 Manitou

6 Rendham

7 Abilene

8 Chalk Community

DISTRIBUTION OF BARITE IN THE TRINITY RIVER TRIBUTARY AREA

Triassic red shales on the Dora Roberts Ranch, 2 miles north of the Otis Chalk community, Howard County, Texas. In general the barite content of the shale beds is low and the deposits are of no economic importance. However, in places weathering of the shale has resulted in a residual concentration of the relatively heavy and resistant barite and some of these localities are potential producers of barite. Of the known occurrences, perhaps the most promising is 5 miles south of Cache, Comanche County, Oklahoma where several thousand tons of barite are estimated to occur in two deposits on the floors of gullies in the Permian shale on the east side of West Cache Creek. The deposits are within easy hauling distance of the railroad at Cache and the barite can be readily concentrated by screening and washing. A somewhat similar residual concentration of barite on the nearly flat floor of an erosional amphitheater is found 9 miles east of Manitou, Tillman County, Oklahoma, but the tonnage available is much smaller. At neither of the above two localities are known reserves sufficient to justify the establishment of a barite plant, but the possibility that other similar deposits exist in the area should not be ignored.

In the Arbuckle Mountains of Oklahoma barite is found in brown clay and limonite derived from the weathering of the Arbuckle dolomite of Cambrian and Lower Ordovician age, notably on the Thompson Ranch 6 miles northeast of Mill Creek, Johnson County and on the Lowrance Ranch south of Sulphur, Murray County. On the Thompson Ranch the barite is found in an open pit from which several hundred tons of iron ore were extracted and is associated with small amounts of pyrite. The occurrences are of significance only in suggesting the possibility of other barite deposits in the region.

Barite, cementing sand grains in sandstones of the Lower Permian Garber formation, occurs in the vicinity of Pauls Valley and Paoli in Garvin County, Oklahoma and has also been reported from Cleveland County, Oklahoma. By weight the barite comprises about one-third of the sandstone and, because of the difficulty of extraction and the limited extent of the barite sandstone, is of no present economic importance.

Sand-barite "rosettes" or "barite roses" (rose-shaped crystal aggregates of barite) are numerous in the Lower Permian sandstones of central Oklahoma or in the gravels derived from them and are most abundant in the upper 100 feet of the Garber sandstone. Similar rosettes occur in the Clear Fork-Wichita formation in southwestern Oklahoma. Rosettes are prized by mineral collectors and are of scientific interest, but because they occur as isolated individuals scattered through the sandstone, and themselves contain much admixed sand, they cannot be recovered economically except locally where weathering may have concentrated a few tons of barite.

There is a rapidly increasing demand for barite-weighted drilling muds in oil well drilling, and as the Trinity River tributary area includes a great number of important oil fields, if workable deposits of barite were found in the tributary area, they would be in a favorable position to compete with barite shipped in from outside sources.

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BUILDING STONE

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Abundant natural building stones are found in the Trinity tributary area, east of the breaks of the High Plains and north and west of the outcrop of the Austin chalk. Toward the Gulf coast natural building stones become progressively scarcer. Scarcity of natural building stones also characterizes the High Plains in the west.

Building stones are as varied as the structures for which they are used. In the Trinity River tributary area, granite, gabbro, marble, limestone, dolomite, sandstone, silicified wood, and glauconite rock are present and are used for building stone.

Technically, granite is an igneous rock composed principally of quartz and feldspar with minor amounts of dark accessory minerals. True granites may vary from very light gray to red, depending upon the amount of dark minerals present and the color of the feldspar. They may range from very fine-grained to coarse-grained or porphyritic. However, in the building and monument trade, the term granite includes any igneous rock capable of being shaped into dimension stone or polished for use in monuments. Gray granite may be a quartz monzonite, a granodiorite, or a diorite, and black granite is a gabbro or basalt.

In the building trade any limestone (calcite or $CaCO_3$) capable of taking a good polish and of attractive color and texture, occurring in sufficiently thick beds and so free of fractures that it can be quarried in large blocks, is termed a commercial marble. The color of marble may vary because of included impurities from white or light gray to green, brown, or red. Interesting textures are produced by included fossils, stylolites, or veins of calcite of contrasting colors.

Sandstone is a sedimentary rock composed of sand grains cemented more or less firmly by a natural cementing material. Its grains are composed almost exclusively of quartz (SiO_2). Pure quartz is colorless and transparent, but many quartz grains are pink, white, gray, or black. Natural cementing materials of sandstone are limonite and hematite, calcite, clay particles, and quartz or chalcedony. According to the cement, the sandstones are classified as ferruginous, calcareous, argillaceous, and siliceous or quartzitic. The nature of the cementing material and the proportion to which it fills the pore space between the sand grains, determine to a large degree the strength, resistance to abrasion, resistance to weathering, porosity, and other physical properties of the stone.

Silicified wood is a term applied to fossil logs in which silica (SiO_2) has replaced the wood without destroying its botanical cell structure. Silicified wood has approximately the hardness and specific gravity of quartz. It occurs in various shades of brown, but in some cases bleaches to a whitish-gray on prolonged exposure.

Glauconite rock is a sedimentary rock composed chiefly of grains of the mineral glauconite cemented more or less firmly by such natural geologic cementing materials as calcite and clay, or limonite and hematite. The mineral glauconite is a soft (Mohs scale, 2), medium-heavy (specific gravity, 2.2 to 2.85), dark green mineral with the chemical composition of a complex iron-aluminum-potassium silicate. Glauconite weathers readily, and most of the glauconite rock used as a building stone in the area is weathered to some extent when quarried. Hence, its color varies from dark green of the fresh rock to olive-brown and rusty brown of the weathered rock. The latter color is due to the presence of limonite and hematite. Glauconite rock is soft, particularly so when freshly quarried, and easily cut by saws and other tools, but it is also low in strength and resistance to weathering. Due to the ease with which it is cut, glauconite rock is used mainly as dimension stone.

Color and surface texture are important properties in several types of building stone, especially in monumental and ornamental dimension stone and terrazzo chips. Clear and bright colors and interesting color patterns are desirable qualities. Pure limestones and sandstones are white, because of the minerals composing their grains, calcite and quartz respectively, are colorless and transparent. Colors of limestones and dolomites are caused mostly by included minerals and impurities such as glauconite (greenish), marcasite or pyrite (bluish), limonite or hematite (yellowish, brownish, reddish), and carbon compounds (brownish, grayish, black). Colors of sandstones are caused mostly by the natural cement holding the sand grains together. Ferruginous cement makes yellow, rust-brown, and red stone, while calcareous or siliceous cement makes white or gray stone.

Surface texture refers to the appearance of the cut or rough-trimmed surface of the dimension stone and considerably affects the interest and esthetic appeal of the rock and structures built from the rock. Some building stones, such as granite, gabbro, and marble, take high polish and retain it. Silicified wood and some hard limestones, likewise take polish. Other stones, notably limestone and glauconite rock, may contain fossils or cavities once occupied by fossils. Some building stones have characteristic forms of fracture on rough trimming. This rough trim used chiefly on outside walls, gives the stone an architecturally interesting appearance.

Shapes and sizes of commercial building stone are manifold. Two chief categories, dimension stone and crushed or broken stone, are recognized. Dimension stone is shaped into slabs, mill blocks, monumental stone, paving blocks, curbings, flagstones, cut-stone blocks, or rough-trimmed blocks, and must conform to more or less rigidly specified dimensions and shapes. The specified dimensions are obtained by sawing, cutting, or splitting with specially designed tools or machines. Pleasing color and surface texture and ability to take polish are desirable qualities of some dimension stone. This type of stone is a substantial, dignified, and an enduring building material used chiefly and relatively costly or at least permanent structures. Many public and business buildings, such as courthouses, post offices, schools, and banks, have exteriors and hallways of dimension stone. In recent years rough-trimmed dimension stone has also been used in increasing quantities for substantial residences.

Crushed and broken stone is of irregular shape and varying dimensions. However, much crushed stone is sold with the screen size specified. Great quantities of this type of stone are used in modern construction as road metal, concrete aggregate, railroad ballast, riprap, asphalt filler for pavements, terrazzo, and roofing granules. In contrast to dimension stone, pleasing color and surface texture are of no importance in this type of building stone, except for use as terrazzo and roofing granules. Terrazzo is a mixture of Keene cement and rock chips, polished after pouring and setting. It is used as flooring in buildings where heavy foot traffic would damage a less durable material. Strength and resistance to weathering are important specified properties of crushed and broken stone in nearly all of its uses.

Man has used building stones since prehistoric times. Monumental ruins; for example, Stonehenge in England, the Roman roads and aqueducts, and the pyramids of Egypt, attest to their use in ancient times. Originally, large structures were built entirely of natural stone. Man-made substitutes of natural stone have been invented and introduced from time to time. Unburned bricks were in use in ancient Egypt. Burned bricks were used for many Gothic churches in Middle Age Europe. Steel and concrete are used widely as building materials in the framework of modern structures. In such buildings dimension stone is used merely as a facing and ornament, but crushed rock may be used extensively in the concrete. Many smaller buildings are made entirely of manufactured building materials such as brick, hollow tile, and concrete. These trends toward the substitution of manufactured materials have resulted in a proportionate decline in the use of natural building stones and particularly of dimension stone. On the other hand, the demands of modern industry and transportation systems have enormously increased the uses of crushed and broken stone.

In 1939, a year not influenced by war demands, the United States produced 117,463,510 tons of various building stones valued at $135,703,819. Of this tonnage only 2.0 percent was dimension stone and the remainder was crushed and broken stone distributed as follows: 82.5 percent, road metal and concrete aggregate; 6.0 percent, railroad ballast; 4.9 percent, riprap; 0.2 percent, asphalt filler; 4.4 percent, diverse uses.

In the Trinity tributary area building stones are quarried in open pits. Only rarely are deposits of stone so thin-bedded and flaggy that they can be removed without extensive blasting. The better grade of stone, particularly dimension stone, requires heavy machinery for cutting and hoisting. Cheap transportation is particularly essential for crushed and broken stone produced in great quantities for a low unit price. Hence canalization of the Trinity River would extend economic shipping distances for stone that is used only locally at present, and would open up territory containing possible new sources of building stone. The great demand for various building stones in the industrial cities of Dallas and Fort Worth on the north and Houston and Galveston on the south, would probably result in the opening of new deposits along the course of the river. Such undeveloped deposits are known to exist.

Silicified wood is found scattered over the surface of the ground, because it is resistant to weathering and remains on the ground long after the enclosing beds have disintegrated. It is gathered locally where concentration is sufficient to warrant collecting and shipping.

Occurrence of Building Stone in the Trinity River Tributary Area

In the Trinity River tributary area, rock suitable for building stone occurs in geologic formations ranging in age from pre-Cambrian to Tertiary. The pre-Cambrian rocks are igneous rocks exposed in the Wichita and Arbuckle Mountains of sourthern Oklahoma. Sandstone, limestone, and dolomite are wide-spread in rocks of diverse ages of the area, but the marble and glauconite rocks are limited to single formations. Silicified wood, although widespread in deposits of Cretaceous and Tertiary age, is of minor importance as a building stone; glauconite likewise is of minor importance. The occurrence of limestone, dolomite, and magnesian limestone are treated in other sections of the report. (See figs. 1 and 14)

Granite

The Wichita Mountain district includes parts of Comanche, Kiowa, Greer, and Jackson Counties, Oklahoma. Igneous rocks ranging in composition from anorthosite gabbro to granite are exposed in a number of areas. The granites are fine- to medium-grained; some porphyritic rocks are present. Varieties of granite present are: flesh red, reddish-brown, and medium to dark gray. The anorthosite gabbro is a coarse-grained, bluish-black heavy rock. Some of the granite areas have widespread joint patterns, making possible the removal of large dimension stone; granites in other areas are so jointed that only small dimension stone or crushed stone can be produced. At present, granite quarries are operated at Granite, Greer County; and at Roosevelt, Cold Springs, Mountain Park, and Snyder, Kiowa County in the western part of the Wichita Mountains.

The Arbuckle Mountain district includes parts of Murray, Johnston and Atoka Counties, south central Oklahoma. Two varieties of granite, phases of the same intrusive body, are recognized in the area. The Tishomoingo granite is a coarse-grained gray granite which is brittle and does not polish well. It is suitable for structural work and large columns, but is not good for monuments. The Troy granite is a medium- to fine-grained gray granite which takes a good polish and is strong and durable. In the past, quarries have been operated at Mill Creek, Ravia, Tishomingo, and Troy, in Johnston County.

Marble

The coarsely crystalline gray to pink St. Clair limestone of Silurian age crops out north of a fault in the vicinity of Marble City, Sequoyah County, eastern Oklahoma. At this locality the St. Clair has been quarried in the past for use as a building and interior ornamental stone. At the Marble City locality the St. Clair limestone is more than 100 feet thick and many good quarry sites are available.

Sandstone

Sandstone beds suitable for building stone are present in many formations of Cambrian, Ordovician, Pennsylvanian, Permian, Triassic, Tertiary, and Quaternary age.

Sandstones of Cambrian and Ordovician age crop out in the Wichita and Arbuckle Mountains of southern Oklahoma and the Ouachita Mountains of central McCurtain County, southeastern Oklahoma. The Reagan sandstone of Cambrian age overlies the pre-Cambrian igneous rocks in the Arbuckle and Wichita Mountains. It is a coarse-grained, arkosic, in part conglomeratic sandstone which is rarely used, even locally, for building purposes because of the presence of pre-Cambrian granite and Arbuckle limestone in the general vicinity. The Simpson group which is also present in the Arbuckle Mountains has a number of prominent sandstone members, but as a general rule the sandstone is so poorly cemented that it is useless as a building stone. Its use as a glass sand is treated in the section on Glass Sand and other specialized uses of sand. The Crystal Mountain sandstone and the Blakeley sandstone of Ordovician age are present in central McCurtain County. Because of the sparsely settled area and the lack of transportation, these sandstones are used only locally.

The Pennsylvanian rock outcrops stretch from Coleman and Brown Counties on the southern border of the Trinity River tributary area northward to the Kansas-Oklahoma border. Some notable sandstone beds of Pennsylvanian age in Texas are:

Brazos River sandstone and conglomerate in Parker, Palo Pinto, and Erath Counties--25 to 30 feet thick.

Lake Pinto sandstone in the same counties--about 20 to 25 feet thick.

Turkey Creek sandstone in the same counties--about 10 to 15 feet thick.

Ricker sandstone in Brown County; about 4 miles southeast of Brownwood.

Avis sandstone in Jack, Young, Stephens, Eastland, Brown, and Coleman Counties--about 5 to 40 feet thick.

In Oklahoma, sandstone beds in the Pennsylvanian rocks form the higher hills and ridges; the intervening shales form the lowlands and valleys. The sandstones are generally light brown to gray, fine-grained and regularly bedded. Prominent sandstone beds are found in the following Pennsylvanian formations in eastern and central Oklahoma.

Hartshorne sandstone, 150 to 200 feet, eastern Oklahoma.

Warner sandstone of the McAlester shale, eastern Oklahoma, 40 feet thick.

Savanna sandstone containing five sandstone beds, 50 to 200 feet thick. Total thickness 1000 feet. Eastern and central southern Oklahoma. (Tamaha sandstone at base.)

Bluejacket sandstone, member of the Boggy shale, central-eastern and northeastern Oklahoma, 50 to 60 feet thick.

Thurman sandstone, eastern and central-southern Oklahoma, 200 feet thick.

Calvin sandstone, central, central-southern, and central-eastern Oklahoma, 145 to 240 feet thick.

Elgin sandstone, central-northern, northern Oklahoma, 50 to 210 feet thick.

Seminole conglomerate and sandstone, central-southern, central Oklahoma; 50 feet of conglomerate and 100 feet of sandstone.

The Permian outcrops are west of the Pennsylvanian and stretch from Tom Green County, Texas, in the south, to the Oklahoma-Kansas border in the north. The best known Permian sandstones in Texas are in the San Angelo formation in Tom Green, Coke, Nolan, Taylor, Jones, Fisher, Stonewall, King, Knox, Foard, Hardeman, and Wilbarger Counties--locally 60 to 250 feet thick.

In Oklahoma, Permian sandstones occur in the Clear Fork and Wichita groups, the Whitehorse sandstone of the Woodward group, and the Duncan sandstone. The sandstone in the Duncan occurs in two or three ledges and ranges in thickness from 75 to 250 feet. The Duncan sandstone is the same as the San Angelo sandstone of Texas.

Triassic outcrops are found in the Panhandle of Texas and along the breaks of the High Plains eastward as far as Nolan County, Texas, and southward to northern Coke County. Red and gray sandstones occur in the Triassic Santa Rosa formation. Beds 25 to 30 feet thick are reported.

Cretaceous outcrops form a continuous belt from eastern Brown County, Texas to Red River, and thence eastward in southern Oklahoma south of the Arbuckle and Ouachita Mountains to the Arkansas border. To the west of this belt in Texas are numerous outliers of Cretaceous rocks. Sandstones firm enough to be of value as building stone are not common in the Cretaceous beds. However, a dark red or black sandstone of Cretaceous age has been used locally for buildings in southeastern Oklahoma.

Tertiary outcrops form a continuous belt east and south of the Cretaceous outcrops and extend southward to San Jacinto and Polk Counties, Texas. Locally, sandstones of varying quality are present in the Tertiary outcrops. Some sandstones, used locally for building, are found in the Carrizo formation, Newby member of the Reklaw formation, Queen City formation, basal Sparta formation, Cook Mountain formation, Wellborn formation, and others. Basal white Sparta sandstone was used as rough-trimmed dimension stone in Cherokee County for the outside walls of the new courthouse in Rusk, the new Grange Hall school, and the new library in Jacksonville. This stone is available in Cherokee County about 2 miles west of Grange Hall school, and in northeastern Houston County in the vicinity of New Glover school. At the latter place the bed is 3 to 5 feet thick. Hard, white sandstones are found in the outcrop belt of the Jackson and Catahoula groups. Many of these have been quarried locally for broken stone and crushed rock. Local thicknesses of 20 feet are known.

Quarternary deposits are found along the Trinity River and other major streams as terrace deposits on either side of the river. Generally these deposits are unconsolidated gravels, sands, and clays. However, locally extensive masses of the porous deposits are indurated by interstitial calcareous or ferruginous cement. The resultant sandstones are generally coarse-grained and conglomeratic. One notable deposit of this kind is on the west side of Neches River, in extreme northeastern Houston County, Texas. This deposit has been quarried in the past, but is far removed from transportation facilities.

Silicified wood

This minor ornamental and veneer stone occurs scattered in deposits of Cretaceous (Trinity group) and Tertiary (Wilcox group and Yegua formation) age. Among the Cretaceous sediments the sands of the Trinity group in Erath and adjoining Texas counties, are the richest in silicified wood. Outcrops of the Wilcox group cross Robertson, Limestone, Freestone, Leon, Anderson, Navarro, Henderson, Van Zandt, Rains, and other east Texas counties. Outcrops of the Yegua formation cross Madison, Leon, Houston, Trinity, Angelina, and Nacodoches Counties.

Glauconite rock

This minor building stone occurs in Weches strata of Tertiary age. The formation crosses Robertson, Leon, Houston, Anderson, Henderson, Cherokee, and many other east Texas counties. (Compare map accompanying chapter on iron ore--Fig. 28.) Locally the beds are sufficiently indurated to be useful as a building stone. The new courthouse at Rusk, Cherokee County, has this stone as a facing of interior hallways and on the lower part of the outside wall. The thickness of the useful portion of the Weches is from 2 to 10 feet only.

Reserves

Building stone is so widely distributed over much of the area that the overall reserves of this resource must be very large. However, locally, there is a scarcity of building stone in some parts of the area, and if natural building stone is to be used in such localities it would have to be shipped in. Building stone is scarce on the High Plains and in the coastal belt of Texas.

Producing companies and localities

The more important building stones produced in the Trinity River tributary area are limestone and granite. An important limestone dimension stone area is the Lueders district, Jones and Schackelford Counties, Texas. Producers and location of quarries of limestone are given in the chapter on limestone. The granite quarries are located in Greer and Kiowa Counties, in the Wichita Mountain area of Oklahoma.

Other kinds of building stone are produced intermittently and on a minor scale at many localities. There are numerous local quarries producing broken stone intermittently for road metal. They are operated by county road crews, the State Highway Department, WPA crews, CCC camps, and other agencies. It is not possible to list all these minor quarries.

Some producing localities of sandstone in Texas are:

Quarry on Cook's Mountain near Crockett, Houston County

Quarry on Texas State Highway No. 106, north of Groveton, Trinity County

Two miles west of Grange Hall school, Cherokee County

Quarries near Homer, southeast of Lufkin, Angelina County

Quarries near Devil's Bend of Naches River, southern Angelina County

Quarries near Zavalla and Perry Deer Park, Angelina County

Quarries near Corrigan, Polk County

Silicified wood producer:

Ross R. Wolfe, Stephenville, Texas

Glauconite rock-producing localities in Texas (inactive)

Quarries near old Glover, northeastern Houston County (Dimension stone used in mission in Mission State Park at Weches.)

WPA quarry, 3 miles east of Rusk, Cherokee County (Dimension stone used in new courthouse at Rusk)

Production of building stone in the Trinity River Tributary Area

Granite Dimension Stone 1/

Year	Short Tons	Cubic Feet	Value	No. of producers
1935	1,910	--------	$169,698	4
1936	5,560	--------	179,070	7
1937	6,290	75,760	201,125	2/
1938	6,140	73,890	279,005	7
1939	3,610	43,730	173,296	6
1940	3,250	38,230	177,085	9
1941	4,000	48,560	225,314	8
1942	13,210	57,040	343,837	10
1943	3,340	37,580	327,428	6
1944	3,660	38,000	182,543	7

1/ All from Oklahoma; no granite was produced in the Texas part of the tributary area.
2/ Not listed

All data from United States Bureau of Mines

Limestone Dimension Stone

For most years the number of quarries producing limestone dimension stone in the tributary area is so few that it is not possible to publish statistics.

Crushed limestone and dolomite

Year	Short Tons	Value
1935	893,486	$ 660,358
1936	1,775,958	1,646,448
1937	1,227,415	1,119,907
1938	1,012,310 1/	1,005,026 1/
1939	2,412,501	2,105,642
1940	1,369,289	1,129,809
1941	2,151,076	1,973,758
1942	3,410,353	3,479,020
1943	3,204,627	2,761,282
1944	1,820,381	1,604,728

Crushed sandstone

Year	Short Tons	Value
1935	45,510	$ 45,335
1939	117,950	79,109
1940	134,420	103,477
1944	37,580	10,380

Miscellaneous stone sold or used by producers

Year	Short Tons	Value
1935	36,198 1/	$ 38,746 1/
1936	55,378 1/	33,260 1/
1937	143,576 1/	99,821 1/
1938	770,959	604,164
1939	186,041	85,375
1940	85,225	30,909
1941	12,700	10,285
1942	No production	------
1943	No production	------
1944	260	2,385

1/ May include chats from Joplin area

All data from United States Bureau of Mines

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CELESTITE

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Celestite ($SrSO_4$), the principal source of strontium and strontium compounds, is a medium-hard (Mohs scale of hardness, 3 to $3\frac{1}{2}$) and heavy (specific gravity, 3.97) mineral, containing 56.5 percent strontium oxide and 43.5 percent sulfur trioxide. It occurs in well-developed crystals, crystalline nodules, or irregular masses, and resembles barite in many of its properties. Pure crystalline celestite is translucent and colorless or sky-blue, but celestite in commercial deposits is usually colored by impurities. It occurs as replacement deposits or cavity fillings in limestone, calcareous sandstone, dolomite, soft sand, sandstone, and shale.

During the war the chief use of celestite was in the manufacture of signal flares and tracer bullets which owe their bright red color to small amounts of strontium compounds. A similar peacetime use of strontium compounds is in fireworks; however, normally this does not require large quantities of celestite. Small quantities of celestite are also used in the manufacture of strontium chemicals.

The use of ground celestite as a weighting medium similar to barite in the manufacture of heavy rotary drilling mud may become of prime importance in the Texas area in the future.

Celestite is mined from shallow open pits in both Brown and Nolan Counties, Texas. In Brown County the celestite is broken from the beds by means of horse-drawn plows. The plows have proven fairly satisfactory and economical, except that in some places considerable losses are sustained from shattering the celestite into pieces too small for handling. In Nolan County the celestite is pried out of exposed ledges with hand tools. During one period of about three days, a steam shovel was used for stripping the ore in the Miller locality in Brown County, and at several times tractors have been employed in drawing plows to expose and break material from the beds. In all deposits the material is roughly sorted and loaded by hand.

Post-war prospects for the domestic celestite industry depend on competition with foreign sources. In normal times celestite is imported to the United States from England, Spain, and Mexico. It can be delivered at the seaboard at prices ranging from 12 to 15 dollars per short ton. Such prices limit the possibilities of shipping domestic celestite to the seaboard or of exporting it. Thus the chief prospects for future use of celestite deposits in the Trinity River tributary area probably rest in local use as a drilling mud conditioner.

The methods employed in the Trinity River tributary area for the mining of celestite are primitive; hence they require very little capital investment and little machinery. The improvement in mining and separating methods might make possible the development of deposits having a larger overburden than the ones worked at present. The only deposits of commercial importance today are those which have only a few feet of overburden.

Occurrences of Celestite in the Trinity River Tributary Area

The mineral celestite in small non-commercial quantities is widely distributed in Texas and has been reported from the Oklahoma part of the Trinity River tributary area. Commercial deposits are restricted to two districts in Texas. (Fig. 7)

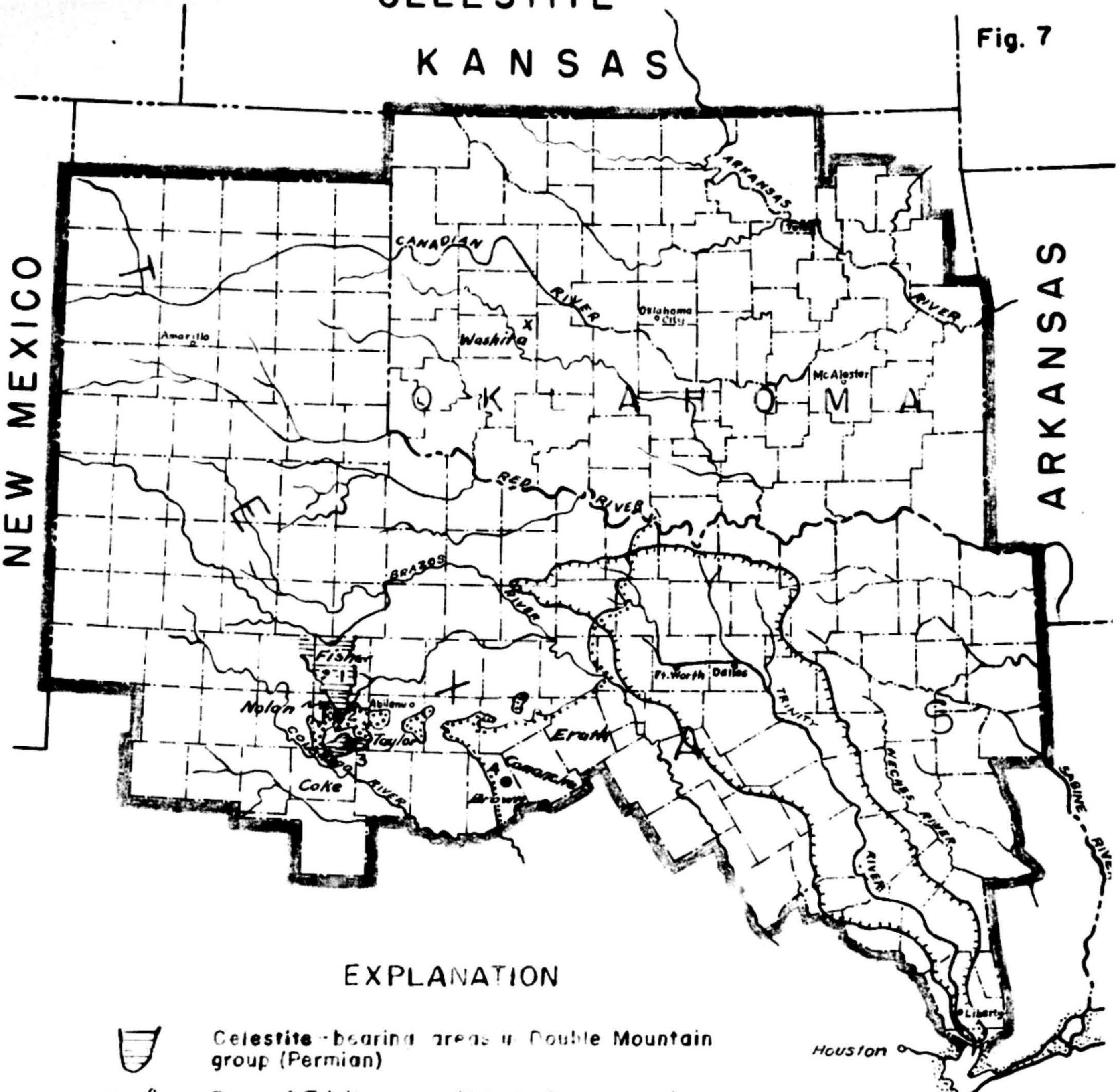
The Nolan district centers in Nolan County and the mineralized area extends southward into northern Coke County and northward as far as central Fisher County. Mining began in 1938. Celestite occurs as replacement deposits in dolomite or dolomitic limestone beds of the Double Mountain group of Upper Permain age. The thickness of the deposits is variable. In Fisher County celestite deposits are restricted to the Claytonville dolomite but in the central part of the district deposits occur in several horizons. In the Boothe deposit 5 miles south of Sweetwater, Nolan County, the enclosing bed is 14 to 20 inches thick and is variably replaced by celestite. The rock mined contains an estimated 70 to 80 percent celestite.

The Brown district centers in eastern Brown County and mineralization extends into Comanche and Mills Counties. Mining began in 1940. The celestite deposits are in impure limestone and shale which lie in the middle of a series of soft sands and clays and are probably a marginal facies of the Glen Rose formation of the Lower Cretaceous Trinity group. Celestite occurs as nodules or bedded deposits but only the bedded deposits are of commercial importance. The beds vary in thickness from 2 to 14 inches and average about 4 to 5 inches. The deposits contain from 70 to 80 percent celestite but some deposits contain as much as 10 to 12 percent barite. One of the largest workable deposits is on the R. L. Miller land about 5 miles northwest of Blanket, Brown County where the celestite bed is about 8 inches thick. Another workable deposit is on the Alpha Baker and J. A. Faulkner land about 4 miles northwest of Blanket The thickness varies from 4 to 10 inches and the grade is unusually uniform.

W. E. Ham of the Oklahoma Geological Survey reports that the largest celestite deposits in Oklahoma occur in thin dolomite beds of Permian age in an area 7 miles long in a north-south direction and 2½ miles wide near Weatherford in northeastern Washita County, Oklahoma. The celestite with a small quantity of strontianite ($SrCO_3$) is present as disseminated crystals in the dolomite, as crystals lining open cavities, or as crystals aligned along bedding planes. Four localities having possibilities of commercial development are known. In three of these localities the celestite deposits are in the Weatherford dolomite and are exposed from several hundred feet to several hundred yards along the outcrop. At these localities

CELESTITE

Fig. 7



EXPLANATION

Celestite-bearing areas in Double Mountain group (Permian)

Base of Trinity group (Lower Cretaceous)

● Celestite deposits
- 1 Roby area
- 2 Sweetwater area
- 3 Blackwell area
- 4 Blanket – Brown district

(1–3: Nolan district)

x Reported occurrence of celestite

DISTRIBUTION OF CELESTITE IN TRINITY RIVER TRIBUTARY AREA the dolomite increases from the normal 12 inches to as much as 30 inches in thickness. The fourth and largest deposit is in a 10-foot dolomite bed near the base of the Cloud Chief formation in the NE 1/4 sec. 28, T. 11 N., R. 14 W. The celestite impregnated dolomite bed crops out in a low hill that covers about 40 acres. No drilling has been done on any of the deposits to determine their extent.

Reserves

Although celestite occurs in numerous scattered deposits in the Trinity River tributary area, many of the deposits are too thin, too irregular, or have too much overburden to be workable. In estimating reserves in the Texas part of the area only those deposits of sufficient thickness and grade and under shallow overburden have been considered.

Estimated reserves in the Brown district	30,000 tons
Estimated reserves in the Nolan district	200,000 tons

Data is insufficient to estimate the reserves of celestite in the Weatherford area of west-central Oklahoma.

Producing Companies

Operating companies within the Trinity River area and plant locations are listed below. Most, if not all, of the celestite produced was used for rotary drilling mud.

Bennett-Clark Company, Nacogdoches, Texas	5 miles south-southwest of Sweetwater, Nolan and Fisher Counties.
The Milwhite Company, Houston, Texas	4 to 5 miles northwest of Blanket, Brown County.
Mudrite Chemicals, Inc., Houston, Texas	Brown County.

Production

Year	Tons Shipped	Number of Producing Companies
1940		2 Producers
1941	1959	3 Producers
1942	1917	3 Producers
1943	4958	4 Producers
1944		2 Producers

All of the above production was from the Brown and Nolan districts in Texas, none having been produced in Oklahoma. Data from the United States Bureau of Mines.

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CLAYS

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Clays are rocks of earthy appearance whose chief characteristic is their plasticity in the wet state. Mineralogically clays are composed of complex hydrous aluminum silicates - the so-called clay minerals - among which are included kaolinite, dickite, nacrite, halloysite, allophane, beidellite, nontronite, and montmorillenite. In addition to aluminum, silica, and water, some of the clay minerals also contain iron, magnesium, calcium, potassium, and sodium. The individual particles of which clay is composed are usually less than 0.002 mm. in diameter and consequently the component minerals can be identified only by microscopic or x-ray methods. Minerals commonly occurring as impurities in clays are quartz, calcite, gypsum. siderite, limonite, pyrite, and muscovite. Many clays contain soluble salts which in some cases may offset their usefulness. Raw clays contain large amounts of water, part of which is mechanically held and part combined chemically with the hydrous silicates. The mechanically held water which evaporates at room temperature is known as "shrinkage water", the remaining water which is driven off by heating to 110° C. is known as "pore water"; the "shrinkage water" and the "pore water" together are known as "water of plasticity". A part of the mechanically held water is retained until the clay is heated to about 200° C., this is known as "hygroscopic" water. The chemically combined water, which is an essential part of the various clay minerals, is given off at temperatures between 450° and 600° C.

In the following chapter, clays are divided according to their use and are discussed under the headings of bleaching clays, burning clays, and drilling clays. This division is somewhat arbitrary as some clays may be used for several purposes, but it is followed for convenience.

Bleaching clays, used mainly in the oil refining industry, are generally derived from the alteration of volcanic ash and have the property to a high degree of decolorizing oils. Burning clays include those plastic, siliceous clays used in the manufacture of brick, tile, and pottery; and the high-alumina clays used in making refractory bricks and shapes. Drilling clays are clays having certain properties which make them useful as the basic ingredient in oil well drilling fluid.

The properties which determine the suitability of a clay for any specific purpose are physical rather than chemical and depend to a large extent on the mineralogic composition and the texture of the clay. Chemical analysis gives little indication of the physical properties, and whether a clay can be used for any given purpose must be determined in most cases by test.

Bleaching Clays

A. L. Jenke, United States Geological Survey

Nearly all clays possess some ability to decolorize mineral, vegetable and animal oils and fats. In general, bleaching clays are classified as active or activable. The naturally active clays, or fuller's earths, are those in which the power to adsorb coloring matter from oils is inherent in the raw product. The activable clays, or bentonites,1/ are those which are either wholly inactive or only slightly active in their natural state, but which can be activated by treatment with dilute acid, rendering them capable of performing the same functions as the naturally active clays. The Trinity River tributary area produces over 15 percent of the total United States output of bleaching clay.

Optically and mineralogically fuller's earth and bentonite are similar, both being hydrous aluminum-silicates of the montmorillonite-beidellite group. Both have a common origin as it can be shown microscopically that both are derived from altered volcanic ash and contain devitrified glass shards in all stages of alteration to clay minerals. Physically, fuller's earth is non-plastic to slightly plastic, possesses a foliated structure, and ordinarily does not slake readily when submerged in water. Bentonite or metabentonite is a plastic, dense clay, with a waxy luster which will slake readily in water. As found in nature, both fuller's earth and bentonite have a high water content (25 to 30 percent moisture) and range in color from white to light gray, cream, buff, brown, or dark gray.

As a general rule the chemically activated clays are much more effective as decolorizing agents than naturally active earths. Artificially activated clays cannot be recovered efficiently or at low enough cost and therefore must be discarded after use. Fuller's earth can be recovered and used several times. However, the activated clays display a distinct advantage over natural earths due to their greater bleaching

1/ True bentonites have the property of swelling several times thier volume upon the addition of water. The bentonite clays of the Trinity River area, although similar in other respects to the bentonites, do not have this property and technically are known as metabentonites. However, in the bleaching trade all activable clays are called bentonites and for this reason the production of metabentonite is listed under bentonite. The terminology of bleaching clays in industry is further complicated by a recent trend to report tonnages mined as fuller's earth rather than bentonite although bentonite may have been reported as mined from a given pit in previous years. In commercial practice a clear distinction is seldom made between fuller's earth and bentonite and it is not unusual to find the two terms used almost interchangeably.

powers and consequently lesser quantities are necessary to produce the desired result. This is a desirable feature, as the smaller the amount of clay used, the smaller is the loss of oil retained in or adsorbed by the clay.

In 1943, 80 percent of all bleaching clay produced in the United States was used as decolorizing agents in the petroleum refining industry; most of the remaining output was used in the refining of cotton seed, soya bean and coconut oil, and in the clarification of crude packing-house lard and grease. Approximately 60 percent of the total bleaching clay output is listed as fuller's earth by producers. Activated clays for bleaching purposes are in part superseding the use of fuller's earth.

Bleaching clays are mined by strip-pit methods, since the over-burden seldom exceeds 10 feet. Pick and shovel or small mechanical shovels are generally used for mining and the raw clay is hauled by truck to processing plants located near the pits. Raw fuller's earth is crushed to minus 3/4 inch and dried in kilns. Further crushing and screening reduce the clay to the size desired by the individual user. The activable clays are treated with dilute sulfuric acid at boiling temperature for several hours, washed free of acid and soluble salts, dried, and then crushed to the desired sizes. Bleaching clay is generally sold in 135 pound bags or shipped in box cars.

The Trinity River tributary area, and especially the lower part of the Trinity River basin, are very favorably located to supply bleaching clay to the great oil refineries of the mid-continent and Gulf coast states. Bleaching clays are bulky, low priced materials, that sell for a small margin of profit and the fortunate location of the principal deposits adjacent to important refining centers makes competition improbable from deposits outside the area. The major oil companies which are the principal users of bleaching clays, commonly operate their own pits and processing plants to supply their own needs.

Occurrence of bleaching clay in the Trinity River tributary area

General occurrence - Bleaching clay is found in several sedimentary formations of Tertiary age which underlie the Coastal Plain in the lower part of the Trinity River tributary area. Bleaching clay is also found in Pliocene or Pleistocene strata in many scattered localities on the High Plains throughout western Texas and western Oklahoma.

Coastal Plain area - As is shown on the accompanying map, (fig.8) bleaching clay deposits in the Coastal Plain area are essentially confined to certain Tertiary strata which cross the Trinity tributary area in three narrow bands roughly parallel to the coast line. These strata lie in the Cook Mountain formation of the Claiborne group, of the Eocene age; the Jackson group, also of Eocene Age; and the Catahoula sandstone, of Miocene (?) age. Because these strata cross the Trinity River, outcrops of bleaching clay might be expected in the lowland areas subject to periodic flooding, but in most cases the clay-bearing formations in the immediate vicinity of the river have been covered by Quarternary alluvium, or have been eroded away, and clay exposures, therefore, are not common.

BLEACHING CLAY

Fig. 8

EXPLANATION

o	Operating mines.
⊘	Abandoned or non-operating.
×	Reported occurrence.
	Pliocene and Pleistocene deposits.
	Catahoula sandstone — Miocene (?)
	Jackson group — Eocene
	Cook Mt. member of Claiborne group — Eocene.

DISTRIBUTION OF BLEACHING CLAY IN THE TRINITY RIVER TRIBUTARY AREA

The only actual outcrops of bleaching clay in the area subject to flooding are at Alabama Ferry on the Trinity River in Houston County, where an exposed bed of bleaching clay 3 to 4 feet thick is found in the Landrum shale member of the Cook Mountain formation. A pit near Carlisle, Trinity County, in the Catahoula sandstone, is very close to the area subject to flood if it is not actually within it.

Within the Trinity River drainage basin bleaching clay is found in the Cook Mountain formation in Houston, Leon and Madison Counties. In this formation in Houston County, bentonite is found at Hurricane Bayou $3\frac{1}{2}$ miles northeast of Crockett, and bentonite outcrops form a line from there to Alabama Ferry, a distance of about 20 miles. Mapping of these numerous outcrops and drilling of the associated deposits were carried on as a W. P. A. project under the supervision of the Bureau of Economic Geology, University of Texas. Important deposits of fuller's earth and bentonite are found in the Catahoula sandstone near Riverside, in Walker County, and a few miles farther to the east in San Jacinto and Trinity Counties.

Outside of the Trinity River drainage basin deposits of Fuller's earth and bentonite occur in the Claiborne group south of Forest, Cherokee County; 2 miles north of Redland, Angelina County; and in Nacogdoches County. Deposits of fuller's earth are being mined 9 miles south of Zavalla, Angelina County, from beds of Jackson age. Near Carmona, in Polk County, 62 feet of pyritic clay, some of which is bentonitic, was found during the course of auger drilling. It is uncertain whether the clay is in the Jackson group or the Catahoula sandstone.

The most important producing areas at present are those near Riverside, Walker County, where the Texas Company and the Continental Oil Company have processing plants; and the deposits near Zavalla and Redland, Angelina County, where several companies produce bleaching clay.

Outcrops of Claiborne, Jackson and Catahoula strata extend beyond the limits of the Trinity River tributary area and deposits of bleaching clay are either being mined or are known at several localities in these formations both east and west of the area.

High Plains area - Bleaching clay occurs as isolated lenses in Pliocene or Pleistocene sediments throughout the High Plains area in western Texas and western Oklahoma. Counties where deposits have been found include Woodward, Ellis, Dewey, Blaine, Roger Mills, and Washita Counties in Oklahoma and Hartley, Potter, Swisher, Briscoe, and Scurry Counties in Texas. Most of these deposits are classed as bentonite, although some fuller's earth is reported in the Texas part of the area, particularly in Briscoe and Swisher Counties. Producing plants are located in Briscoe County, Texas. Others in Woodward County, Oklahoma, six miles west of the town of Woodward, are no longer operating.

Other localities - Deposits of bleaching clay are reported from Wagoner and Haskell Counties, Oklahoma, near the Arkansas River, and from the valley of the Red River in Cotton County, Oklahoma. Detailed information is lacking regarding these deposits but they appear to be in pockets or lenses in Quarternary terrace gravels.

fuller's earth. The total output of bleaching clays from the Trinity river tributary area in the past 10 years is given in the following table:

Year	Fuller's earth Short tons	Value	Bentonite 1/ Short tons	Value 1/
1935	40,904	$391,389	4,805	$58,508
1936	46,176	455,493	1,247 2/	9,976 2/
1937	48,252	460,928	235 2/	2,354 2/
1938	36,749	346,490	4,464 2/	44,640 2/
1939	36,537	341,048	4,336 2/	43,860 2/
1940	32,454	261,379	3,000 2/	30,000 2/
1941	61,399	556,741	0 2/	0 2/
1942	68,577	577,631	2,500 2/	28,250 2/
1943	76,561	584,390	3,912 2/	44,532 2/
1944	93,057	738,969	1,764 2/	39,427 2/

1/ May include some bentonite used as rotary drilling mud
2/ From Texas part of tributary area only; Oklahoma production not available

All data from United States Bureau of mines

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Burning Clays

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Burning clays are so abundant, and the products derived from them are so much in use in everyday life that the general public pays them scant attention. Yet these clays are a very important natural resource because of their wide range of uses in industry and their abundance and cheapness.

The useful properties of burning clays derive from the fact that when wet they may be molded or pressed into many desired shapes and then changed by heating into hard and rigid ceramic products that are resistant to water and weathering. As clays vary in behavior under the firing process they are conveniently classified on the basis of the properties which they exhibit after firing. One such classification is given below.

(1) White or cream burning clays

Open burning or porous. Uses: pottery and refactories.

Dense burning and nonrefractory. Uses: pottery including whiteware, porcelain, stoneware, terra cotta, abrasive wheels, zinc retorts, face brick, saggers.

Dense burning and refractory. Uses: crucibles and glass pots.

(2) Buff burning clays
Refractory. Uses: Abrasives, fire brick, terra cotta, sanitary ware, glazed and enamelled brick, glass pots, saggers, retorts.

Nonrefractory. Uses: bricks, architectural terra cotta, stoneware, yellow ware, face brick, sanitary ware, paving brick, abrasive wheels.

(3) Red or brown or dark burning clays
Open pit or porous. Uses: brick, drain tile, hollow blocks, flower pots, pencil clays, ballast.

Dense burning. Uses: conduits, sewer pipe, paving brick, floor tile, electrical porcelain, cooking ware, silo block, artware, face brick, architectural terra cotta, roofing tile, hollow blocks, flower pots, slip clays.

(4) Light gray or cream burning clays containing some calcium or magnesium carbonate. Use: common brick.

It would be difficult to list all the ceramic uses of clays. The wide range of useful products obtained from the various burning clays is indicated in the foregoing classification and new ones are continually being developed.

In the United States in 1939, clays of all classes exclusive of brick clays sold and used totaled 3,927,764 short tons valued at $17,046,773. Among these the burning clays greatly predominated, with fire clay 56.7 percent, kaolin 20 percent, and ball clay 3.2 percent. Miscellaneous clays made 10.3 percent of the total, followed by bentonite and fuller's earth with 5.6 percent and 4.2 percent respectively. The average value of the kaolin sold was $8.94 per ton, of the ball clay $7.28, and of the fire clay $2.62.

Most clay deposits are worked as open pits, the method of excavation depending upon the character of the clay, thickness and extent of beds, and character of the overburden. Small deposits, or those containing more than one variety of clay difficult of separation otherwise, may be mined by hand, but are usually uneconomical to operate. In some deposits the clay face may be undercut at the base and caused to fall, thus breaking up the material so that it may be handled readily. Thick beds of uniform quality are best handled by machines such as drag lines or shovels and planers. The development of the bulldozer has greatly facilitated and cheapened the removal of overburden in preparation for handling by machines of greater power and capacity. Underground mining is commonly used only for extracting the better grades of bedded clay and usually is carried out by the room-and-pillar method.

Ordinary burning clay products have restricted markets on account of transportation costs and because of competition, which is commonly near at hand. Some of the lower grade products might, by some special virtue or reputation, invade reasonably distant market territories, but the great majority of them must be used close to the place where originated. Products made from the higher grade clays have a somewhat wider market.

In an established industry such as the manufacture of brick and tile, the element of competition is of prime consideration. Brick plants are in operation over a large part of the Trinity River tributary area wherever raw materials are readily accessible. In the great majority of cases the clay deposit and the brick plant are owned and operated by the same company. In the past many more plants were operating than at the present time, but broadening of markets and improvements in transportation have tended to concentrate the industry in fewer hands and localities.

Capital requirements of the average brick plant are moderate. However, the economic factors of greatest importance are cheap fuel and transportation. Cheap and efficient fuel in the form of natural gas is available in great quanitites in many locations in the Trinity River tributary area. If the Trinity River were to be opened up to cheap water transportation ceramic plants of the tributary area would have two great economic advantages. Under those circumstances it is possible that the markets for ceramic products made in the area could be extended greatly and that many of the products could be exported for sale in Mexico and the Antilles. The expected expansion in building coupled with the increasing shortage of lumber should swell the demand for all kinds of ceramic building materials.

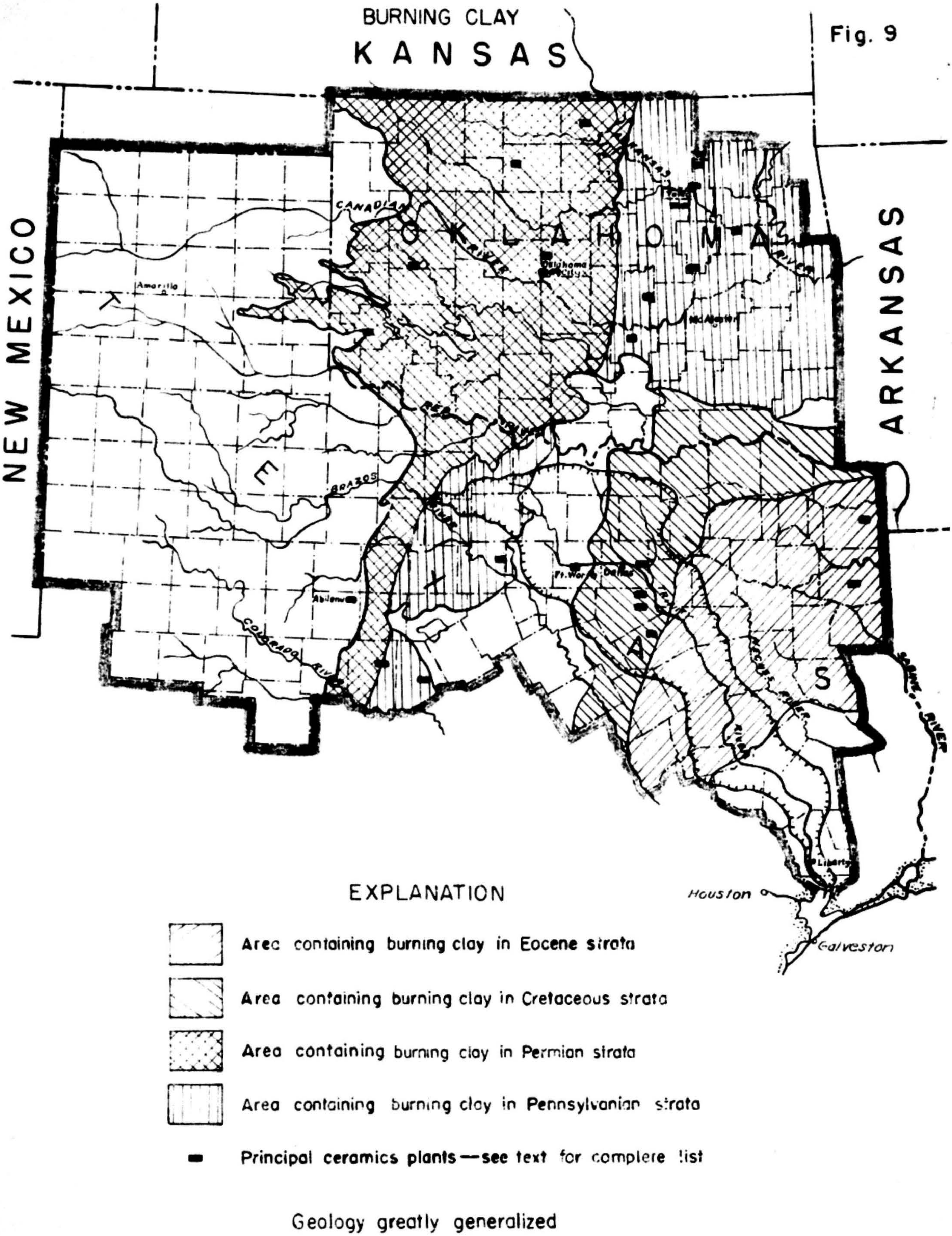
Occurrence of burning clays in the Trinity River tributary area

Burning clays occur widely over the Trinity River tributary area. Nearly all parts of the area have deposits of burning clays except the region underlain by the Cenozoic deposits of the High Plains. The presence and general character of the clays are determined by the geologic formation in which they are found.

Occurrence of burning clays in Texas - Clays, or shales, suitable for making brick and tile or similar low-grade products are found over a wide area along the outcrops of the Pennsylvanian and Permian formations in Texas. Extensive and thick beds of shale occur in the Strawn Canyon groups of Pennsylvanian age in Brown, Eastland, Erath, Palo Pinto, Parker, and Wise Counties. In the Strawn group the principal shale beds are the Mingus shale, 250 to 300 feet thick, the East Mountain shale up to 300 feet thick, and the Salesville shale about 150 feet thick. The Canyon Brownwood shale and its equivalents outcrop from Brown County to Wise County, increasing in thickness from 180 feet in the south to approximately 400 feet in the north. Equally extensive but much thinner beds of shale occur also in the Canyon strata overlying the Brownwood shale.

In the Upper Pennsylvanian Cisco group, as well as in the Permian formations outcropping over a wide area farther west, numerous beds of shale occur. Like those in the upper Canyon strata they are thinner than those in the Strawn. They tend to be very erratic in both distribution and lithologic character. They grade into "red beds" to the north and northeast. Above the Wichita group, the remaining Permian formations are predominantly of "red bed" facies and hence contain none but the lowest grades of burning clay materials. The Cisco formations contain several

Fig. 9



DISTRIBUTION OF BURNING CLAY IN THE TRINITY RIVER TRIBUTARY AREA beds of coal and it is probable that shales associated with the coals might be found to have ceramic uses.

Burning clay deposits are abundant in the Woodbine, Eagle Ford, Austin, Taylor, and Navarro formations of Cretaceous age. These formations crop out through a wide belt which includes the most densely populated area in Texas. Although lower grade clays predominate, the deposits probably are the most important in the state due to their location within, or close to, a highly industrialized area.

The Woodbine outcrop extends from northern McLennan County through Hill, Johnson, Tarrant, Denton, and Grayson Counties to Red River in extreme northwestern Fannin County. Other small outcrop areas occur in the valley of Red River in Lamar and Red River Counties. Beds range in thickness from a few feet to over 600 feet.

The Eagle Ford shale outcrops across McLennan, Hill, Johnson, Ellis, Tarrant, Dallas, Denton, Collin, and Grayson Counties, and continues adjacent to the valley of Red River along the northern sides of Fannin and Lamar Counties and into northwestern Red River County. The thickness ranges from a few feet to several hundred feet.

The Bonham clay, a provincial facies of the Austin chalk, occurs in Grayson, Fannin, Lamar, and Red River Counties and varies from a few feet up to about 400 feet in thickness.

The Taylor strata outcrops from McLennan County to Red River and occupies parts of McLennan, Limestone, Hill, Navarro, Ellis, Kaufman, Dallas, Rockwall, Collin, Hunt, Fannin, Delta, Lamar, Red River, and Bowie Counties. The clay beds in the Taylor are interrupted along the outcrop by the development of interfingering beds of chalk, marl, and sand. The total thickness of the formation is somewhat over a thousand feet, and part of it is shale suitable for brick making.

The outcrop of the Navarro strata across the area is divisible into three formations, the medial Nacatoch sand separating clay or clay-marl beds in the lower and upper parts. The outcrop extends through parts of Limestone, Navarro, Henderson, Kaufman, Hunt, Hopkins, Delta, Franklin, Red River, and Bowie Counties. Its total thickness is comparable to that of the Taylor formation.

In the Eocene formations outcropping in the southeastern part of the Trinity River tributary area, the useful burning clays are mostly associated with the lignite-bearing beds of the Wilcox and Yegua groups. However, the Midway, Claiborne, and Jackson strata also contain clays, at least of the lower grades. In the lignitic beds of the Wilcox and Yegua are found deposits of refractory or semi-refractory clays that can be used in the manufacture of pottery, stoneware, and fire brick. Outcrop belts of the Eocene strata are as follows:

Midway; Limestone, Freestone, Navarro, Henderson, Kaufman, Van Zandt, Rains, Hunt, Hopkins, Delta, Franklin, Titus, Red River, and Bowie Counties.

Wilcox; Robertson, Limestone, Leon, Freestone, Navarro, Anderson, Henderson, Van Zandt, Rains, Wood, Harrison, Marion, Panola, Rusk, Nacagdoches, Hopkins, Franklin, Camp, Titus, Morris, Red River, Bowie, and Cass Counties.

Mt. Selman; Robertson, Leon, Freestone, Anderson, Houston, Cherokee, Nacogdoches, Henderson, Van Zandt, Smith, Wood, Hopkins, Franklin, Titus, Camp, Morris, Cass, Marion, Harrison, Upshur, Gregg, and Rusk Counties.

Cook Mountain; Robertson, Leon, Houston, Anderson, Cherokee, Nacagdoches, and Angelina Counties.

Yegua; Madison, Walker, Houston, Trinity, and Angelina Counties.

Jackson; Walker, Houstin, Trinity, Polk and Angelina Counties.

In addition to the burning clays found in the older formations, the more argillaceous terrace materials along major streams are often suitable for making brick or other low-grade wares. Deposits of this type represent the most likely sources of raw materials in that part of the area covered by red bed and continental deposits of the High Plains.

Occurrence of burning clays in Oklahoma - Burning clays are abundant throughout Oklahoma, almost every county containing deposits which are suitable at least for the manufacture of common brick. Clays which might be used for refractory purposes are found in Cherokee, Kay and Woodward Counties; and fire clays underlie many of the coal beds in Oklahoma. Most of the clay deposits are associated with rocks of Pennsylvanian or Permian age. This is due in part to the extensive area underlain by Pennsylvanian and Permian sediments; burning clay deposits in Oklahoma are also found in Ordovician, Mississippian, Cretaceous and Quaternary sediments.

Reserves

No attempt has been made to estimate accurately the total reserves of various burning clays found in the Trinity River tributary area. If special high-grade clays, such as refractory clays, are exempted it is evident that the resources of the ordinary types of clays, that is, brick clays, are very large and practically inexhaustible.

Producing companies and products

Texas - There are 20 to 30 concerns engaged in the production or processing of burning clays in the Texas part of the tributary area. Large brick industires are located in Ellis, Harris, Henderson, and Palo Pinto Counties. Pottery is made at Athens, Dallas, Marshall, Mount Pleasant, and other towns. The only large region where there are few ceramic plants is the High Plains area, where raw materials suitable for this kind of industry are generally scarce.

The following is a list of producers in the Texas portion of the Trinity River tributary area. These were all active in 1943 unless otherwise indicated.

Brick and Tile

Name of company	Location of plant or pit
Abilene Brick Co., Abilene, Texas (idle in 1943)	Taylor County
Acme Brick Co., Fort Worth, Texas	Denton, Ellis, Parker, Wichita, Wise Counties
Athens Brick and Tile Co.	Nacogdoches County
Atlanta Brick Co., Atlanta, Texas	Cass County
Atlas Pressed Brick Co., Ferris, Texas	Ellis County
Barron Brick Co., Palmer, Texas	Ellis and Limestone Counties
Brownwood Brick & Tile Co., Brownwood, Texas	Brown County
Erath Supply Co., Arlington, Texas	Erath and Palo Pinto Counties
Ferris Brick Co., Ferris, Texas	Dallas and Ellis Counties
Garrison Brick Co., Garrison, Texas	Rusk County
W. H. Johnson, Shreveport, Louisiana	Harrison County
J. C. Jones, L. R. Honeycutt, et al., Henderson, Texas	Rusk County
Marshall Brick Co., Marshall, Texas	Harrison County
Martin Brick Co., Coleman, Texas	Coleman County
Mineral Wells Clay Products Co., Mineral Wells, Texas	Palo Pinto County
Palmer Brick Co., Palmer, Texas	Ellis County
Palo Pinto Coal Co., Mineral Wells, Texas	Palo Pinto County
Pan-Tex Clay Products Co., Amarillo, Texas (closed in 1943)	Potter County
Reliance Clay Products Co., Dallas, Texas	Palo Pinto and Smith Counties
Texas Brick Co., Brownwood, Texas	Brown County
Tri-State Brick & Tile Mfg. Co.	Harrison County
Whitselle Brick & Lumber Co., Corsicana, Texas	Navarro County

Fire Brick

Acme Brick Co., Atlanta, Texas	Denton County
General Refractories Co., Philadelphia, Pennsylvania (Troup works)	Cherokee County (pit) Smith County (kilns)
Harbison-Walker Refractories Co., Pittsburgh, Pennsylvania; (Athens, Texas)	Henderson County
Thermo Fire Brick Co., Sulphur Springs, Texas	Cherokee and Hopkins Counties

Pottery

Name of company	Location of plant or pit
Athens Tile & Pottery Co., Athens, Texas (idle in 1943)	Henderson County
The Hogue Pottery, Mt. Pleasant, Texas	Titus County
Lovefield Clay Co., Dallas, Texas	Hopkins County
Marshall Pottery Co., Marshall, Texas	Harrison County
Montgomery Porcelain Products Co., Lovefield, Dallas, Texas (idle in 1942-43)	Dallas County

Oklahoma

The following list of 15 ceramic plants which were active in 1945 is taken from "Oklahoma Manufacturers" by Thuesen (23).

Manufacturer	Location of Plant: Town	Location of Plant: County	Product
Acme Brick Co.,	Oklahoma City	Oklahoma	Hollow building tile, facing tile, common and face brick, acid brick, refractories.
Acme Brick Co.	Tulsa	Tulsa	Brick and tile
Baker Co., Earl A.	Bethany	Oklahoma	Tile
Blackwell Brick Co.	Blackwell	Kay	Brick, face, and common.
Davis Brick Co.	Enid	Garfield	Brick
Ellis Glazing Co.	Henryetta	Okmulgee	Glazed products
Frankoma Potteries Inc.	Sapulpa	Creek	Pottery
Mangum Brick & Tile Co.	Sapulpa	Greer	Brick and tile
Muskogee Materials Co.	Muskogee	Muskogee	Concrete blocks, bricks.
Sapulpa Brick & Tile Co.	Sapulpa	Creek	Brick and tile
Sheaffer Tile Co., G. V.	Oklahoma City	Oklahoma	Tile
United Brick & Tile Co.	Tulsa	Tulsa	Brick and tile
United Brick & Tile Co.	Collinsville	Tulsa	Brick and tile
Western Brick Co.	Clinton	Custer	Brick and tile
Wewoka Brick & Tile Co.	Wewoka	Seminole	Brick and tile

Production

Year	Raw clay burned into clay products at mine or pit: Texas Short Tons	Oklahoma Short Tons	Fire clay produced: Texas 2/ Short Tons	Value
1943	442,710	103,554	Not reported	
1944	213,804	71,955	24,403 1/	$82,490 1/

1/ Includes some stoneware clay from Harrison County.
2/ No data available for production of fire clay in Oklahoma.

All data from United States Bureau of Mines. According to the Bureau, statistics prior to 1943 are very incomplete.

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Drilling Clay

A. L. Jenke, United States Geological Survey

Drilling clay, commonly called "drilling mud" in the petroleum industry, is any clay which when finely ground and mixed with water makes a suitable medium for removing rock cuttings from drill holes, and for lubricating or cooling the drill stem and bit in rotary drilling. The Trinity River tributary area, as one of the great oil producing sections of the United States, uses large quantities of drilling clay in the preparation of drilling muds.

Drilling clay must be a very fine-grained to colloidal clay or shale, free from grit and sand, and resistant to flocculation by minerals in solution. The most important properties of drilling mud are purely physical--including weight, viscosity, gel strength, and thixotropic characteristics. (Thixotropy refers to the ability of a fluid to set rapidly to a thick jelly-like mass when circulation is stopped, and to become fluid again when agitated). The last three physical properties are dependent upon the particle size of the clay and especially on the relative proportion of particles of colloidal size.

Besides the primary functions of drilling muds--removing rock cuttings and lubricating and cooling the drill stem and bit--additional functions of a good rotary mud are: (1) to seal the walls of a drill hole to prevent sloughing of the formation, loss of mud into the formation, and dilution of the mud by water from the formations penetrated; and (2) to prevent high-pressure gas blowouts. To control high gas pressures and prevent gas blowouts when drilling, ground barite ($BaSO_4$)or celestite ($SrSO_4$) are added to the drilling mud to increase the weight of the mud column. The addition of colloidal bentonitic clays assists in holding the heavy materials in suspension.

Deposits of drilling clay are usually to be found at or very close to the surface, and are mined by simple strip-pit methods using light weight mechanical shovels, drag lines, or scrapers. Processing of the raw material may involve air-drying in a shed and grinding to about 200 mesh, or, in the case of the more valuable clays such as metabentonite, the material is dried in rotary kilns or gas fired furnaces and then ground to the desired size in hammer mills. The clay is usually sold in 100 pound bags.

As drilling clay is a bulky, low cost commodity, its source must be as close to the point of consumption as possible. Drilling clay sells for $4 to $10 per ton. The higher priced clays, used where drilling conditions are especially difficult, are sold under various trade names.

Specialized drilling clays find their greatest applications in the Gulf Coast oil fields, where gas pressures are high and drilling conditions are difficult. Specialized drilling muds find some application in other oil field localities in the Trinity River tributary area, but are not as widely used as these in the Gulf Coast fields because of generally more favorable drilling conditions, and because in some instances the shale formations penetrated in drilling yield satisfactory mud materials without the addition of specialized drilling clays. The future demand for drilling clay from deposits in the Trinity River tributary area will depend in large measure on drilling activity in and adjacent to the area.

Occurrences of Drilling Clay in the Trinity River Tributary Area

No production of drilling clay is reported from the Trinity River basin although any of the reported occurrences of bentonitic clay from the Eocene Jackson and Claiborne groups or the Miocene Catahoula formation of the Gulf Coastal Plain may be acceptable as high grade drilling clay. The location of reported bentonitic clay occurrences in the Trinity River basin are given under Bleaching Clay.

In the Trinity River tributary area outside the drainage basin, drilling clay is mined from the Jackson group of the Eocene in Angelina County and from Eocene strata in Hopkins County. On the High Plains west of Texas, drilling clay has been reported from Pliocene formations in Bailey, Briscoe, Cochran, Crosby, Dickens, Donley, Garza, Gray, Hartley, Howard, Lamb, Lynn, and Terry Counties. In 1943 Howard and Terry Counties produced drilling clay. In the Trinity River tributary area in Oklahoma occurrences of bentonitic clays of Pliocene age, suitable for drilling clay, are reported from Blaine, Dewey, Ellis, Haskell, Roger Mills, Wagoner and Woodward Counties, but no production is in progress.

Reserves

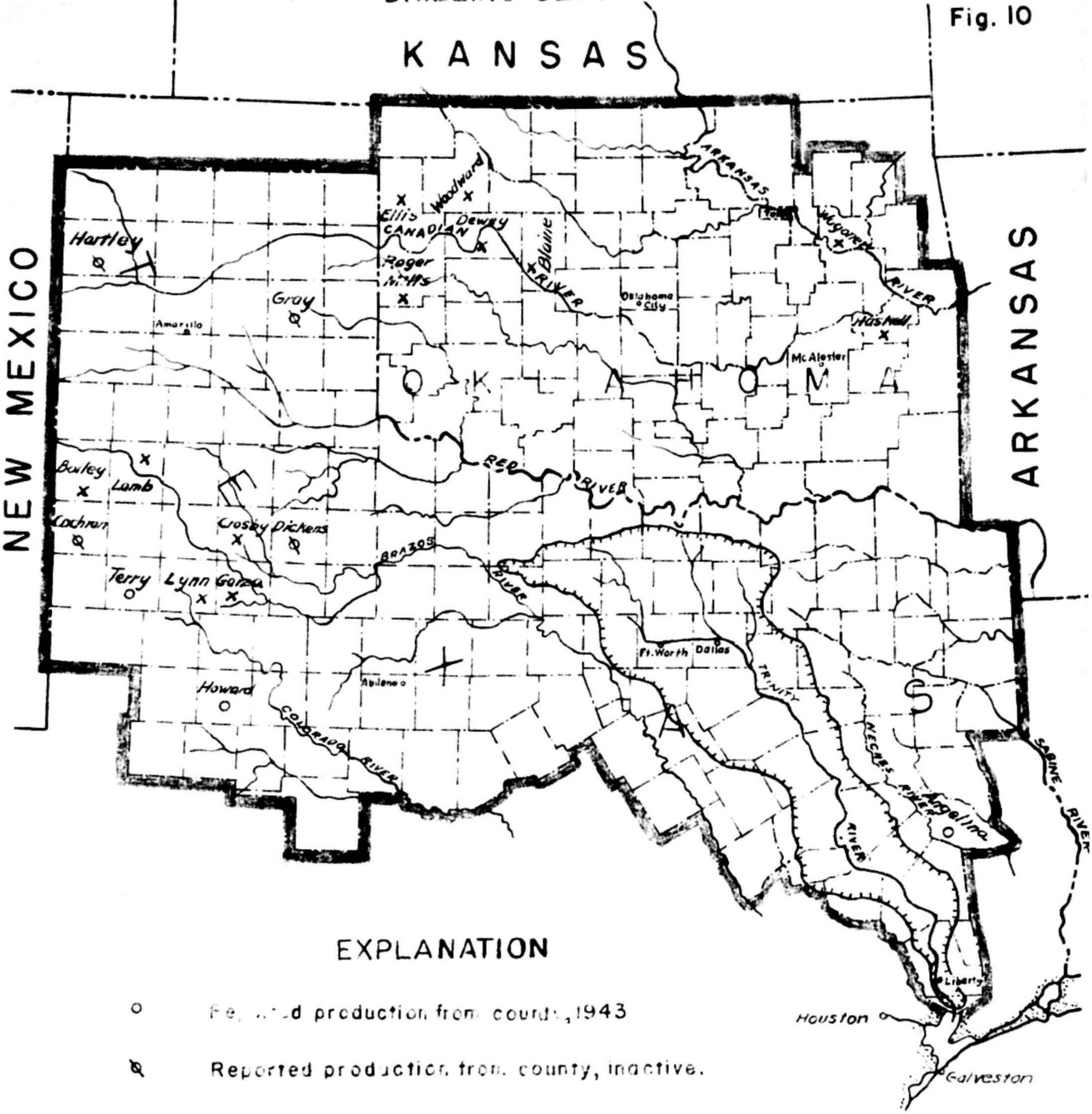
In the Trinity River tributary area probably unlimited reserves of clay and shale suitable for drilling clay are present in the Tertiary formations of the Gulf Coastal Plain and in the High Plains.

Producing Companies

The companies and location of pits producing drilling clay in the Trinity River tributary areaare given in the following table:

Name of Company	Location
C. A. Jones	Howard County, Texas
Tri County Clay Co.	Terry County, Texas
Xact Products Co., Inc.	Angelina County, Texas

Fig. 10



EXPLANATION

○ Reported production from county, 1943

⊘ Reported production from county, inactive.

x Reported occurrence in county.

DISTRIBUTION OF DRILLING CLAY IN THE TRINITY RIVER TRIBUTARY AREA

Production

The production of drilling clay for the 10 year period 1935-1944 in the Trinity River tributary area is given in the following table:

Year	Short Tons	Value
1935	No information	-----
1936	No information	-----
1937	14,000	70,000 1/
1938	8,000	80,000
1939	No information	-----
1940	No information	-----
1941	5,500	49,000
1942	7,601	18,204
1943	9,321	53,431
1944	11,000	33,000

1/ Estimated

All data from United States Bureau of Mines

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DOLOMITE AND MAGNESIAN LIMESTONE

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Dolomite rock and magnesian limestone are sedimentary rocks composed chiefly or partly of the mineral dolomite. This mineral is medium hard (Mohs scale of hardness, 3.5 to 4.0, slightly harder than calcite) and comparatively heavy (sp. gr. 2.8 to 2.95). Its chemical composition is $CaMg(CO_3)_2$; theoretically it contains 30.4 percent CaO, 21.9 percent MgO, and 47.7 percent CO_2. Most natural dolomites contain iron or manganese replacing a portion of the magnesium.

Dolomite rock had a spectacular demand as a source of metallic magnesium during the war. A plant at Austin, Texas, south of the Trinity River tributary area, manufactured magnesium from dolomite quarried in the Llano-Burnet area and magnesium salts obtained as a by-product in refining potash salts at Carlsbad, New Mexico. Magnesium metal is used for signal flares and incendiary bombs; aluminum-magnesium alloys were used in the manufacture of airplanes and airplane engines, where light weight and strength are prime considerations. In 1943, which was the first year of greatly expanded magnesium metal production in the United States, 887,830 short tons of dolomite rock or 25 percent of the total dolomite rock produced specifically for the magnesium content were used for this purpose.

Dead-burned and untreated dolomite are used as refractory lining for metallurgical furnaces. Dolomite is also a raw source of magnesia (MgO) which has refractory and other uses. Before the war the refractory uses of dolomite rock and dolomitic limestone accounted for five-sixths of the United States production and in 1943 about 70 percent of the total dolomite production was for this purpose.

Dolomitic limestone is used by paper mills for the making of sulphite pulp and dolomite is used for making basic magnesium carbonate for heat insulation. These two uses included about 8 percent of the total production in 1943. Small amounts of exceptionally pure dolomite, that is, free of or very low in iron, specially prepared as dead-burned dolomite and sold under the trade name Calcimag, are used in glass manufacture.

The economic aspects of future production of dolomite rock or dolomitic limestone in the Trinity River tributary area depend on many factors of competition and supply. Dolomite rock suitable for production of metallic magnesium can be obtained in parts of Texas outside the Trinity River tributary area and one such deposit is already well-developed and provided with transport and production facilities. Dolomite rock from this deposit can be produced and shipped cheaply and the deposits would compete with dolomite produced from within the tributary area. Additional competitors of dolomite and dolomitic limestone produced in the Trinity River tributary area are the potash mines of New Mexico, which are potential producers of magnesium salts, chiefly sulphate and chloride, and the chemical plants along the coast of Texas and Louisiana which produce or can produce magnesium salts and metal economically.

Occurrence of dolomite and dolomitic limestone in the Trinity River Tributary Area

No dolomite or dolomitic limestone of importance is known from the Trinity River Basin but dolomite and magnesian limestone are abundant in other parts of the tributary area. The Arbuckle group in the Arbuckle and Wichita Mountains of southern Oklahoma is of Cambrian and Ordovician age and has great thicknesses of high-grade undeveloped dolomite rock and magnesian limestone. The Central Mineral Region of Texas also has thick and extensive dolomite deposits but their outcrop is south of the Trinity River tributary area. A few dolomitic limestone beds are known from the Pennsylvanian rocks of Oklahoma and Texas. Widespread but thin beds of dolomite and magnesian limestone are present in the Permian rocks of the western part of the Trinity River tributary area in northern Texas and western Oklahoma.

The Arbuckle group in the Wichita and Arbuckle Mountains is more than 7,000 feet thick but it has been studied in detail in only a few places. The Arbuckle group has been subdivided into a number of formations. The lower part is Cambrian in age and it has been divided into the Fort Sill, Royer, Signal Mountain and Butterly formations. The upper part is Ordovician in age and has been subdivided into McKenzie Hill, Strange, Cool Creek, Kindblade, and West Springs Creek. Ten miles south of Davis in Murray County the lower 2,250 feet of the group is predominantly magnesian and 1,500 feet of this thickness is close to pure dolomite in composition.

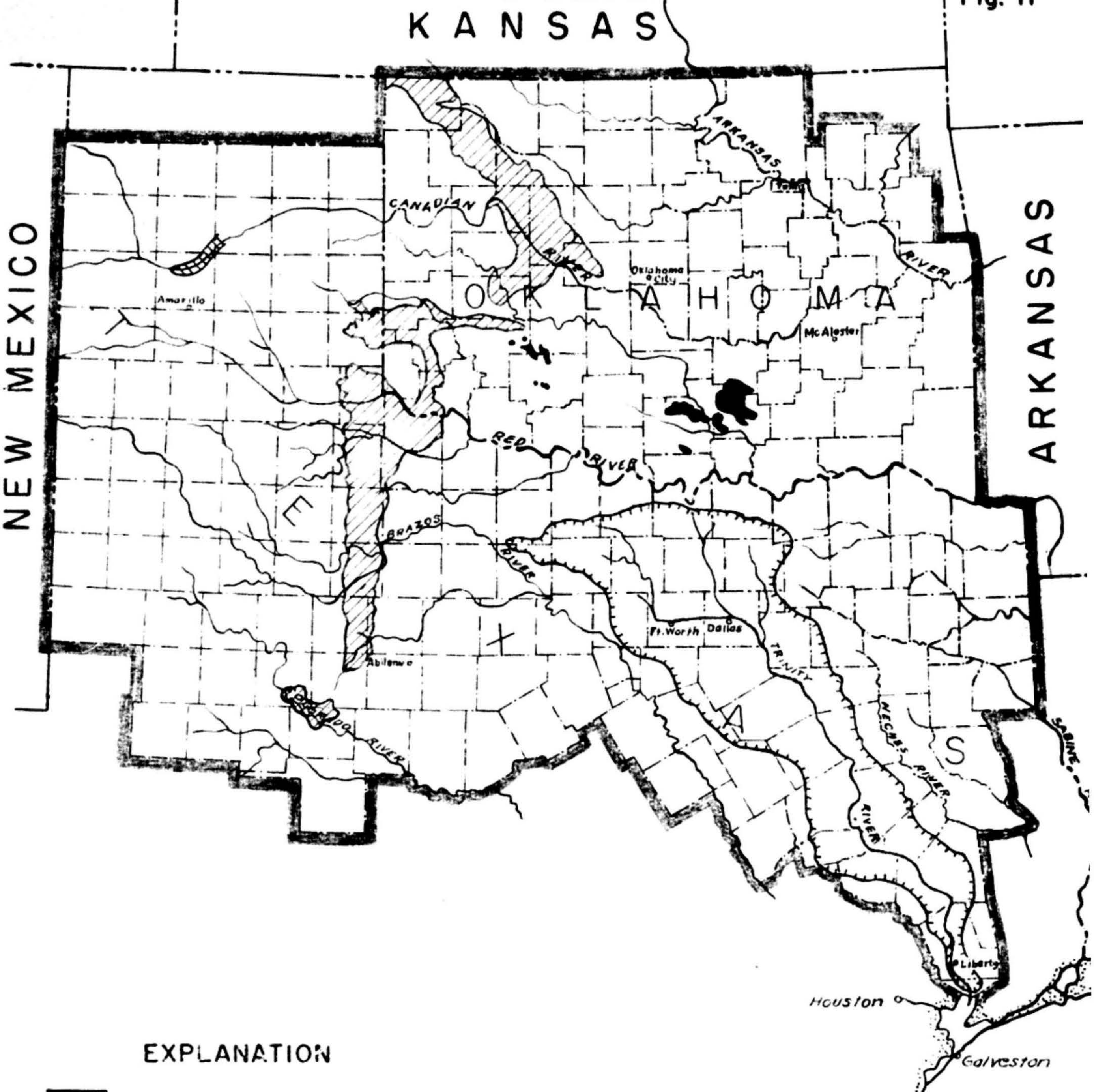
Southwest of Mill Creek, Johnston County in the Arbuckle Mountains the Royer dolomite crops out over a wide area. Dolomite is also present north of Mill Creek. Analyses of samples from beds in the Royer range from 18.7 to 21.5 percent MgO. The Butterly dolomite is present only in the Arbuckle Mountains. No analyses from this dolomite are listed in the literature. The Strange dolomite crops out a few miles northwest of Lawton, Comanche County, but is present only in the Wichita Mountains. It is a high-grade dolomite with beds 80 feet thick. Analyses range from 20.5 to 21.8 percent MgO and average 21.0 percent. Dolomite also crops out 9 miles south of Gotebo, southeastern Kiowa County. Analyses of this material range from 18.3 to 20.7 percent MgO. The Kindblade is also a dolomite and the West Spring Creek formation contains some dolomite in the eastern Arbuckle Mountains. These formations have not been studied in detail and no analyses have been publishe

Pennsylvanian limestones in northeastern Oklahoma are known to be in part magnesian. The Wildhorse limestone in sec. 21, T. 22 N., R. 10 E. contains 18.0 percent MgO but the formation is only 10 feet thick at that locality. Other formations in Oklahoma containing magnesi limestone are the Avant, Dewey, and Hogshooter limestones. In Texas a f reef-like masses in rocks of the Canyon area of Pennsylvanian age may co tain magnesian limestone.

Dolomite and dolomitic limestone occur as thin beds in several Permian red bed formations which crop out in the western part of the area. (See Fig. 11.) The dolomite beds in the Permian strata are a part of a series of chemical precipitates formed in dessication basins. There is an apparent cyclic repetition of greenish shale, dolomite, and gypsum or anhydrite overlain by red shale of presumably continental

DOLOMITE AND MAGNESIAN LIMESTONE

Fig. 11



EXPLANATION

Outcrop of Arbuckle group, Cambrian and Ordovician

Outcrop of Permian strata containing dolomites or dolomite limestones

Outcrop of Alibates dolomite, upper Permian

DISTRIBUTION OF

DOLOMITE AND MAGNESIAN LIMESTONE IN THE TRINITY RIVER TRIBUTARY AREA origin. Underground, where protected from erosion or removal by solution, sodium chloride and other readily soluble salts commonly overlie the gypsum as a continuation of the dessication cycle. The dolomite beds are at the base of the main gypsum beds on the outcrop and are transitional with them. The contact zone is fairly sharp but marked by interfingering of the two materials.

In the Texas part of the tributary area a dolomitic limestone, the Merkel, occurs near the top of the Permian Clear Fork group and extends through Runnels, Taylor, Jones, Stonewall, Knox, and Foard Counties, Texas. Ordinarily it consists of dolomitic limestone from 1 to 2 feet thick or two separate strata about 2 feet thick separated by a shale break.

Dolomites appear at the base of several gypsum beds in the Blaine and Dog Creek formations across Coke, Nolan, Fisher, Stonewall, King, Knox, Foard, Cottle, Childress, and Hardeman Counties, Texas. Of these dolomite beds the Acme dolomite is 1 to 10 feet thick, and the Guthrie is 2 to 10 feet, the Mangum is about 3 feet, the Childress is not more than 2 feet thick, and the Sweetwater dolomite is from 1 to 3 feet thick. Solution of the underlying gypsum has made the dolomite beds slump and break into great piles which could be quarried with ease.

Stratigraphically one of the highest beds of dolomite is the Alibates. This rock is found along the Canadian River in Potter and Moore Counties (10) 1/. It is a massive, white, crystalline dolomite, cherty in places, usually separated by shale into two beds, of which one is about 9 feet thick and the other about 2 feet. Thicknesses up to 11.7 feet are reported. This dolomite contains acid-insoluble residues of 1.16 to 2.16 percent and R_2O_3 of 0.36 to 0.84 percent.

In southwestern Oklahoma three thin dolomite beds have been recognized in the Blaine formation of Permian age. The Mangum dolomite is located near the top of the Blaine formation. It contains more than 5 percent silica and may be highly calcitic in some locations. Thirty feet below the Mangum is the Creta dolomite which is 1 to 2 feet thick and is very pure. In the northern part of the southwestern Blaine outcrops the Jester dolomite occupies almost the same stratigraphic interval as the Creta in the southern part of the area. North of the Canadian River 4 dolomites have been recognized in the Blaine formation. These dolomite beds are 1 to 2 feet thick.

The Woodward group which is divided into the Dog Creek, Whitehorse, Day Creek and Cloud Chief members overlies the Blaine formation. The most prominent dolomite bed in the Woodward group is the Day Creek dolomite which ranges up to 5 feet and averages 2 feet in thickness. The Greenfield dolomite occurs near the base of the Whitehorse sandstone Analyses show a MgO content of 20.08 and 25.28 percent.

In the Weatherford area two dolomites are recognized in the Permian rocks. The lower bed is the Greenfield dolomite 60 feet below the top of the Whitehorse and the upper bed is at the base of the Quarermaster formation. The bed at the base of the Quartermaster is 6 to

1/ See reference in bibliography.

15 feet thick and is probably equivalent to the Day Creek dolomite. In the Weatherford area the Greenfield dolomite may contain more magnesia than theoretically pure dolomite.

Reserves

Reserves of high-grade dolomite in the Arbuckle group in the Arbuckle and Wichita Mountains of southern Oklahoma are very great. Although studied in detail in only a few places it is probable that over 1/5 of the 7,000-foot Arbuckle group is composed of high-grade dolomite. Quarry sites are plentiful but transportation facilities are available at only a few places. The various thin dolomite beds in the Permian rocks of the Trinity River tributary area can be traced in outcrop over great distances. The Bureau of Economic Geology of the University of Texas has estimated reserves of 30,000,000 tons of dolomite and dolomitic limestone from Permian rocks within the Texas portion of the Trinity River tributary area. At least an equal quantity of material is available in western Oklahoma. However, it seems at present improbable that the Permian dolomite beds will be utilized in the near future except possibly for local use as crushed stone or building stone because of the great reserves of high-grade rock available in the Arbuckle and Wichita Mountains within the tributary area, in the Llano-Burnet Region south of the tributary area, and elsewhere in the United States.

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GYPSUM AND ANHYDRITE

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Gypsum, ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$) are widely distributed in the Permian rocks of western Oklahoma and north-central Texas. Rock gypsum crops out along the main drainages as white ledges, frequentl tinted by included impurities or surface stained by the enclosing red shales. Gypsum gives way to anhydrite down the dip of the beds; anhydrit only rarely crops out at the surface. The Trinity River tributary area produces almost 15 percent of the total United States output.

Gypsum is very soft (Mohs scale of hardness, 2 -, easily scratched by the finger nail) and light in weight (sp. gr., 2.3); anhydrite is harder (hardness, 3 to 3.5) and heavier (sp. gr., 2.9). When crystalline and relatively free from inclusions, gypsum is called selenite; gypsum when mixed with clay and sand is known as gypsite. When calcined between 300° and 350° F., gypsum loses its water of crystallization and a product, $2(CaSO_4).H_2O$ is formed; calcined gypsum upon the addition of water sets to a smooth compact material.

Approximately three-quarters of the total Unied States output of gypsum is calcined and used in the building trades as the base for plaster, Keene's cement, and pre-fabricated lath, wall board, sheathing board and tile. The remaining one-quarter of the United States production is used principally as a retarder in Portland cement; a small quantity is used as agricultural gypsum. Anhydrite in small percentages can be substituted for gypsum as a retarder in Portland cement; it can also be used as an agricultural fertilizer, and as a natural mineral filler.

Gypsum is quarried in open pits and is then calcined in kettles following crushing and grinding or in rotary kilns following crushing to uniform size. The product of the rotary kiln is frequently ground to size while the calcined material is still hot to achieve a more uniform product.

Besides adequate reserves of crude gypsum rock, the requirements for the establishment of a gypsum-product plant are cheap fuel for calcining and cheap transportation to population centers where the finished product can be marketed. Building materials can stand only limited transportation charges as they must compete with material from other producing localities; because of this gypsum plants are located along established railroad lines. At the present time the principal markets for gypsum produced within the Trinity River tributary area are the large cities within the area. Calcined gypsum and gypsum products manufactured in Colorado, Kansas and Arkansas limit the market of Trinity tributary area plants in a northerly and, to a lesser extent, in an easterly direction.

Under war time construction restrictions the demand for gypsum products lagged except for pre-fabricated building material which made remarkable gains. With the removal of building restrictions the demand for all calcined gypsum products should increase greatly. In addition, the use of gypsum as a retarder in cement, and as fertilizer in agriculture should create a strong demand for the uncalcined product.

Occurrences Within the Trinity River Tributary Area

Occurrences in the Permian Rocks

Within the Trinity River tributary area the commerically important gypsum deposits are confined to sediments of Permian age. The Permian gypsum-bearing beds crop out from Woods County, Oklahoma, on the Kansas border southward to the valley of the Colorado River in Coke County, Texas, a distance of about 400 miles. The gypsum-bearing beds continue northward into Kansas; south of the Colorado River the Permian rocks are covered by Cretaceous and Tertiary deposits. No Permian rocks crop out within the Trinity River drainage basin, and gypsum deposits associated with these rocks are likewise outside the drainage basin.

The gypsum beds thicken, thin, and in many places, lens out entirely along the line of outcrop. However, a single bed or series of beds at a given locality is remarkably consistent both in grade and thickness. The gypsum-bearing shales commonly form escarpments or low hills; a notable example of this topographic expression of the gypsum beds is the Gypsum Hills along the southwestern side of the Cimarron River Valley in Oklahoma.

Regionally, the gypsum-bearing beds dip very gently to the west. Eastward and westward flowing streams cutting through the flat-lying beds have given the line of outcrop a highly serrated appearance. The gypsum and anhydrite occur in the Blaine and Cloud Chief formations in Oklahoma and the Double Mountain formation in Texas. Individual beds may be locally as thick as 60 feet and beds 20 feet thick over large areas are common.

Other Occurrences

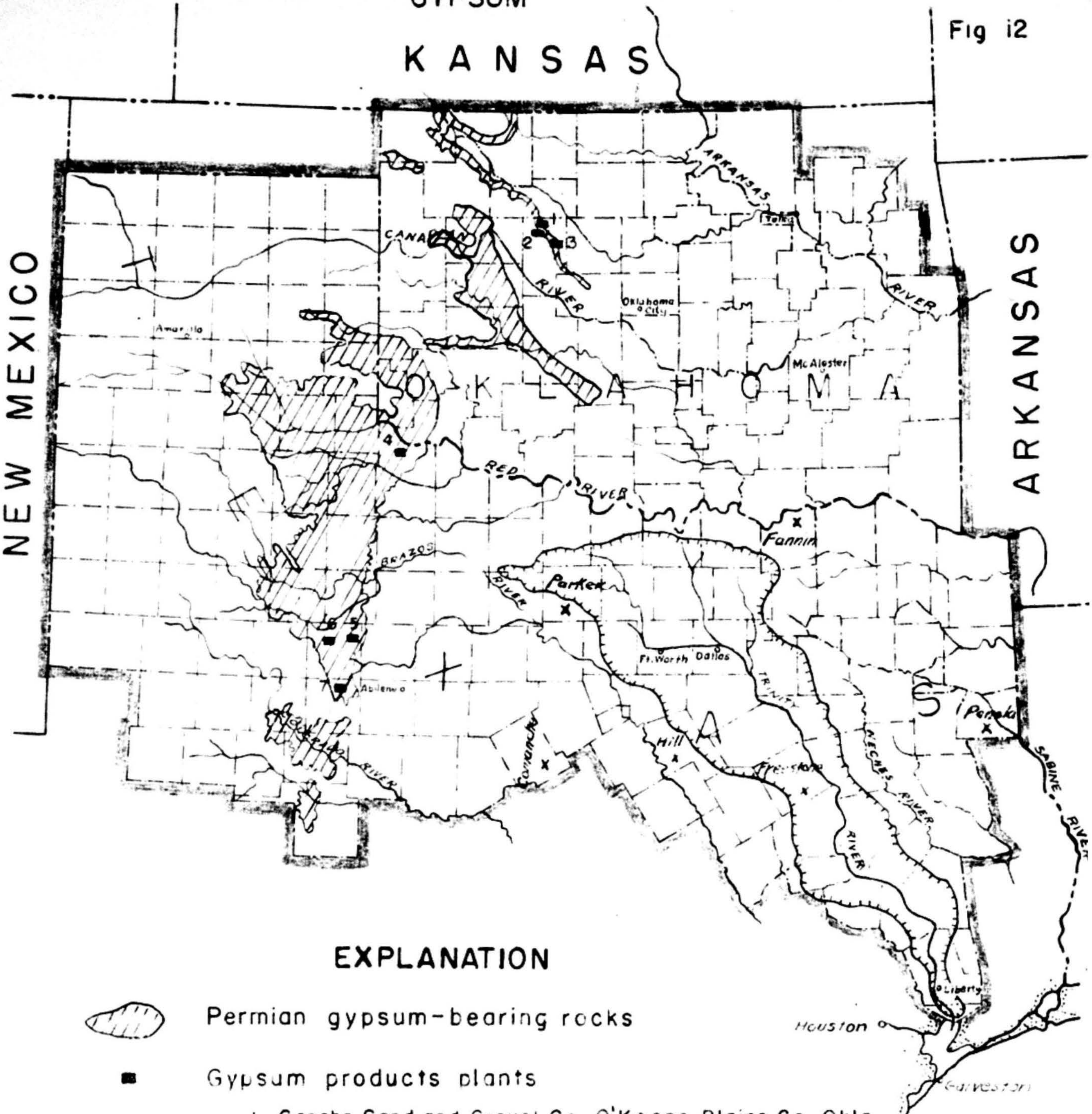
Anhydrite and some gypsum have been found in wells in the Trinity and Fredericksburg divisions of the Cretaceous in Parker and Freestone Counties within the Trinity River drainage basin and in Fannin, Comanche, Hill, and Panola Counties outside the basin; anhydrite also occurs at depth in the cap rock of salt domes at a number of localities within the Trinity River basin. None of these deposits are of commercial importance at the present time. The distribution of the gypsum-bearing Permian and Cretaceous rocks and the location of gypsum products plants in the Trinity River tributary area are shown on the accompanying map. (Fig. 12.)

Reserves

It has been estimated that in Oklahoma alone, reserves of 125 billion tons of gypsum within 100 feet of the surface are available. In the entire Trinity River tributary area the reserves of gypsum should be considered unlimited. Reserves of anhydrite are many times those of gypsum, but they are under considerably greater cover.

GYPSUM

Fig 12



EXPLANATION

Permian gypsum-bearing rocks

Gypsum products plants

1 Concho Sand and Gravel Co., O'Keene, Blaine Co., Okla.
2 U.S. Gypsum Co., Southard, Blaine Co. Okla.
3 Universal Atlas Cement Co., Watonga, Blaine Co., Okla.
4 Certain-teed Products Co., Acme, Hardeman Co., Texas
5 Celotex Co., Hamlin, Fisher Co., Texas
6 National Gypsum Co., Rotan, Fisher Co., Texas
7 U.S. Gypsum Co., Sweetwater, Nolan Co., Texas

x Counties where gypsum and anhydrite have been reported in drill holes from Cretaceous rocks

DISTRIBUTION OF GYPSUM IN THE TRINITY RIVER TRIBUTARY AREA

Producing Companies

Operating companies within the Trinity River tributary area, plant locations, and plant capacities are listed below:

Oklahoma

Concho Sand and Gravel Co.	O'Keene, Blaine County	Closed in 1942 for duration of war
U. S. Gypsum Co.	Southard, Blaine County	4 Kettles
Universal Atlas Cement Co.	Watonga, Blaine County	----------

Texas

Certain-teed Products Co.	Acme, Hardeman County	5 Kettles
National Gypsum Co.	Rotan, Fisher County	4 Kettles
Celutex Co. (Formerly Texas Cement Plastor Co.)	Hamlin, Fisher County	9 Kettles
U. S. Gypsum Co.	Sweetwater, Nolan County	6 Kettles

The Universal Atlas Cement Company mines gypsum for use as a retarder in Portland cement and does not calcine its output. The National Gypsum Company is reported to be doubling the capacity of its calcining plant. The Concho Sand and Gravel Company produced crude gypsum in 1942, but closed down for the duration of the war.

Production

Gypsum output of the Trinity River tributary area for a ten-year period is given in the following table:

PRODUCTION OF GYPSUM IN THE TRINITY RIVER TRIBUTARY AREA

Year	Short Tons Crude Gypsum Produced	Value in Dollars	Number of Mines
1935	304,960	290,508	8
1936	372,227	302,128	7
1937	410,104	534,658	8
1938	360,178	461,035	7
1939	410,745	431,892	7
1940	491,374	578,187	8
1941	663,054	746,951	7
1942	613,993	751,065	7
1943	618,944	796,133	6
1944	518,640	803,159	6

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MINERAL RESOURCES OF THE TRINITY RIVER TRIBUTARY AREA IN TEXAS AND OKLAHOMA

Compiled by

THE UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

AND

THE UNIVERSITY OF TEXAS

BUREAU OF ECONOMIC GEOLOGY

PART II

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HELIUM

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Helium is a very lightweight, chemically inert gas found in small percentages in certain petroleum natural gas fields in the United States. It is colorless, odorless, and tasteless and, being chemically inert, it is nonpoisonous, noninflammable, and nonexplosive. Of all gases helium is the most difficult to liquify and solidify.

The principal use of helium is in lighter-than-air craft where its great lifting power (only 8 percent less than hydrogen, the lightest of the gases), and its noninflammability make it ideal for this purpose. Before the war over 90 percent of the United States output was used for lighter-than-air craft, and during the war this percentage probably increased greatly. An increasing quantity of helium is being used in the medical profession in the treatment of pulmonary diseases such as asthma, and in anesthetics. A similar use of helium is in diving helmets and caissons to prevent the occupational disease known as the "bends". During the war helium was used to provide an inert atmosphere in welding magnesium and an increasing use in metallurgy following the war is probable. The use of helium as a tracer gas by the petroleum industry to determine the extent of underground migration of natural gas or air that is injected in pressure maintenance or cycling operations probably will be one of the most important peacetime helium developments. Other uses of helium are in radio tubes and electric signs, for cooling electrical equipment, and in specific heat determinations and other scientific research.

Helium is separated from the other constituents of natural gas by a process which involves liquifying all the constituents of the gas except the helium. The refined helium which is about 98.2 percent pure is shipped in tank cars or in small gas cylinders under pressure and the remaining gas sold as a fuel.

Until the war, the Panhandle district of Texas had a virtual monopoly on helium production, and that district probably is still the most important helium source because the Bureau of Mines Amarillo and Exell Helium Plants are near Amarillo in Potter County, Texas. To meet increased demands by the Armed Forces for helium, the Bureau of Mines also constructed and operated helium plants at Cunningham and Otis, Kansas, and Shiprock, New Mexico. The Shiprock Plant processes gas produced in the nearby Rattlesnake field, San Juan County, New Mexico, where helium-bearing gas was discovered in 1942. Natural gas containing helium is also known from southeastern Colorado, eastern Utah, and southeastern Ohio. Beginning in 1927, small, privately-owned plants were operated intermittently at Dexter, Kansas, and Thatcher, Colorado, but these plants with related helium-bearing natural gas properties were purchased by the Government in 1938 and have now been dismantled. The government-built plants in Texas have enough capacity to exceed the normal peacetime demand.

Occurrence of Helium in the Trinity River Tributary Area

Helium in natural gas was first identified in 1905 from a shallow gas well at Dexter, Cowley County, Kansas, about 13 miles north of the Oklahoma border. However, the first experimental production was in 1918 from pilot plants operated under the direction of the Bureau of Mines at Fort Worth in Tarrant County, and Petrolia in Clay County, Texas. The natural gas used by these pilot plants was from the Petrolia gas field in northern Clay County, about 30 miles north of the Trinity River Basin. Following the war a larger plant was constructed at Fort Worth and operated until 1929, when the Bureau of Mines Amarillo Helium Plant was opened.

The helium plant at Amarillo was built to process natural gas from the Cliffside gas field in Potter County about 12 miles northwest of Amarillo. The Government has acquired the gas rights in about 50,000 acres, the entire Cliffside gas field. The gas is produced from Permian rocks at depths ranging from 3,200 to 3,600 feet and is under pressure of more than 600 pounds per square inch. The helium content of the Cliffside natural gas is about 1.8 percent. In fifteen years of operation only about 3 percent of the gas reserves of the Cliffside field have been used for the production of helium by the Government. The residue gas following helium extraction is sold in the city of Amarillo for fuel.

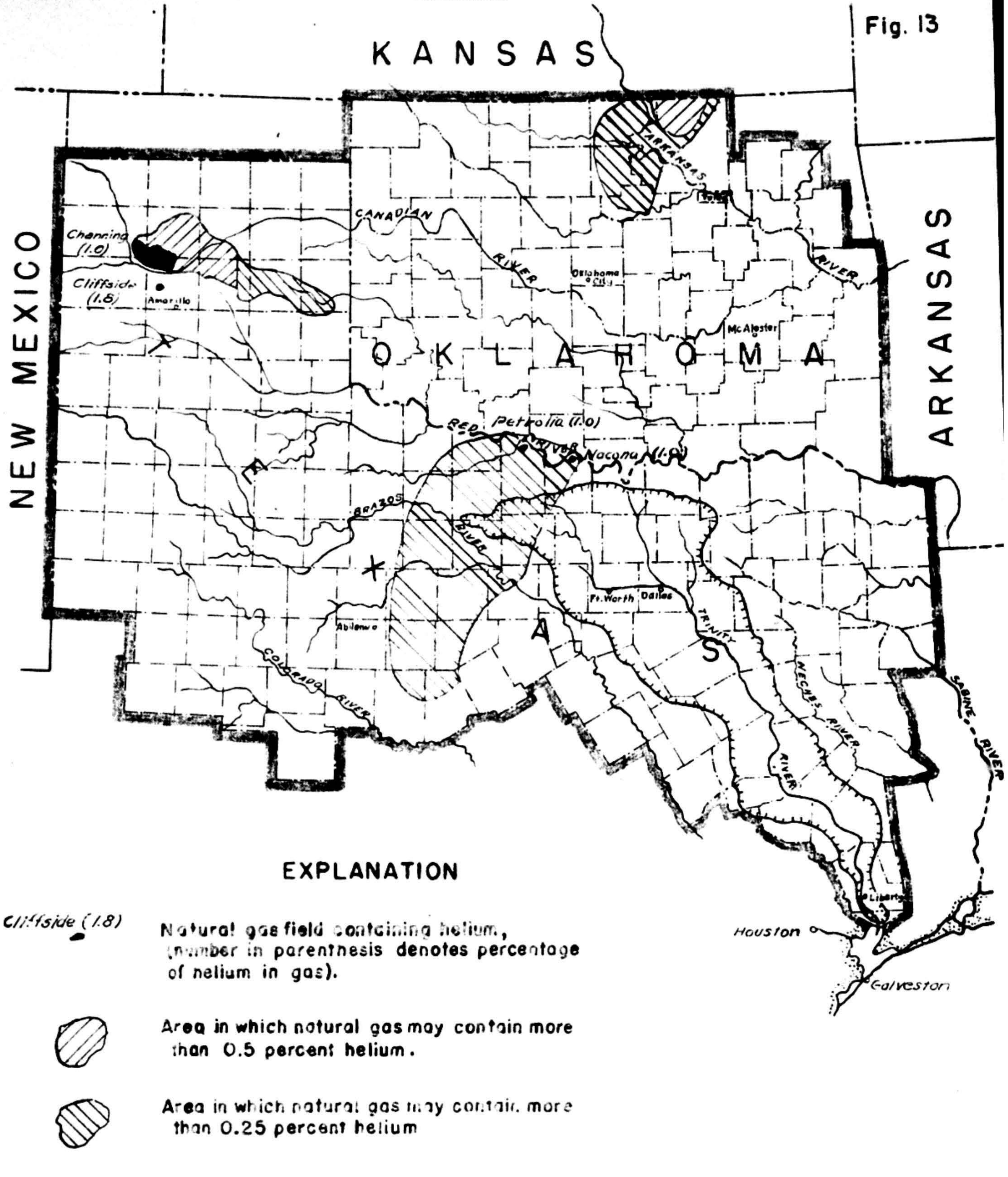
During the war, the Exell Helium Plant, with a capacity of 60 million cubic feet per year, was built at Exell, 30 miles north of Amarillo, to process gas from the Channing area, which is in the southwestern part of the main Panhandle field in Moore, Potter, Oldham, and Hartley Counties, Texas. Natural gas in the Channing area carries about 1 percent helium.

Other areas in the Trinity River tributary area which may contain as much as 0.5 percent helium in natural gas are northwestern Osage County, Oklahoma, a southern extension of the discovery area in Cowley County, Kansas and southwest of the Petrolia field in Brown and Coleman Counties, Texas on the southern boundary of the Trinity River tributary area.

Reserves in the Trinity River Tributary Area

Natural gas reserves of the Cliffside field have been conservatively estimated at 100,000,000,000 cubic feet containing 1,800,000,000 cubic feet of helium. Although reserves of helium in the Channing area have not been published, they are probably greater than in the Cliffside field. Some of the helium in the gas from the Channing field is removed i the Exell Plant which processes commercial gas flowing to regular domestic and commercial consumers. The helium is recovered whether a market exists or not, the volume of helium in excess of market requirements being transported through a high pressure pipeline approximately 12 miles to the Government-owned Cliffside gas field where it is injected

Fig. 13



DISTRIBUTION OF HELIUM IN THE TRINITY RIVER TRIBUTARY AREA

Adapted from maps by Rogers (1921) and Dobbin (1935) and stored for future use. The natural gas in northwestern Osage County Oklahoma and the area southwest of the Petrolia field, Texas, contain considerably smaller percentages of helium and the reserves are, in large part, depleted by the production of oil. These areas cannot be regarded as important helium reserves in comparison with the great reserves in the Texas Panhandle area.

Production

Fiscal Year	Cubic Feet
1934	6,534,270
1935	10,218,480
1936	4,663,355
1937	4,809,230
1938	5,830,752
1939	6,281,906
1940	9,450,855
1941	16,173,430
1942	29,962,530
1943	58,951,155
1944	137,268,144
1945	128,431,764

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Preface to chapter on Limestone, Caliche

and Shell Deposits

The uses of limestone are so many and various that limestone is treated under several headings. Limestone for agricultural, metallurgical, chemical, and similar uses is treated on pp. 112-122. Limestone used as dimension stone in the building industry and as crushed or broken stone for construction purposes is discussed in the chapter on Building Stone (pp. 66-77). The use of limestone in the cement industry is described in the chapter on Portland Cement Materials (pp. 127-133), and the occurrence and uses of dolomite and magnesian limestone are discussed on pp. 100-104.

stone in which the spaces between the fossil shells are not wholly filled with natural cementing material. Chalk in its pure form is an earthy or pulverulent limestone of loosely cemented, very fine grains of calcite or microscopic calcareous fossils. Lithographic limestone is a hard limestone of uniform microscopic grain size.

The admixture of other minerals or sedimentary materials such as dolomite, glauconite, quartz grains, shale or clay, results in dolomitic, glauconitic, arenaceous, and argillaceous limestones. Several different colors are produced by various included minerals or impurities, including glauconite (greenish), carbon compounds (brown or gray to black), marcasite or pyrite (bluish), and iron oxides (yellowish to brown or reddish).

Caliche is a deposit of calcite and other minerals produced at the surface of the ground by the evaporation of ascending capillary groundwaters in arid and subarid climates. Substances carried in solution by those groundwaters are left behind on evaporation of the water and form a surface crust. As most groundwaters of the region carry calcium carbonate in solution, the mineral calcite is commonly the chief constituent of the caliche crusts. The thickness of these caliche crusts is variable according to the length of time the formative process has been active, and to other local conditions. Caliche is usually white or light-colored, pulverulent, and without bedding or only crudely bedded. Due to its nature as an evaporation residue it is mixed in varying proportions with soil particles such as sand or clay.

Shell deposits are the remains of ancient shell banks of marine or brackish water origin. Nearly all shell banks of the Texas Coast are composed predominantly of the loose valves of dead oysters of the common oyster species, Ostrea virginica (Gmelin). These shells are composed of calcium carbonate ($CaCO_3$) and small quantities of phosphatic and organic substances. Freshly dredged shell deposits also contain traces of common salt (NaCl), which can be removed by washing with fresh water.

Because limestone is found in great abundance in almost every country of the world, it has been used by man since very early times. In agriculture, limestone and related geologic materials are used raw or burned as liming agents for the improvement of soils. These liming agents are spread on soils that are too acid or which are deficient in lime. Their effect is to neutralize soil acids and acid clays, to release plant food elements from some soil minerals, to supply calcium or calcium and magnesium as plant food elements, to promote the growth of some crop plants such as legumes, and to improve the tilling properties of soils. Limestone used for these purposes is ground or pulverized and is commonly called agstone or agricultural limestone. Related geologic materials used for these purposes are quicklime and hydrated lime der ed from limestone or oyster shells, crushed or pulverized oyster shells, and calcareous marl. The chief porperty of these liming materials is their ability to neutralize acids and is expressed in specifications as "calcium carbonate equivalent". Most commercial agstone varies between 90 and 100 percent of calcium carbonate equivalent; agstone of less than 85 percent is not used except where better materials are not available. Crushed or pulverized limestone or oyster shells for soil treatment use should pass a 4-mesh screen and range down to dust size.

In construction, limestone is used as a raw material in the manufacture of lime and cement and as building stone; these uses are discussed under "Portland Cement Materials" and "Building Stone". Lime is made from limestone by heating to drive off the carbon dioxide, a process commonly called burning. Lime is an ingredient of the following varied construction materials: mortar, plaster, sand-lime brick, stucco, cold-water paints, and silica brick. Lime used for these purposes must burn to a white color and must not contain more than 5 percent of such impurities as silica, alumina, or oxides of iron. In general, high-calcium lime is used.

In chemical and other industries, limestone, either as limestone or burned lime, is used in many ways as an indispensable ingredient in hundreds of products. Metallurgical uses are: as flux in the smelting of metalliferous ores (in blast furnaces for pig iron; basic open-hearth process for steel; electric steel furnaces; nonferrous-metal smelters for copper, nickel, lead, zinc, gold, silver, antimony, and other metals), in ore concentration including cyanidation, and in wire drawing. Some chemical uses or products are: acid neutralization, liquid and powder bleach, calcium carbide, cyanamide, precipitated calcium carbonate, chromates, gas purification, insecticides, fungicides, disinfectant, calcimine, paints, explosives, matches, and fertilizers. Industries that use large quantities of limestone or lime are: paper mills, water purification plants, glass works, tanneries, and sugar refineries.

Of the total limestone production in 1940, t. United States used 22.5 percent for agricultural purposes, 5.7 percent for constructio purposes exclusive of building stone, railroad ballast, riprap, road material, and concrete; and 71.8 percent for metallurgical, chemical, and other industrial purposes. The total tonnage for these uses was 43,279,129 short tons; this figure does not include dolomite and dolomitic limestone, which are discussed in another chapter. In short, limestone is the most useful and most versatile of the stones used in our economy.

Among the agricultural uses in the United States crushed limestone is the most important, (8,724,160 short tons in 1940, or 90 percent of total agricultural uses); next is limestone burned to lime or hydrated lime (886,500 short tons, or 9 percent), oyster shells (92,213 short tons, or less than 1 percent), and calcareous marl (25,516 short tons, or about 1/4 of 1 percent).

Among the chemical and industrial uses in the United States, limestone for flux in various smelters is the most important, (22,856,910 short tons in 1940, or 73 percent of total chemical and industrial uses).

Limestone is obtained in open quarries. The particular quarrying method used varies according to the hardness of the rock, the thickness of the individual beds, and the nature of the product desired and sold by the quarry. Blasting is necessary in nearly all quarries.

Caliche is generally much less coherent than limestone and is usually obtained by scraper or dragline. Blasting is not necessary in many localities.

Oyster shell deposits are most economically obtained by a dredge which scoops up the loose shells from the shell bank under water. The dredge shells are loaded on barges and transported directly to users by barge or transshipped by other means. For some uses washing to remove traces of common salt is necessary.

Limestone, caliche, or oyster shells are cheap materials, available in many places. Hence they cannot be shipped great distances unless transportation is very cheap, except in the cases of a few types that are very pure or desirable and cannot be duplicated readily.

In the postwar period limestone will be in great demand for several reasons. The cumulative shortage of housing must be relieved. Hence building materials including those derived from limestone will be in demand at an increased rate. It is estimated that the abnormal need for building materials might be sustained for ten years (19) 1/. In Texas, agricultural liming agents are not used as extensively as in other states. It is possible that the use of these agents will increase in Texas, provided farm income remains at high levels. Industrial and chemical uses of limestone or lime have increased in Texas in the last years because of the newly established chemical and industrial plants

1/ See reference in bibliography.

of the region. There is a reasonable prospect that all major branches of limestone use may expect substantial gains in the era after the war.

Occurrence of Limestones in the Trinity River Tributary Area

The numerous limestone formations occurring in the Trinity River tributary area are grouped according to their geologic ages. Limestones of Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian, Cretaceous, and Tertiary age are present. The limestone resources of the Trinity Rivery basin are limited to the northern one-third of the drainage area. In the basin the limestone beds are found in Pennsylvanian, Permian, Cretaceous, and Tertiary rocks.

Great thicknesses of limestone of Ordovician age are found in the Arbuckle and Wichita Mountains of southern Oklahoma. The 7,000-foot Arbuckle group contains many beds of fairly pure calcium carbonate particularly in the upper part of the section. The lower part of the Arbuckle group is predominantly dolomite or magnesian limestone and is treated under that heading. In addition to the Arbuckle group there are limestones in the Simpson group and the Viola limestone in the Arbuckle Mountains.

Limestone of exceptional purity occurs in the St. Clair limestone of Silurian age in northern Sequoyah County, Oklahoma. The Chimneyhill limestone of Silurian age and the Hunton limestone of Devonian and Silurian age are also present in the Arbuckle Mountains. In the northeastern corner of the Trinity River tributary area the Mississippian Boone limestone and the overlying Pitkin limestone crop out on the flanks of the Ozark dome. The Boone limestone is very cherty except for the St. Joe limestone member at the base and the Short Creek oolite near the top of the Boone section.

Rocks of Pennsylvanian age in the Trinity River tributary area contain many limestone beds. In Texas the Pennsylvanian limestone beds dip regionally a few degrees westward and are present on the surface in two areas separated from each other by overlapping Cretaceous sediments. In Oklahoma Pennsylvanian limestones are also present in two areas. The principal area is in the north-central part of the state and the remaining outcrops are the Wapanucka limestone south of McAlester and east of the Arbuckle Mountains.

The Pennsylvanian outcrops in Texas contain several limestone layers, of which the important ones are:

Dennis Bridge limestone in Parker County, Texas; about 10 feet thick
Palo Pinto limestone in Eastland, Palo Pinto, and Wise Counties; about 50 to 100 feet thick
Adams Branch limestone in Brown County; about 10 to 30 feet thick
Merriman limestone in Eastland, Stephens, Palo Pinto, and Jack Counties; about 20 to 175 feet thick

Chico Ridge limestone in Wise County: about 300 feet thick
Clear Creek limestone in Brown County; about 10 to 25 feet thick
Ranger limestone in Brown, Eastland, Comanche, Stephens, Palo Pinto Jack, and Wise Counties, about 15 feet thick
Home Creek limestone in Coleman, Brown, Eastland, Stephens, Palo Pinto, Young, and Jack Counties; about 10 to 50 feet thick
Bunger limestone in Young, Stephens, Palo Pinto, and Eastland Counties; about 6 feet thick
Gunsight limestone in Coleman, Brown, Eastland, Stephens, Young, and Jack Counties; about 2 to 25 feet thick

The more important limestone beds in the Pennsylvanian rocks of north-central Oklahoma are:

Fort Scott limestone (Higginsville limestone and Blackjack limestone), northeastern Oklahoma; 10 to 20 feet thick
Oologah limestone, splits north of Rogers County into Pawnee and Altamont limestone; Pawnee, 20 to 25 feet thick, and Altamont, 12 feet thick
Lenapah limestone, northeastern Oklahoma; 8 to 20 feet thick
Hogshooter limestone, northeastern, central-northern, and central Oklahoma; 5 to 19 feet thick
Pawhuska limestone, northeastern and central-northern Oklahoma; divided into Deer Creek limestone; 7 to 10 feet thick, and Lecompton limestone member, 6 to 14 feet thick
Foraker limestone, central-northern and central Oklahoma; 50 to 74 feet thick
Neva limestone, central-northern Oklahoma; 6 to 11 feet thick

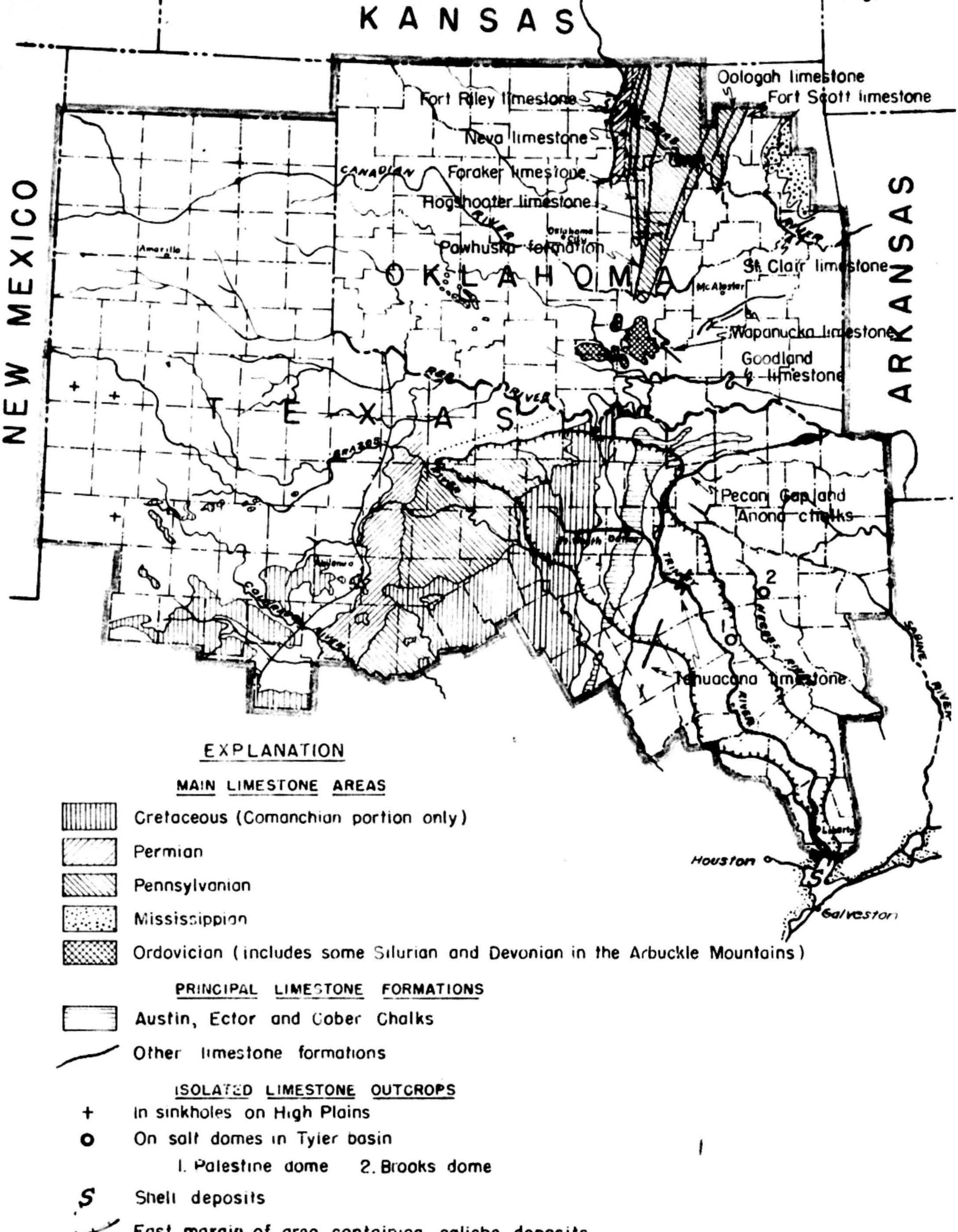
The Wapanucka limestone which is near the base of the Pennsylvanian crops out in two discontinuous areas, one in Atoka, Pittsburg, and Latimer Counties, and the other in Coal and Johnston Counties. The Wapanucka is 300 to 500 feet thick and variable in character; near Bromide it is oolitic and extremely pure but to the northeast it becomes cherty.

Other limestones which are too thin or too impure for commercial use in the area are the Tiawah, Verdigris, Checkerboard, Dewey (or Belle City), Avant, Birch Creek, Labadie, Oread, Turkey Run, Bird Creek, Stonebreaker, and Brownville limestones.

The Permian outcrops which lie west of the Pennsylvanian exposures, begin in Tom Green County, Texas, on the southern border of the Trinity tributary area and extend northward to the Oklahoma-Kansas border. In the southern part of the area, the Permian contains marine limestone beds which increase in purity and thickness towards the south. To the north the individual beds thin and pass into nonmarine "red beds" Still farther north, in northern Oklahoma, Pottawatomie marine limestone beds again replace the continental "red beds". The southern transition is rather abrupt and occurs chiefly in the latitude of Baylor County, Texas. The most persistent of the limestones is a member of the Lueders group, which disappears in northern Wichita County, Texas.

LIMESTONE, SHELL AND CALICHE

Fig. 14



DISTRIBUTION OF LIMESTONE, SHELL AND CALICHE DEPOSITS IN THE TRINITY RIVER TRIBUTARY AREA

The principal Permian limestones in Texas are:

Sedwick limestone in Coleman, Callahan, Shackelford, and Throckmorton Counties; 15 to 60 feet thick
Coleman Junction limestone in Coleman, Callahan, Shackelford and Throckmorton Counties; 3 to 20 feet thick
Elm Creek limestone in Coleman, Callahan, Shackelford, Throckmorton, and Baylor Counties; 20 to 50 feet thick
Jagger Bend limestone in Throckmorton and Baylor Counties; 8 feet thick
Talpa limestone in Coleman, Callahan, Shackelford, Throckmorton, and Baylor Counties; 6 feet thick
Lueders limestone in Runnels, Coleman, Taylor, Callahan, Shackelford, Jones, Haskell, Throckmorton, Baylor, Wilbarger, and Wichita Counties; averaging about 15 feet thick

The northern area of marine Permian rocks in north-central Oklahoma contain a number of limestone beds. The more important Permian limestone beds are:

Wreford limestone, central-northern Oklahoma; 25 to 50 feet thick
Fort Riley limestone, central-northern Oklahoma, (magnesian limestone); 8 to 10 feet thick
Winfield limestone, central-northern Oklahoma; 10 to 11 feet thick
Herington limestone, central-northern Oklahoma; 12 to 15 feet thick

The Gray Horse, Red Eagle, and Cottonwood limestones are other thin limestone beds of Permian age in central-northern Oklahoma.

A continuous cover of Cretaceous formations begins in the south in eastern Brown County, extends northward to Red River, and then turns eastward in southern Oklahoma into Arkansas. To the west of this continuous cover in Texas there are outliers of the Cretaceous formations among the high hills of the region, notably along the Callahan divide in Callahan, Taylor, and Nolan Counties. In the High Plains Cretaceous beds occur also around some filled sinkholes. Some of the prominent limestones of the Cretaceous are:

Limestones in the Glen Rose formation in Bosque, Comanche, Erath, Hood, Parker, Somervell, and Wise Counties, Texas; varying in thickness from a few feet in the west to several hundred feet in the east
Comanche Peak, Edwards, and Goodland limestones in a great many counties in the Texas part of the area; up to 100 feet thick
Georgetown limestone on the salt dome west of Palestine in Anderson County, Texas.
Duck Creek limestone from McLennan County to Grayson and Cooke Counties, Texas; 30 to 120 feet thick
Fort Worth limestone from Tarrant County to Grayson and Cooke Counties, Texas; averaging about 30 feet thick
Main Street limestone from McLennan County to Grayson and Cooke Counties, Texas; from 8 to 50 feet thick

Austin, Ector, and Gober chalk from McLennan County to Lamar County, Texas; in some counties up to 700 feet thick. Austin chalk occurs also on the Palestine and Keechi salt domes, Anderson County, Texas, and Brooks salt dome, Smith County, Texas

Pecan Gap and Annona chalk from Marlin in Falls County to Bowie County, Texas; 10 to 250 feet thick

The Goodland limestone, 25 feet thick, is the most important Cretaceous limestone in southern Oklahoma. Generally it is a pure white, semi-crystalline rock about 25 feet thick. The Caddo limestone, 150 feet thick, and the Bennington limestone, 10 feet thick, are other Cretaceous limestones in the Oklahoma part of the area.

Tertiary rocks crop out east and south of the Cretaceous outcrop area. However, limestone is rare in the Tertiary series and those limestones that do occur are usually of poor quality. Most noteworthy is the Tehuacana limestone in Limestone, Navarro, and Kaufman Counties, Texas. It is 4 to 30 feet thick.

Reserves

The wide distribution of the limestones and the great thickness of some of the beds make it impossible to obtain an accurate estimate of the tonnage available. However, it is evident that the Trinity River tributary area contains very large reserves of this important natural resource. The small outcrop of Georgetown limestone on Palestine salt dome, Anderson County, Texas, was estimated by McCammon (18) to contain at least 100,000 tons.

Producing Companies

Companies and location of quarries producing limestone or lime in the Trinity River tributary area are given below. As some of the cement plants and producers of building stone, riprap, crushed limestone, and railroad ballast are also potential or actual producers of limestone or lime as discussed in this chapter, they are included in the list.

Name of Company and Location of Plant	Location of Quarry, or Other Source of Supply
Austin Contracting Company, Denison, Texas	Oklahoma
Dallas Lime Company, Dallas, Texas	Dallas County, Texas
Fox-Cotton Building and Veneer Stone Company, Lueders, Texas	Jones County, Texas

Hall Bros. Rock Crusher, Brownwood, Texas	Brown County, Texas
Kelley Stone Company, Lueders, Texas	Jones County, Texas
Lone Star Cement Corporation, Dallas, Texas	Dallas County, Texas
R. W. McKinney, Nacogdoches, Texas	Somervell County, Texas
Morgan Construction Company, Dallas, Texas	Erath County, Texas
Southwest Stone Company, Dallas, Texas	Wise County, Texas
Trinity Portland Cement Company, Dallas, Texas	Dallas and Tarrant Counties, Texas
Universal Atlas Cement Company, Waco, Texas	McLennan County, Texas
West Texas Cut Stone Company, Lueders, Texas	Jones and Shackelford Counties, Texas
Bromide White Lime Company, Bromide, Oklahoma	Johnston County, Oklahoma
St. Clair Lime Company, Sallisaw, Oklahoma	Sequoyah County, Oklahoma
Pedro Simpkins, Ada, Oklahoma	Johnston County, Oklahoma
S. L. Underwood & Sons	Jones County, Texas
Updegraff Sand and Stone Company	Woods County, Oklahoma
Wittmer Stone Company	Kay County, Oklahoma

Producers of oyster shells from Galveston Bay are:

The Champion Paper & Fiber Company, Houston Division, Houston, Texas
W. D. Haden, Beaumont, Texas
W. L. Jones & Son, Houston, Texas
John M. Kilgore, Anahuac, Texas
Parker Brothers, Palacios, Texas

Production of Lime

(Total Texas Production)

The following data represent production for the entire State of Texas. Production in the Trinity River tributary area is possibly about one-half of the total.

	Lime, Including Quickline and Hydrated Lime		Hydrated Lime	
Year	Short Tons	Value	Short Tons	Value
1935	38,863	362,636	20,749	195,969
1936	51,281	470,510	22,968	238,978
1937	49,135	440,069	24,415	226,271
1938	49,352	429,664	24,264	235,445
1939	62,048	524,748	23,735	221,476
1940	64,274	543,130	22,822	231,459
1941	77,783	632,099	27,415	262,349
1942	67,377	559,279	23,355	225,039
1943	132,167	1,034,355	32,308	304,244
1944	94,923	757,141	35,075	332,657

Data from United States Bureau of Mines.

Statistics for the production of lime in Oklahoma are not available.

For statistics on the production of crushed limestone and dolomite, see Chapter on Building Stone.

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PHOSPHATE ROCK

A. L. Jenke, United States Geological Survey

Phosphate rock is found in the Trinity River tributary area of Texas and Oklahoma but due to their low grade, small size, and location, no attempts have been made in the past to exploit the deposits. Rock phosphate is not a mineral but rather a mixture of cryptocrystalline or amorphous phosphates of Ca, Al, or Fe in sedimentary rock. Normally it contains 25 to 35 percent of P_2O_5 and 40 to 50 percent of CaO.

Phosphate in the Trinity River tributary area is found disseminated throughout shale beds or as discrete nodules and irregular concretions in limestone, chalk, and shale beds. The nodules usually show concentric structure and their shapes may be almost spherical, ovoid, flat or rounded (plate-like). They vary in size from a few millimeters to 3 or 4 inches in diameter. When pure, the nodules are white to very light-gray; they are soft, and fracture readily.

Phosphatic rock finds its greatest use in agriculture, where its function is to add phosphorus to soil deficient in this important life-giving element. Other important uses are in the manufacture of stock and poultry feeds, elemental phosphorus, phosphoric acid, and a number of other phosphorus chemicals. Rock phosphate is often treated with sulphuric acid to produce super-phosphate which is much more soluble than the untreated material and can be assimilated more readily by plants.

The phosphorus content of rock phosphate is usually expressed in terms of phosphorus pentoxide (P_2O_5), and the grade of the marketed product is expressed in terms of bone phosphate of lime (B.P.L.), which refers to the theoretical percentage of $Ca_3(PO_4)_2$ in the material. To be acceptable as a fertilizer, rock phosphate should contain at least 50 percent B.P.L. Commercial Florida rock phosphate averages 78 to 83 percent B.P.L.

Occurrence of Phosphate Rock in the Trinity River Tributary Area

Occurrence in the Trinity River Basin

Small amounts of phosphatic material in the form of nodules in conglomerate beds are found in the basal sections of several Upper Cretaceous formations that crop out in the Trinity River basin. Localities in which phosphatic nodules are found in the basin are: (1) in Tarrant County, one mile northeast of Tarrant Station, where the nodules are in the base of the Eagle Ford shale; (2) in Dallas County, in the Texas Portland Cement Company quarry 3 miles west of Dallas at the base of the Austin chalk; (3) in Ellis and Hill Counties, where a phosphatic conglomerate at the base of the Taylor marl can be traced in outcrop; (4) in Collin County near Lavon, where nodules are found in the basal part of the Pecan Gap chalk member of the Taylor marl; and (5) in Kaufman County near Kaufman, where phosphatic nodules and glauconitic sand are present in the basal portion of the Navarre group.

In addition to the occurrences mentioned, there is a persistent, but thin, bed of small phosphatic nodules at and near the base of the Kincaid formation of the Midway group of Lower Eocene age. In the Trinity River basin the contact of this formation with underlying Upper Cretaceous sediments can be traced from north to south through Kaufman, Henderson, Navarro, and Limestone Counties and offers a local potential source of low-grade phosphatic rock. In Bexar County, outside the Trinity River tributary area, greensand containing phosphate nodules has been produced from the Kincaid formation and used as a soil conditioner.

The Weches greensand member of the Mount Selman formation (Eocene, Claiborne group), is found in Anderson, Houston, and Leon Counties. It has been suggested that the greensand might contain enough phosphorus to justify its use as a fertilizer. Texas laws do not allow greensand to be sold as a fertilizer, but farmers may mine and use it themselves. Greensands also occur in the lower part of the Reklaw member of the Mount Selman formation and in the basal Crockett member of the Cook Mountain formation. The Reklaw is mapped in Henderson, Anderson, Freestone, and Leon Counties in the Basin, and the Crockett is mapped in Houston and Leon Counties.

Occurrence of Phosphate Rock Outside the Trinity River Basin

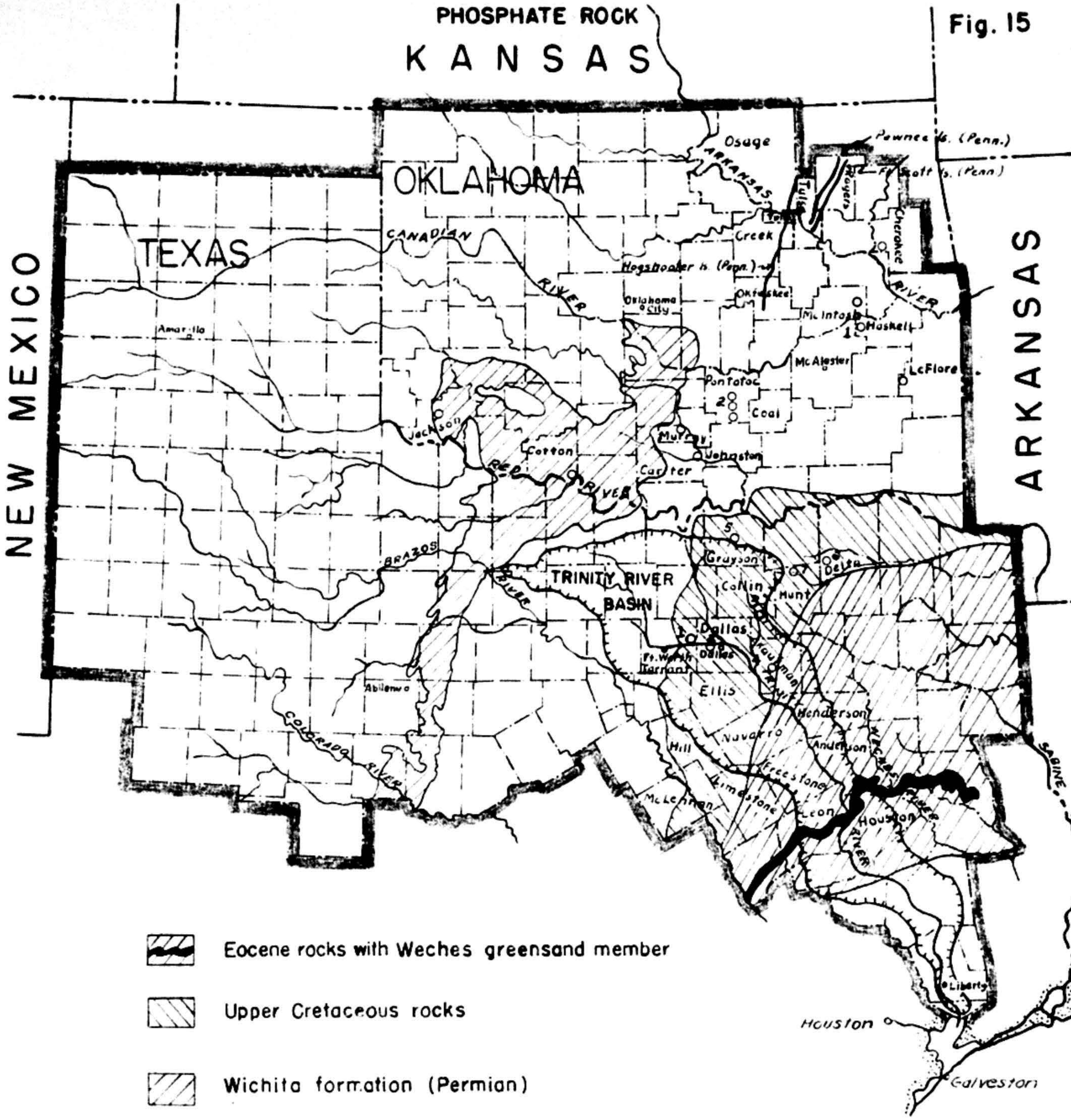
Outside the Trinity River basin phosphate is found in small amounts in the Wichita group of Permian age, in Upper Cretaceous rocks and in the basal Midway and Claiborne beds mentioned above. In the vicinity of Sherman, Grayson County, phosphate nodules occur in the so-called "Fish Bed Conglomerate", at the base of the Austin chalk or the top of the Eagle Ford shale; in the McLennan County extension of the phosphatic conglomerate in the base of the Taylor marl; in Delta County near Pecan Gap; and in Hunt County near Wolfe City, where phosphate is found in the base of the Pecan Gap member of the Taylor marl.

In the Trinity tributary area of Oklahoma the more important occurrences of phosphate are in three general areas: northeastern Oklahoma, the Arbuckle Mountain area, and east-central Oklahoma.

In the northeastern part of the state, the Fort Scott limestone of the Henrietta group of Pennsylvanian age has a middle black shale phase containing phosphate concretions. The outcrop of this formation crosses Rogers and Tulsa Counties. The Pawnee limestone, also Pennsylvanian in age, can be traced through Rogers and Tulsa Counties just west of the Verdigris River. This formation also has a middle black shale bed containing black phosphatic nodules.

The Pennsylvanian Hogshooter limestone of the Drum group, cropping out in a general north-south direction across Tulsa, Osage, Creek, and Okfuskee Counties, has a thin basal bed which contains phosphatic concretions in all its outcrops.

Fig. 15



o Known occurrence of Phosphate Rock

Texas	Oklahoma
1. Tarrant Station	1. Brooken
2. Portland Cement Co. Quarry	2. Ada
3. Lavon	
4. Kaufman	
5. S[illegible]man	
6. Pecan Gap	
7. Wolfe City	

DISTRIBUTION OF PHOSPHATE ROCK IN THE TRINITY RIVER TRIBUTARY AREA

The Sylamore sandstone member of the Chattanooga shale (Devonian ?) crops out in the northern part of Cherokee County and contains phosphatic material in the form of pebbles and grains.

In the Arbuckle Mountain area, phosphate nodules are found in the black shales and cherts of the Devonian Woodford chert. A persistent bed of greenish-yellow clay, 6 to 8 inches thick, and containing phosphate nodules is found at the contact of the Woodford chert and the overlying Sycamore limestone which is Mississippian in age. Where the Woodford chert is overlain by the Welden limestone (Mississippian), the phosphatic bed averages about 5 feet in thickness. The Woodford chert crops out in Pontotoc, Murray, Carter, Coal, and Johnston Counties. Some detailed work has been done in the area south of Ada in Pontotoc County on the phosphate occurring in the uppermost portion of the Woodford chert. There the phosphate is found in a residual band 60 feet wide and 1 foot thick beneath the weathered edge of the overlying Welden limestone.

Phosphatic nodules and plates are recorded in two outcrops in what is probably the Boggy shale of Pennsylvanian age. The localities mentioned are within 2 miles of one another and are near Brooken in Haskell County in south-central Oklahoma.

Another occurrence of phosphate is known in the extreme southeast corner of Cotton County, where the material is found as nodules in a red shale bed in the Permian Wichita formation.

Other occurrences of phosphate rock are found in Jackson, LeFlore and McIntosh Counties. These deposits are either of very low-grade or are relatively unknown.

Economic Aspects and Reserves

No phosphate rock has been produced in the Trinity River tributary area of Texas or Oklahoma, and it is likely that none will ever be produced except perhaps for local use, as all known deposits are too low in grade to compete with the Florida, Tennessee, Idaho, or Montana phosphates. However, it is possible that in the Trinity River basin the Weches greensand or the Kincaid beds might furnish a local supply of rock suitable for use as a fertilizer. Most commercial fertilizers employ a "filler". Glauconite could be used for this purpose, and the Weches and Kincaid glauconites might find use in this way.

In Oklahoma the most promising occurrence is the Hogshooter limestone. Although the phosphorus content is low, this formation is reported to be a good source of agricultural lime and any phosphatic material which it contains would enhance its value as a soil conditioner. The bed of phosphatic shale at the top of the Woodford chert south of Ada has been mentioned as a possible future local source of phosphate rock, especially where weathering has concentrated the phosphate nodules. The tonnage of weathered material, however, probably does not exceed 3,000 tons, averaging about 20 percent P_2O_5. During the summer of 1938, the Agricultural Experiment Station of the Oklahoma A. and M. College, began testing Oklahoma phosphates under actual growing conditions. Neither the results of the tests nor the source of the phosphate are known.

The reserves of low-grade phosphate deposits in the Trinity River tributary area are probably very great and some of the deposits might be exploited for local consumption in future years. The tremendous reserves of high-grade phosphate rock in Florida, Tennessee, Idaho and Montana make the large-scale development of the Trinity deposits most unlikely.

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Portland Cement Materials

D. M. Kinney, United States Geological Survey

Portland cement is the most importand and most widely manufactured of the hydraulic cement materials in use today. It is an aggregate of complex chemical compounds formed by calcining to incipient fusion a carefully blended mixture of calcareous, siliceous, and aluminous rocks. When ground to flour-fineness this calcined mixture, or sinter, is Portland cement. The raw materials that go into the manufacture of Portland cement are limestone and shale; both rocks are abundant in the Trinity River tributary area of Texas and Oklahoma. The tributary area also possesses gypsum, anhydrite, bentonite, volcanic ash (pumicite), and iron ore, which are utilized to a minor extent in Portland cement manufacture. The Portland cement industry has assumed major proportions in Texas but only one plant is operated in the Trinity River tributary area of Oklahoma.

Portland cement may be manufactured by fusing crushed cement rock, a clayey limestone containing between 68 and 72 percent calcium carbonate, 18 to 27 percent clay, and less than 5 percent magnesium carbonate, or by fusing a mixture of limestone, shale and minor constituents which have been blended in the correct proportions. Cement rock, although widely used in the eastern United States, is rare in the Trinity tributary area where Portland cement is made by fusing a mixture of the raw products.

Limestone used in the manufacture of Portland cement must contain at least 75 percent $CaCO_3$, and less than 7 percent magnesium carbonate. Other calcareous materials such as marl, chalk, and shells may be substituted for crystalline limestone in the manufacture of Portland cement. Chalk is widely used in the Portland cement industry in Texas.

The aluminous and siliceous elements required for the manufacture of cement are obtained from clay or shale. Clay or shale suitable for use in the manufacture of Portland cement must contain between 55 and 65 percent silica, and the alumina plus iron oxide should average between 1/3 and 1/2 the silica. The shale must be low in magnesium carbonate, gypsum or anhydrite, iron sulphides, and alkalies. Free silica in the form of sand or chert is objectionable in any cement material because it does not combine with the lime when the mixture is calcined.

Mining Methods and Processing

Portland cement materials are usually produced in large, highly mechanized quarries. They are then crushed, dried, and passed on to the grinding mill where they are ground, mixed, and pulverized. The proportion of limestone to shale or clay in a mix is not fixed but depends entirely upon the chemical composition of the constituents. If the limestone is pure (90 percent $CaCO_3$ or more) and the shale is essentially a hydrous aluminum silicate free from impurities, the limestone to shale ratio will be roughly three to one. Variation in specifications demanded by the consumer also greatly affects the proportion of the raw materials.

The mixed and pulverized material is then calcined to incipient fusion in a rotary kiln at a temperature of about 1550° C. (2822° F.). The kiln may be fired by coal, oil or gas, all of which are abundant in the Trinity River tributary area. The clinker or calcined product as it comes from the kiln is in small, glassy, greenish-black lumps. After cooling it is ground and pulverized. Gypsum, used to retard the setting time of the cement, is added between the grinding and pulverizing. Portland cement is sold in bulk by the carload, in wooden barrels weighing 376 pounds, or in 94-pound bags.

Uses

Portland cement as an ingredient of concrete is second only to structural steel in importance as a construction material. The more important uses of concrete are in the construction of highways, dams, piers, and foundations. Reinforced with steel it is used in the construction of buildings, bridges, and tunnels. Portland cement is also used as a mortar, plaster, and stucco.

Economic Aspects

Raw materials suitable for the manufacture of cement are abundant throughout the country. As cement plants require a large initial investment and must operate on a relatively large scale to be successful, the choice of a plant site is dependent not only on an adequate source of raw materials, but also on the accessibility to centers of population. A supply of cheap fuel is another determining factor. Cement plants are usually near large cities and the market for a given plant is limited by the location of other plants. The construction and repair of highways, buildings and dams, following the restricted building during the war period, should bring about great activity in the Portland cement industry in postwar years.

Occurrence of Cement Material in the Trinity River Tributary Area

Trinity River Basin

The Eagle Ford shale and the overlying Austin chalk of Upper Cretaceous age are the most important sources of Portland cement materials in the Trinity River basin; raw material from these formations is being used by the Lone Star Cement Company and the Trinity Portland Cement Company, which are located just west of Dallas in Dallas County. In the Trinity basin the contact between the Eagle Ford shale and the Austin chalk can be traced southward through Grayson, Denton, Collin, Dallas, Ellis, and Hill Counties. In the Palestine salt dome about 8 miles west of Palestine, Anderson County, the Austin chalk and the Eagle Ford shale crop out at the surface. It has been suggested that the Palestine dome might be a source of Portland cement materials.

A second plant of the Trinity Portland Cement Company, located just north of the city limits of Fort Worth, is using limestone from the Duck Creek formation and shale from the underlying Kiamichi formation, both of which are of Lower Cretaceous age. A kaolinitic clay from the Simsboro sand member, Rockdale formation, Wilcox group of Lower Eocene age, is mined in Freestone County and is shipped to Houston where it is mixed with oyster shells and manufactured into white cement.

Occurrences of Cement Materials Outside Trinity River Basin

Elsewhere in the Trinity tributary area, but outside the Trinity River basin, the contact of the Austin chalk on the Eagle Ford shale can be traced northeastward through Grayson and Fannin Counties and southwestward through Hill and McLennan Counties, Texas. In McLennan County the rock is quarried from these beds a few miles southwest of Waco for use in the Universal Atlas Cement Company plant there. Kaolin and kaolinitic clay in the Simsboro sand member of the Rockdale formation also is found in Limestone and Robertson Counties, Texas. Oyster shells, dredged from the coastal bays in Texas are used as a source of lime by cement plants in the Houston area. Galveston Bay is well supplied with extensive deposits of oyster shell.

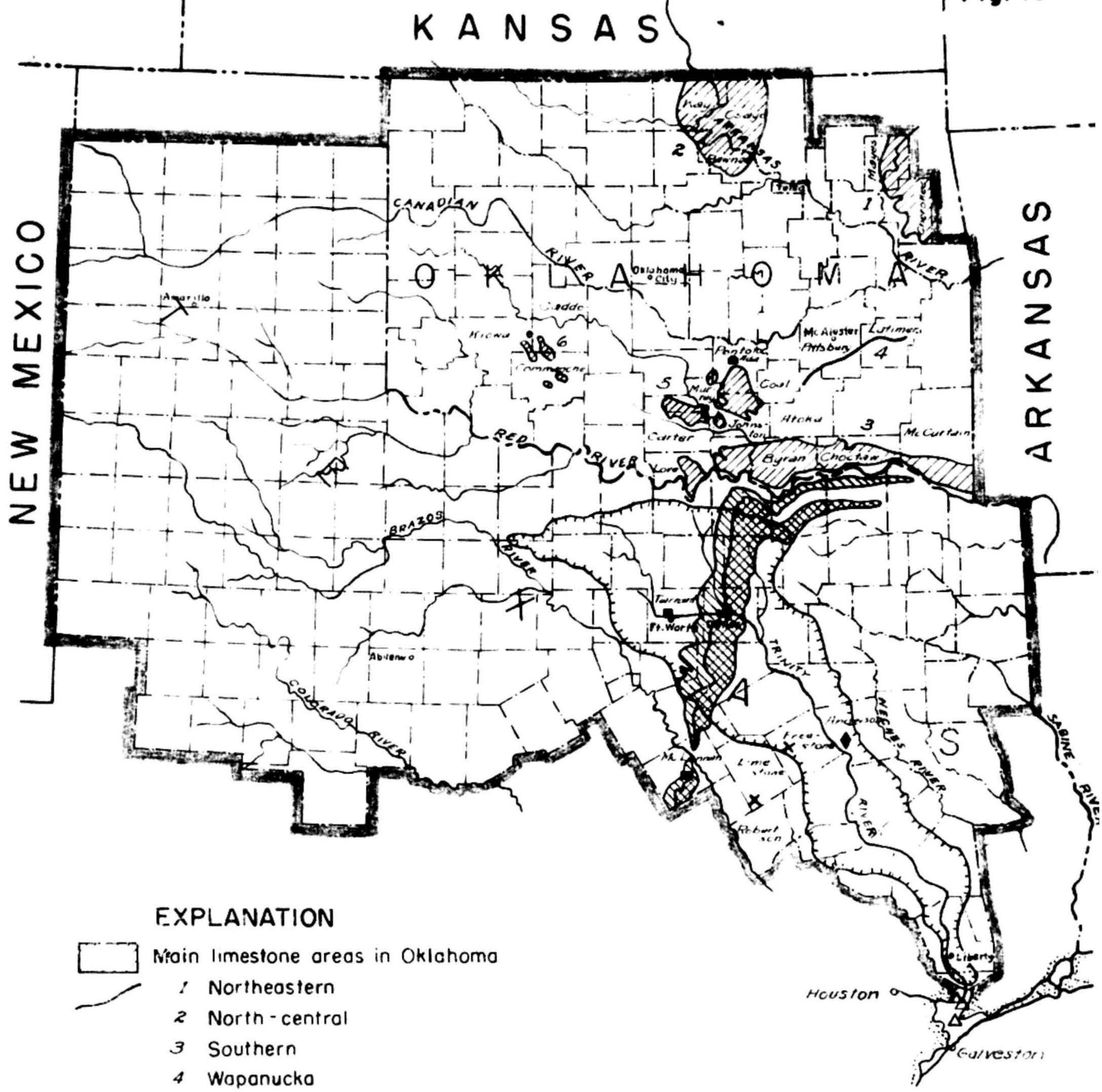
Oklahoma is well supplied with limestone and shale suitable for Portland cement manufacture. Six main limestone areas are recognized: (1) northeastern, (2) north-central, (3) southern, (4) Wapanucka, (5) Arbuckle Mountain, and (6) Wichita Mountain.

The northeastern area includes Cherokee County and the eastern part of Mayes County. Limestone suitable for Portland cement manufacture in this area is the Upper Ordovician Fernvale limestone of the Richmond group, the St. Clair limestone of Silurian age, the Boone and Pitkin limestones of Mississippian age, and the Morrow formation of Pennsylvanian age. For the most part, the Boone is too cherty for use as Portland cement material but the basal member of the Boone, the St. Joe limestone and the Short Creek oolite member in the upper part of the Boone, are high-calcium limestones.

The eastern half of Kay County, the western part of Osage County, and almost all of Pawnee County comprise the north-central area. Rocks suitable for Portland cement are the Wreford, Florence, Fort Riley, and Winfield limestones in the Chase group of Permian age, and the Harrington limestone of the Sumner group, also Permian in age. In Pawnee and Osage Counties suitable limestone beds are found throughout Carboniferous and Permian strata. In Pawnee County the Stonebreaker limestone member of the Buck Creek formation, the Brownsville limestone of the Waubaunsee group, and the Red Eagle (?) limestone member of the Elmsdale formation, all of Pennsylvanian age are high-calcium limestones.

PORTLAND CEMENT

Fig. 16



EXPLANATION

Main limestone areas in Oklahoma

1 Northeastern
2 North - central
3 Southern
4 Wapanucka
5 Arbuckle Mountain
6 Wichita Mountain

Eagle Ford shale - Upper Cretaceous

Austin chalk - Upper Cretaceous

△ Oyster shell beds

✖ Occurrence of Kaolin in Simsboro sand member of Rockdale formation - Eocene

♦ Palestine salt dome

▬ Portland cement plants

DISTRIBUTION OF
PORTLAND CEMENT MATERIALS AND PLANTS IN TRINITY RIVER TRIBUTARY AREA

The southern area includes an east-west band of Cretaceous rocks cropping out south of the Arbuckle and Ouachita Mountains. The most important Portland cement rock in this area is the Goodland limestone of the Fredericksburg group which is Lower Cretaceous in age. Its outcrop extends from Love County through Marshall, Johnston, Atoka, Bryan, Choctaw, and McCurtain Counties. The Goodland limestone is overlain by the Kiamichi formation which contains shale suitable for Portland cement manufacture.

The Wapanucka area in Atoka, Coal, Johnston, Pittsburg, Pontotoc, and Latimer Counties includes outcrops of the Pennsylvanian Wapanucka limestone which is an important source of lime and crushed rock, particularly near Bromide in Johnston County. An underlying shale is suitable for cement manufacture.

The Arbuckle Mountains occupy all or part of Carter, Johnsto Murray and Pontotoc Counties and contain great thicknesses of limeston suitable for the manufacture of Portland cement. These rocks include the Arbuckle limestone of Cambro-Ordovician age, the Simpson group and Viola limestone both Ordovician in age, the Hunton limestone which is Silurian and Devonian (?) in age, and the Mississippian Sycamore limestone. The Simpson group contains shale beds well adapted for use as raw material in Portland cement manufacture. The Ordovician Sylvan shale crops out in Pontotoc County and is used, together with the Viola limestone, in the manufacture of Portland cement in the plant of the Oklahoma Portland Cement Company at Ada.

In the Wichita Mountain region of Caddo, Comanche, and Kiowa Counties, limestone suitable for Portland cement manufacture is present in the Arbuckle and the Viola limestones. The latter is confined to a few isolated hills.

The Boone and Pitkin limestones in Muskogee and Sequoyah Counties, the St. Clair limestone in Sequoyah County, the Fort Scott limestone in Rogers County, and the Oolagah limestone in Tulsa and Rogers Counties, are suitable for Portland cement manufacture and are adjacent to clay or shale deposits.

Reserves

The reserves of rock suitable for the manufacture of Portlan cement in the Trinity River tributary area are great. These raw materials, together with a plentiful supply of gas, oil and coal for fuel, make the area one of the greatest potential producers of Portland cement in the country. Actual increases in production are thus dependent on, and limited by, increases in local population and demand, rather than on raw materials.

Portland Cement Plants in Trinity River Tributary Area

Texas

Name of Company	Location	Location of Quarry
Lone Star Cement Corp.	Cement City	Dallas County
Trinity Portland Cement Co.	Eagle Ford	Dallas County
Trinity Portland Cement Co.	Fort Worth	Tarrant County
Universal Atlas Cement Co.	Waco	McLennan County

Oklahoma

Name of Company	Location	Location of Quarry
Oklahoma Portland Cement Co.	Ada	Pontotoc County

Production of Portland Cement in the Trinity River Tributary Area

Year	Cement Produced (In bbls. of 376 lbs.)
1935	2,632,383
1936	3,666,078
1937	4,039,132
1938	3,534,351
1939	3,768,781
1940	3,568,939
1941	4,721,985
1942	6,016,117
1943	5,443,278
1944	2,875,770

*Data from United States Bureau of Mines

RAW MATERIALS USED IN THE MANUFACTURE OF PORTLAND CEMENT IN THE TRINITY RIVER TRIBUTARY AREA

(In Short Tons)

Year	Limestone	Shale	Gypsum	Iron Ore	Sand	Mill Scale	Oyster Shells	Cinders
1935	709,234	119,571	17,967					
1936		No Information Available						
1937		No Information Available						
1938	946,780	163,432	23,764	3,578	10,402	735		
1939		No Information Available						
1940	952,328	169,961	23,923	5,368	6,507			
1941	1,254,132	230,553	30,719	2,354	13,980			
1942	1,608,331	249,785	38,823	1,391	23,051			
1943	1,502,423	226,429	34,038	4,932	29,872	1,886	1,251	273
1944	814,371	112,612	19,821	2,366	20,854			

*Data from United States Bureau of Mines

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SAND AND GRAVEL

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Sand and gravel are relatively abundant throughout the Trinity River tributary area and in total yearly tonnage exceed all other natural resources with the exception of petroleum products. As ingredients of concrete aggregate, sand and gravel have played an important part in the erection of the larger buildings of the cities and the development of a fine road system; great quantities of sand and gravel are also mixed with asphalt to form macadam surfaced roads or used without binders on unimproved roads.

The terms sand and gravel do not have precise usage in commercia practice; in one classification sand ranges from 1/16 mm. to 4 mm. in diameter and gravel from 4 mm. to 64 mm. (approximately 2 1/2 inches) in diameter. Another classification gives the sand range from 200 mesh to 1/4 inch and gravel from 1/4 inch to 3 1/2 inches. By definition, sand and gravel must be unconsolidated granular material. Sand is formed chiefly of the most resistant of the common rock forming minerals, quartz, but it may contain significant quantities of less resistant rocks like limestone and marl derived from local sources. As a general rule gravel is composed mostly of quartz and igneous rock pebbles, but in many localities in the Trinity River tributary area the pebbles are dominantly of limestone derived from formations cropping out in the area. An ironstone gravel, used locally for road metal, is formed from the weathering of certain Tertiary formation in Texas.

The principal use of sand and gravel is in concrete aggregate and road metal; more than 82 percent of the total Trinity River tributary area output is used in this manner for buildings and paving. Approximatel 15 percent of the total Trinity River tributary area output is used for railroad ballast. The remaining 3 percent includes the output of glass sand, molding sand, grinding and polishing sand, engine sand, filter sand, and other specialized uses of sand and gravel.

Sand and gravel deposits are worked by a number of methods or combination of methods using a great variety of equipment. The method or combination of methods used vary with the size of the deposit, the tonnage requirements of the operation, the distance to the processing plant, the available water supply, the available transportation, the physical characteristics of the deposit (the actual thickness of the gravel or sand-beari bed, the amount of overburden, and the presence of large boulders with the sand and gravel), and the personal experience and equipment available to the operators. Some of the common equipment used for excavating sand and gravel are power shovels, draglines, excavator cranes, dipper dredges, ladder dredges, hydraulic dredges, and hydraulic giants.

More than 70 percent of the sand and gravel output of the United States is processed by washing and size sorting before it is marketed. Specifications for the various grades of sand and gravel are today becomin more rigid and a greater proportion of prepared sand will probably be used in the future. The only large users of unprocessed sand and gravel are the municipal, county, and state governments for use on secondary roads. Equipment required for the preparation of sand and gravel for the market are crushers, screens, elevating machinery, and an adequate supply of water for washing. The plants may be located at the site of a large deposit or in some cases, the run-of-pit material may be hauled to a centrally located plant from a number of small pits. Small deposits may also be worked by small washing planes which can be dismantled and moved when the deposit is exhausted.

Sand and gravel are bulky, cheap commodities that can stand only limited transportation charges and, as the material is present in abundance along almost every major stream, any pit that is not operating at peak efficiency could, or would, be abandoned in favor of a more profit able development. Since the most important use of sand and gravel is in the preparation of concrete aggregate for buildings and pavement, the greatest demand for this material is near centers of population. Near large cities a sand and gravel pit may be very valuable while a similar pit in a sparsely settled area may be almost worthless.

Occurrence of Sand and Gravel in the Trinity River Tributary Area

In the Trinity River tributary area sand and gravel occur as recent deposits in the flood plains of the major streams and their tributaries, as river terrace deposits of Pleistocene or Pliocene age raised 40 to 100 feet above the present stream level, as unconsolidated sand and gravel deposits capping interstream divides, and as Tertiary or older unconsolidated geologic formations. The principal sources of commercial construction sand and gravel are the flood-plain and terrace deposits along the larger streams, although large quantities of material for county and state roads are produced from other types of deposits.

Sand and Gravel in the Trinity River Basin

The most extensively developed sand and gravel deposits in the Trinity River Basin are in the flood plain of the Trinity River between Fort Worth and Dallas. The deposits occupy well defined areas, commonly elliptical in shape, surrounded by dark clay and loam. The deposits are variable in thickness; most deposits average 15 feet in thickness and thicknesses of 35 feet have been reported. Overburden removed may range from 4 to 12 feet. Individual deposits may contain as much as 2,000,000 cubic yards of material. Deposits near Fort Worth contain a higher proportion of gravel to sand than the deposits further down stream, but even in the Fort Worth-Dallas area, sand is produced in considerable excess of demands and the material is stock piled at the gravel pit. Good gravel deposits in the Fort Worth-Dallas area are becoming increasingly hard to find and consequently more valuable.

Gravel and sand deposits above Fort Worth and Dallas are being worked on Denton Creek in southern Denton County and on the Clear Fork of the Trinity River southwest of Fort Worth in Tarrant County. One deposit near Bowie in Montague County is on the interstream divide between Denton Creek, a tributary of the Trinity River, and the Red River.

Gravel and sand deposits below Dallas on the Trinity River are being worked south of Crandall in Kaufman County, east of Ferris in

Ellis County, at Trinidad in Henderson County, and at Romayer and Rayburn in Liberty County. For the most part these deposits are on old terrace deposits slightly above all but the highest flood waters. The deposits in Liberty County are especially valuable as they are located near Houston on the Coastal Plain where coarse gravel deposits are very rare. The Liberty County deposits produce a great excess of sand over gravel.

Sand and Gravel in the Tributary Area Outside the Trinity River Basin

Sand and gravel deposits have been worked along the Arkansas, Canadian, Cimarron, Washita, and Red Rivers in Oklahoma and the Colorado, Brazos, Trinity, and Red Rivers in Texas. Some of the deposits are in the flood plains of the rivers but the majority are river terrace deposits of Pleistocene or Pliocene age. Frequently as many as four terrace deposits can be recognized. The highest terrace is believed to be Pliocene in age and frequently it is very poorly preserved. The lowest terrace is just above the level of the flood plain and is believed to be of Pleistocene age. The intermediate deposits are generally well preserved and, in part, stripped of their sedimentary cover, making them easily developed. The terrace deposits may be paired on opposite sides of the stream, or a deposit on one side may have no counterpart on the other.

The terrace deposits are composed of clay, silt, sand and gravel commonly cemented with varying amounts of caliche and may be as much as 60 feet thick. Gravel in the terraces is more abundant near the base of the deposit. The gravels are formed of the more resistant rock materials especially quartz and igneous rocks, although limestone fragments derived from the underlying rocks are abundant in places.

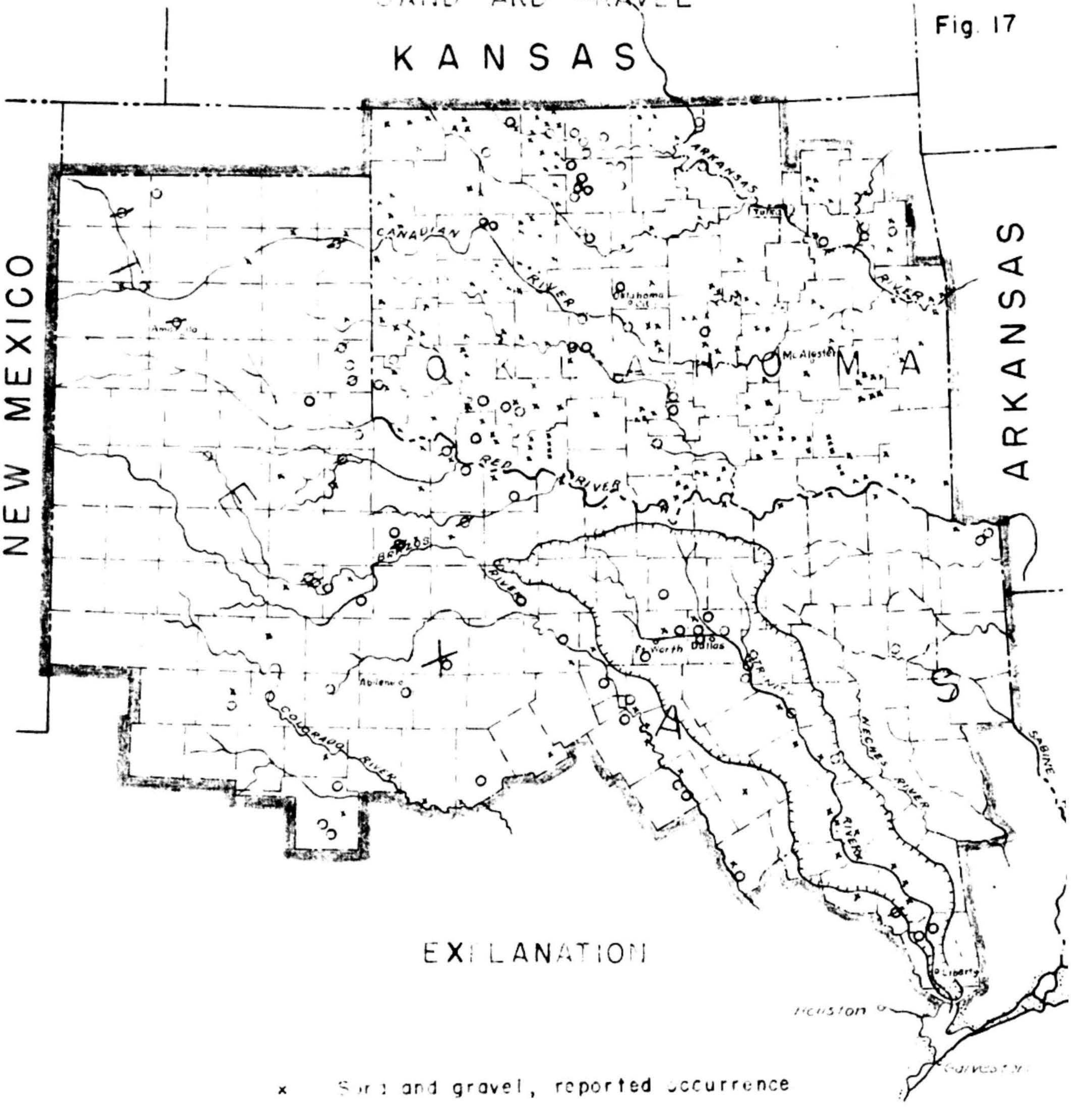
In many places unconsolidated sand and gravel deposits cap interstream divides. These deposits probably are remnants of old fluviatile deposits spread on the flood plain of eastward flowing streams which were ancestral to the present drainage. They are frequently worked by the state and county authorities and used as local sources of sand and gravel for building roads. These gravels generally include clay and marl with the more resistant igneous rocks or rock forming minerals and commonly are iron stained by long exposure to surface waters and the atmosphere.

Many Tertiary and older formations of consolidated or semi-consolidated material are possible sources of construction sand and gravel. In weathered outcrop such consolidated formations may make an excellent source of construction material. Abundant sand can be had from the Ordovician Simpson group in the Wichita and Arbuckle Mountains of Oklahoma, from sandstones in the Mississippian, Pennsylvanian, and Permian rocks, from the Dockum sandstone of Triassic age, from Trinity and Woodbine sandstones of Cretaceous age, and from many of the Tertiary formations both within and without the Trinity River Basin. Included in the latter are ironstone gravel deposits derived from the weathering of Weches and Landrum strata.

The High Plains are underlain by the Ogallala and Arikaree formations of Miocene and Pliocene age. These formations are for the most part river deposits laid down by streams flowing eastward from the

SAND AND GRAVEL

Fig. 17



EXPLANATION

× Sand and gravel, reported occurrence

o Sand and gravel, producing locality

ø Sand and gravel, former producing locality

DISTRIBUTION OF SAND AND GRAVEL IN THE TRINITY RIVER TRIBUTARY AREA

Rocky Mountains and are made up largely of poorly sorted clay, silt, sand, and gravel. They range from a feather edge to over 500 feet in thickness and are the surface formations over most of north and west Texas, the area known as the Llano Estacado.

For 100 miles east of the High Plains escarpment, sand and gravel deposits of the Seymour and other formations of Pleistocene age occur as isolated patches overlying Permian and Triassic rocks. These deposits are believed to have been derived from the Ogallala and Arikaree formations by eolian (wind) action and also may be, in part, residual after these formations. It is known that the Ogallala and Arikaree formations extended considerably east of their present locations at one time. The Seymour is cemented by caliche so that some deposits are not suitable for use as construction sand and gravel without preliminary crushing.

Reserves

The overall reserves of sand and gravel for construction purposes are very large both in the Trinity River Basin and in the rest of the tributary area. Locally near the major cities some of the better deposits have become exhausted. There is no actual shortage, however, even in the vicinity of Dallas and Fort Worth as a slightly increased price permits working those deposits which are smaller, under deeper overburden, farther from the market, or which contains a higher proportion of sand to gravel. In the lower part of the coastal plain the proportion of sand to gravel is excessive and in some cases, particularly in the Houston area, sand and gravel for concrete aggregate cannot be obtained locally and must be shipped in from outside sources. The canalization of the Trinity River would tend to stimulate production in the upper part of the Trinity Basin to supply the Houston market.

Sand and Gravel in the Trinity River Tributary Area

Producing Localities

Cimarron River:

Main Drainage
1) North of Waynoka, Woods County, Oklahoma
2) Two plants near Dover, Kingfisher County, Oklahoma

Turkey Creek
1) At Drummond, Garfield County, Oklahoma
2) Three plants west of Enid, Oklahoma

Arkansas River Tributary:

Salt Fork, Arkansas River
1) North of Alva, Woods County, Oklahoma
2) Northeast of Cherokee, Alfalfa County, Oklahoma
3) East of Goltry, Garfield County, Oklahoma
4) West of Pond Creek, Grant County, Oklahoma
5) West of Medford, Grant County, Oklahoma
6) South of Medford, Grant County, Oklahoma

Arkansas River Tributary: (Continued)
Red Rock Creek
Two plants in Red Rock Creek, Garfield County, Oklahoma
ArArkansas River Proper:
1) On Beaver Creek, Kay County, Oklahoma
2) Ralston, Pawnee County, Oklahoma
3) Osage, Osage County, Oklahoma
4) Six pits near Tulsa, Oklahoma
5) East of Haskell, Wagoner County, Oklahoma
6) Yahola, Wagoner County, Oklahoma
7) North of Muskogee, Wagoner County, Oklahoma
West Cache Creek
1) At Faxon, Comanche County, Oklahoma

Concho River Drainage:
1) South Concho River near Christoval
2) Spring Creek east of Tankersley, Tom Green County, Texas
3) At Orient

Colorado River:
1) South of Coahoma, Howard County, Texas

Red River Drainage:
Prairie Dog Town Fork
1) Indian Creek west of Memphis, Hall County, Texas
2) North of Childress, Childress County, Texas
Pease River
1) Northern Floyd County, Texas
2) West of Paducah, Cottle County, Texas
Wichita River
1) North of Benjamin, Knox County, Texas
2) Near Iowa Park, Wichita County, Texas
McKinley Bayou
1) North of Leary, Bowie County, Texas
North Fork
1) Two plants near Granite, Greer County, Oklahoma
2) Two plants near Snyder, Kiowa County, Oklahoma
3) On Elm Fork west of Jester, Greer County, Oklahoma
4) On headwaters of Salt Fork, southwest of Vinson, Harmon County, Oklahoma
Washita River
1) Near Mountain View, Kiowa County, Oklahoma
2) Two plants near Verden
3) West of Lindsay, Garvin County, Oklahoma
4) East of Paul's Valley, Garvin County, Oklahoma
5) Two plants near Wynnewood, Garvin County, Oklahoma
6) North of Sulphur, Murray County, Oklahoma
7) Two plants near Reagan, Johnston County, Oklahoma
8) Two plants near Tishomingo, Johnston County, Oklahoma
9) On Caddo Creek, south of Milo
West Cache Creek
1) South of Cache, Comanche County, Oklahoma
2) At Faxon, Comanche County, Oklahoma
3) North of Frederick, north of Slough Creek, Oklahoma
4) North of Indiahoma, Comanche County, Oklahoma

Canadian River Drainage:
1) North of Tascosa, Oldham County, Texas
2) North of Boden, Potter County
3) Northwest of Stratford, Sherman County, Texas
4) South of Camargo, Dewey County, Oklahoma
5) Near Taloga, Dewey County, Oklahoma
6) North of Minco, Grady County, Oklahoma
7) West of Norman, Cleveland County, Oklahoma
8) North of Stratford, Garvin County, Oklahoma

North Canadian
1) Near Concho, Canadian County, Oklahoma
2) West of Oklahoma City, Oklahoma County, Oklahoma
3) East of Tecumseh, Pottawatomie County, Oklahoma
4) North of Weleetka, Okfuskee County, Oklahoma

Brazos River Drainage:

Double Mt. Fork
1) Near Yellow Lake, Hockley County, Texas
2) West of Sagerton, Stonewall County, Texas

Salt Fork
1) West of Peacock, Stonewall County, Texas

White River
1) At Plainview, Hale County, Texas

Clear Fork
1) Sweetwater Creek, south of Sweetwater, Nolan County, Texas

Brazos River Proper
1) South of Newcastle, Young County, Texas
2) Near Mineral Wells, Palo Pinto County, Texas
3) Near Granbury, Hood County, Texas
4) South of Georges Creek, Johnson County, Texas
5) Northeast of Walnut Springs, Bosque County, Texas
6) Two pits at Waco, McLennan County, Texas
7) Southwest of Hearne, Robertson County, Texas

Trinity River Drainage:
1) North of Arlington, Tarrant County, Texas
2) North of Grand Prairie, Dallas County, Texas
3) South of Crandall, Kaufman County, Texas
4) East of Ferris, Ellis County, Texas
5) East of Crisp, Ellis County, Texas
6) Trinidad, Henderson County, Texas
7) Lamb Creek near Rayburn, Liberty County, Texas
8) Romayor, Liberty County, Texas

Sabine River:
1) Big Sandy, Upshur County, Texas

Interstream Divides:
1) North of Bowie, Montague County, Texas, between Trinity and Red River drainage
2) At Hooks, Bowie County, Texas, between Sulfur River and Red Rive

Sand and Gravel Producers in the Trinity River Tributary Area

Texas

Name of Producer	Location of Sand or Gravel Deposit
Brown County	
Brownwood Sand and Gravel Co. (Hall Bros. Rock Crusher) Brownwood, Texas	East side of Pecan Bayou, 3 miles south of Brownwood on Williams Ranch road
Dallas County	
East Texas Gravel Company, 1107 Santa Fe Building, Dallas, Texas (Out of Business)	On Parson's Slough near County line, 1 mil north of southeast corner of county
Gifford-Hill & Company, Inc., 610 North Texas Building, Dallas, Texas	(1) West side of Trinity River, 3 miles northeast of Irving (2) Three miles west-northwest of Eagle F
Lagow Materials Company Seagoville, Texas	East side of Trinity River, 4 miles north-west of southeast corner of county
C. W. Roberts Sand & Gravel Company, 915 North Tyler Street, Dallas, Texas	(Same as Gifford-Hill & Company, Inc.)
Fred J. Smith Gravel Company, 1303 Southwestern Life Bldg., Dallas, Texas	(1) Knight Pit on Frisco Railroad, 4.9 miles south of Carrollton (2) Ord Pit on St. LSW Railroad, 1 mile west of Carrollton (3) Trinity Mills Pit, 2 miles north of Carrollton on MKT Railroad and Highway 77
Vilbig Bros., 2517 Eakin Street, Dallas, Texas	(1) 2 miles southwest of Irving (2) 3 miles northeast of Eagle Ford
C. C. White, 4309 Park Place, Dallas, Texas	West side of Trinity River, 3 miles south-west of Carrollton
Mitchell Gravel Co., Dallas, Texas	South side of Trinity River, 6 miles northeast of Lancaster
Bussey Gravel Pit (Operator Unknown)	Just east of Mitchell Gravel Co. locality
Murdock Gravel Pit (Operator Unknown)	On small stream near Trinity River, 7 mil southeast of Dallas.
Mrs. M. F. Farrell 3710 Potomac, Dallas, Texas	7 miles northeast of Arlington on south side of Trinity River, and 1 mile south of Dorothy spur on Rock Island Railroad
Floyd County	
Quitaque Sand & Gravel Co., Lubbock, Texas	10 miles southwest of Quitaque

Hall County

R. T. McElreath, Box 344, Memphis, Texas	4 miles west of Memphis on Sec. 17, Block 20, H & GH Railroad

Haskell County

J. J. McCasland, Haskell, Texas	Sand pit in southwest part of the town of Haskell

Hood County

Lain Gravel Company, Cleburne, Texas	Banks of Brazos River near Granbury

Johnson County

Lain Gravel Company, Cleburne, Texas	Eighteen miles west of Cleburne, 2 miles south of Highway 67

Kaufman County

East Texas Gravel Company, 1107 Santa Fe Building, Dallas, Texas	(1) 6½ miles south of Seagoville (2) 1 mile east of Elm Fork (3) 3½ miles west of East Fork of Trinity River

McLennan County

Potts-Moore Gravel Company, 1610-12 Amicable Building, Waco, Texas	Three miles north of Waco near left bank of Brazos River on Dripping Springs road
Edwin D. Neeley, Box 1313, Waco, Texas	Locality Unknown

Montague County

O. W. Watson, Bowie, Texas	Three miles north of Bowie and 1/2 mile east of Highway 81

Mitchell County

Hillsdale Gravel Company, Box 906, Sweetwater, Texas	Locality unknown

Nolan County

Hillsdale Gravel Company, Box 906, Sweetwater, Texas	On Santa Fe Railroad, 3.2 miles west of Sweetwater on Sweetwater Creek, east of railroad

Oldham County

Western Sand and Gravel Company, Box 168, Amarillo, Texas	At Jude, on FWDC Railroad, 8 miles south of Channing near Canadian River

Palo Pinto County

Lain Gravel Company, Inc., Cleburne, Texas	Six miles southwest of Mineral Wells

Polk County

Texas Silica Sand Company, 2310 Calhoun Avenue, Houston, Texas	Five miles east of Corrigan, on road to Stryker

Potter County

Texas Sand and Gravel Company Box 1532, Amarillo, Texas	One mile east of Oldham County line, south of Canadian River on east side of FWDC Railroad

San Jacinto County

Urbana Sand and Gravel Company, Urbana, Texas	One mile east of Highway 33, and 1 mile south of Trinity River

Stonewall County

Hamlin Sand and Gravel Company, Hamlin, Texas	One mile south of Brazos River, and 10 miles northeast of Hamlin

Tarrant County

Fort Worth Sand Company, Inc., 700 East Sixth Street, Fort Worth, Texas	Between Rock Island Railroad on the north, and Trinity River on the south; beginning 2 miles west of Hurst Station and extending 4 miles east

Young County

Ed Tetmeyer, Newcastle, Texas	Two miles southwest of Newcastle on Throckmorton Highway

Miscellaneous

The following have reported production, but the locality of the deposits from which the material was obtained is unknown.

Central Sand and Gravel Company	McLennan County
Mrs. H. F. Farrell, 3710 Potomac Avenue, Dallas, Texas	Tarrant County
Gann Sand and Gravel Company, Fort Worth, Texas	Tarrant County

Gifford-Hill and Company, Inc., Dallas, Texas	Bowie, Ellis, and San Jacinto Counties
Jeffries & Batts, Box 1742, Fort Worth, Texas	Tarrant and Hood Counties
Walter Kelley and E. W. Tibbets	Floyd County
Joe Meadows, Paducah, Texas	Cottle County
M. A. McCarty	Bosque County
M. C. Myers, Peacock, Texas	Stonewall County
Holland Page, Austin, Texas	McLennan County
F. L. Pederson, 807 North Polk Street, Amarillo, Texas	Potter County
Southwest Construction Company	Dallas County
Texas Construction Materials Company	Liberty County
Waco Materials Company	McLennan County
West Texas Sand and Gravel Company	Howard County

Oklahoma

Cherokee County

Grand Roads Gravel County

Greer County

A. S. Coffman

Kay County

Blackwell Sand and Gravel Company
Otae Sand and Gravel Company

Muskogee County

Pioneer Sand and Gravel Company
Tulsa Sand Company

Pawnee County

Osage Sand Company

Pottawatomie County

Midwest Materials and Construction Company

Tulsa County

Arkansas River Sand Company
Bagby Harris Sand Company
Chandler Materials Company
Layman and Company
McMichael Concrete Company
Smith Sand Company
Standard Paving Company
Tulsa Sand Company

Woods County

Waynoka Sand and Gravel Company

PRODUCTION OF ALL TYPES OF SAND AND GRAVEL IN THE TRINITY RIVER TRIBUTARY AREA

Texas

Year	Commercial Production Short tons	Commercial Production Value in dollars	No. of Producers	Non-commercial Production* Short tons	Non-commercial Production* Value in dollars	Total Production Short tons	Total Production Value in dollars
1935	2,042,469	1,584,231	--	581,504	86,149	2,623,973	1,670,389
1936	2,440,581	2,135,656	--	982,064	198,858	3,422,645	2,334,514
1937	2,535,040	1,958,150	26	778,711	119,671	3,313,751	2,077,821
1938	2,017,295	1,542,816	25	1,161,737	361,709	3,179,032	1.904,525
1939	2,415,261	1,581,744	30 1/	975,696	212,017	3,390,957	1,793,761
1940	[illegible],266,603	1,541,474	34	894,054	200,874	3,160,657	1,742,348
1941	4,142,081	2,876,583	--	1,210,562	181,234	5,352,643	3,057,817
1942	6,128,736	4,884,270	37	1,181,604	164,339	7,310,340	5,048,609
1943	3,875,447	3,204,435	32	777,465	95,081	4,652,912	3,299,517
1944	3,486,013	2,862,070	34 1/	415,046	92,231	3,901,056	2,954,301

Oklahoma

Year	Commercial Production Short tons	Commercial Production Value in dollars	No. of Producers	Non-commercial Production* Short tons	Non-commercial Production* Value in dollars	Total Production Short tons	Total Production Value in dollars
1935	442,477	287,447	--	734,385	47,826	1,176,865	335,273
1936	723,357	426,832	--	596,805	96,238	1,320,162	523,070
1937	633,757	651,397	19 1/	283,102	46,737	916,859	394,395
1938	433,697	244,245	21	376,859	105,967	810,556	350,212
1939	550,491	975,696	13 1/	975,696	212,017	1,526,187	516,466
1940	490,817	250,384	18	538,453	22,610	1,029,270	272,994
1941	817,030	557,200	16	646,070	46,475	1,463,100	603,675
1942	1,689,234	1,202,940	--	1,419,461	743,648	3,108,695	1,946,588
1943	1,332,613	1,006,704	--	808,346	183,113	2,140,959	1,191,817
1944	735,156	534,165	16	520,946	75,932	1,256,102	610,097

* Municipal, county, and state organizations.
1/ May be more producers than shown.

All data from United States Bureau of Mines.

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GLASS SAND AND OTHER SPECIAL SANDS

by

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A very pure silica sand (SiO_2) is the major ingredient in the manufacture of glass. Other special silica sands which require sand similar in some respects to glass sand are filter sand, abrasive sand, engine sand, and molding sand. Sand for the highest quality optical glass must contain 99.8 percent SiO_2 and not more than .015 percent Fe_2O_3. Common bottle glass sand may contain as little as 95 percent SiO_2 but must contain less than 1 percent Fe_2O_3. Iron is very undesirable in glass sand as it affects the color. The maximum allowable alumina content of common glass sand is 4.0 percent. The presence of lime (CaO) and magnesia (MgO) in small quantities is not highly objectionable although magnesia raises the melting point of the mixture. Glass sand must pass a 20 mesh screen but only 2-3 percent may be finer than 80 mesh. The requirements for the other specialized uses of sand are for the most part physical. Filter sand must be fairly uniform texture and the grain size must be within certain limits. Abrasive sand, besides being dominantly of silica, is sold graded according to size. (See discussion of abrasive sand in chapter on Natural Abrasives) The only requirements for engine sand is that it must have a minimum of small particles. Silica sand for lining furnaces and metal molds must have a range of particle sizes and sufficient clay or added plastic fire clay to give the sand bonding properties.

Glass sand in the Trinity River tributary area is mined in open pits using jets of water under pressure. The material is pumped to the plant where it is washed to remove the clay and much of the iron oxide. The sand is sold as moist sand, or as dry sand after having been dried in a rotary kiln.

Glass sand produced in the Trinity River tributary area is used in the manufacture of most of the glass produced in southwestern United States. Because of the abundance of cheap fuel, particularly natural gas, much of the glass is manufactured in the vicinity of the glass sand deposits. Glass sand is also produced from the St. Peter sandstone in northern Arkansas and eastern Missouri; these competing sources severely limit the northern and eastern shipments of glass sands produced in the Trinity River tributary area. In some instances glass sand from Arkansas is shipped to glass plants located in the Texas part of the Trinity River tributary area.

Occurrence of Glass Sand in the Trinity River Tributary Area

Sands suitable for the manufacture of glass are found in the Simpson formation of Ordovician age in the Arbuckle Mountain area in Oklahoma, the Burgen sand of Ordovician age near Tahlequah in northeastern Oklahoma, the basal Cretaceous Trinity sand in southeastern Oklahoma and north central Texas, and in the Carrizo, Queen City, and Sparta sands of Eocene age in the Gulf Coastal Plain of Texas. The sands of the Simpson group and the Burgen formation are suitable for making container glassware and plate glass. The sands in the basal Cretaceous and Eocene are suitable for container glass only. (See fig. 18)

The glass sands in the Simpson group occur in the Oil Creek and McLish formations in Johnston, Murray, Pontotoc, and Carter Counties. In the central Arbuckle Mountains the Oil Creek sand is at the base of the Simpson group and ranges in thickness from 150 to 400 feet. The McLish sand is about 165 feet thick and overlies the Oil Creek sand. Three companies produce sand from the Oil Creek sand and one company's quarry is in the McLish sand. The Burgen sand is exposed five miles northeast of Tahlequah in Sequoyah County, Oklahoma and may be present at shallow depth at other localities in northeastern Oklahoma. Northeast of Tahlequah at least 50 feet of very pure silica sand are exposed. Both the Oil Creek and McLish sands of the Simpson group and the Burgen sand are correlated with the St. Peter sandstone which is mined extensively for glass sand in the Missiisippi Valley.

The basal Cretaceous Trinity sand extends from Parker County, Texas, west of Ft. Worth northward and then eastward in southern Oklahoma north of the Red River to the Arkansas border. The Trinity sand is from 5 to 20 miles in width but deposits of sand suitable for the manufacture of glass are rare. Much of the Trinity sand is poorly sorted and contains clay and other impurities. However, south of the main body of Trinity sand in Texas a sand deposit in the basal Trinity is being mined at Santa Anna in Coleman County to supply a local plant manufacturing bottles and glass containers.

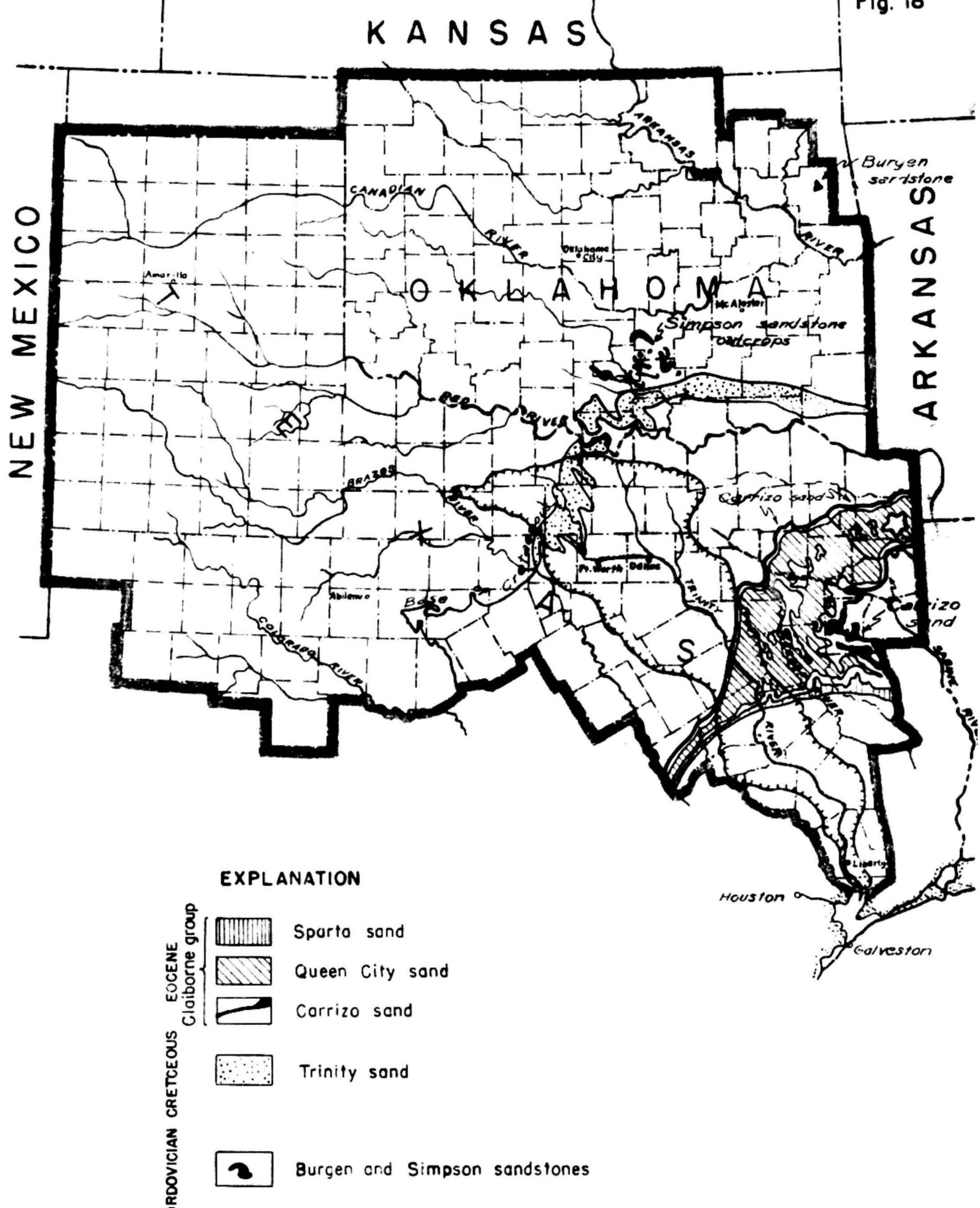
The Eocene Carrizo, Queen City and Sparta sands of the Gulf Coastal Plain may have deposits of sand suitable for the manufacture of bottles but for the most part sand lenses in these formations contain too much iron and are too fine-grained.

The basal Cretaceous Trinity sand and the Eocene Carrizo, Queen City, and Sparta sands cross the Trinity River Basin but deposits of sufficient purity for the manufacture of common bottle glass are rare. Glass sand used in this part of Texas is imported from northern Arkansas or southern Oklahoma.

Reserves

Reserves of high grade glass sand in the Oil Creek and McLish sands of the Simpson group in the Arbuckle Mountains are very large. These sands are of sufficient purity for the manufacture of container and plate glass and with beneficiation they might be made acceptable for optical quality glass. Reserves of glass sand in the Burgen sand in the vicinity of Tahlequah, Sequoyah County are difficult to estimate because of the lack of outcrops but they are of sufficient size to supply large scale industrial development. Sands in the basal Cretaceous and Eocene rocks have not been investigated sufficiently to warrant any estimate of reserves.

Fig. 18



DISTRIBUTION OF GLASS SAND AND OTHER SPECIALIZED SANDS IN THE TRINITY RIVER TRIBUTARY AREA

Companies Producing Glass Sand

Company	Geologic Age of Sand Deposit
Mill Creek Sand Company Mill Creek, Oklahoma	Oil Creek sand, Simpson group
Sulphur Silica Company Sulphur, Oklahoma	Oil Creek sand, Simpson group
Mid-Continent Glass Sand Company Roff, Oklahoma	McLish sand, Simpson group
Oklahoma Silica Sand Company Hickory, Oklahoma	Oil Creek sand, Simpson group

Glass manufacturing companies in the Tributary area in Texas are the Knox Glass Company at Palestine and the Owens-Illinois Glass Company at Waco, Texas.

There are several glass manufacturers in Oklahoma.

Production of Glass Sand

An appreciable amount of glass sand is produced in the tributary area, principally in Johnston and Pontotoc Counties, Oklahoma, but the production figures are not available.

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SOLUBLE SALTS

D. M. Kinney, United States Geological Survey

Potash, common salt (or halite), calcium chloride, magnesium chloride, bromine, magnesium sulfate, and sodium sulfate are highly soluble compounds which, because of their solubility in water, occur more or less together in nature. Bromine, although not produced as a salt, is present in brines as soluble bromides and is grouped with the soluble salts. All of these compounds are present in sea water, in bedded deposits derived from the evaporation of sea water, in connate waters of marine sedimentary formations, or in saline lakes in areas underlain by evaporite deposits. Through various physical and chemical processes the different salts may be concentrated, making feasible the commercial recovery of at least some of the soluble compounds. Gypsum and anhydrite are commonly of similar origin but because of their lesser solubility, they are treated in a separate section.

Potash

Potash, a term originally applied to impure potassium carbonate (K_2CO_3) extracted from wood ashes, but now applied more loosely to various other potassium-bearing salts, is essential to agriculture as a plant food and has many uses in industry. Since potash is produced commercially as any one of several potassium salts, for purposes of comparison the potash content is customarily expressed as "equivalent" potassium oxide (K_2O) although potassium oxide is neither found in nature nor produced commercially. Potentially great potash reserves are present in the Permian rocks of the western part of the Trinity River tributary area but the only commercial development has been near Carlsbad, New Mexico to the west of the tributary area.

The principal potassium bearing minerals in the rocks of the Permian Basin are sylvite (KCl), langbeinite ($2MgSO_4.K_2SO_4$), carnallite ($KCl.MgCl_2.H_2O$), and polyhalite ($K_2SO4.MgSO4.2CaSO4$). The sylvite occurs with varying amounts of halite (NaCl), the mixture being known as "sylvinite". Sylvinite is the source of most of the potash output in New Mexico although langbeinite is also mined. Polyhalite, although the most abundant of all the potassium minerals in the Permian basin, contains only 15.6 percent equivalent potash and is not at present used as a commercial source of potash.

Nearly 90 percent of the United States annual consumption of potash is used in the preparation of commercial fertilizers; without potash-bearing fertilizers, the cotton, tobacco, potato, citrus fruit and truck crops would be greatly reduced. In industry potash or its derivatives are used in the manufacture of glass, pottery, soap, and matches. In the form of potassium nitrate (KNO_3) or saltpeter, it is an essential ingredient in the manufacture of black powder and other explosives and is used for the preservation of meat. As potassium cyanide (KCN) it is used in the extraction of gold and silver from their ores and in photography and electroplating.

In New Mexico, potash salts are mined from depths of 800 to 1,000 feet by the room-and-pillar method. The crude sylvinite ore is either crushed and then purified by a system of solution and fractional crystallization, or ground and then concentrated by floating either the halite or the sylvite.

Prior to World War I, the United States was dependent upon imports of potash, the bulk of which came from the great Stassfurt salt deposits of Germany. Cessation of imports caused a serious situation; the price of potash as potassium chloride or sulfate rose to over $900 a ton of available K_2O. During the war, various saline lakes, kelp, and industrial wastes were used as sources of potash. Starting in 1911, the United States Geological Survey and the Texas Bureau of Economic Geology collected information and publicized the possibility of finding potash in the thick salt-bearing Permian rocks of the Permian Basin in Texas and New Mexico. This resulted in a number of government and private drill tests and the discovery by a private company in 1925 of the potash deposits in Eddy County, New Mexico. Commercial production in New Mexico began in 1931 and since that time the United States has been virtually independent of foreign sources.

Occurrence of potash in the Trinity River tributary area

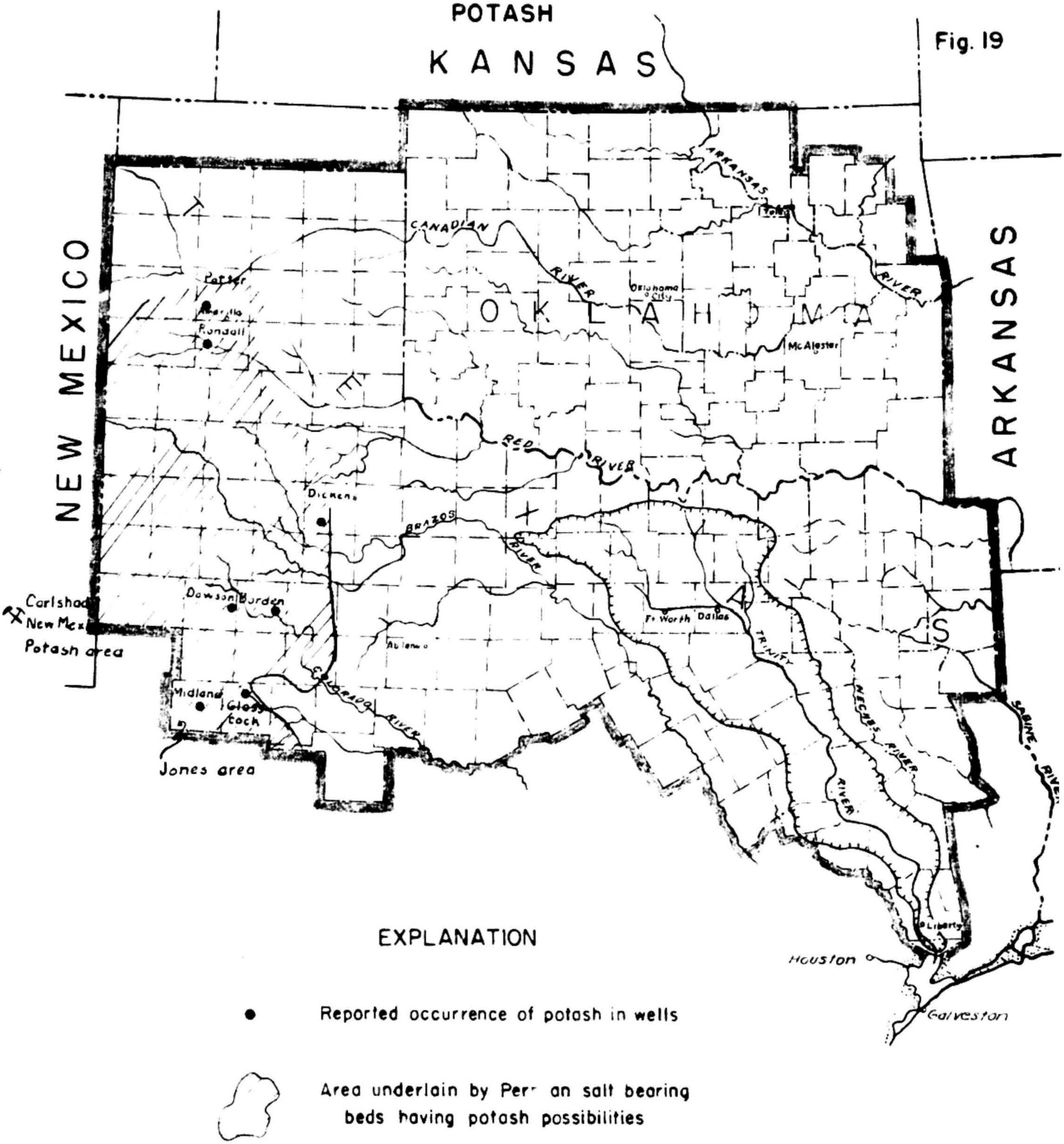
Potash brine or potash minerals in well cores have been reported from Borden, Dawson, Dickens, Glasscock, Midland, Potter, and Randall Counties and are probably present at places in the intervening counties of the Permian Basin in the Trinity River tributary area. (See accompanying map for reported occurrences and area showing potash possibilities). Very little is known of the thickness, extent and composition of the potash beds, the only data being from oil wells scattered over a great area and a few test holes drilled specifically for potash. Practically all of the potash so far discovered is in the form of polyhalite, an exception being the Jones area in southwestern Midland County where 5 feet of polyhalite and 6 feet of soluble potash salts--perhaps sylvite--were penetrated in drill holes at depths ranging from 1,900 to 2,000 feet. From mine development and core drill holes in the Eddy County, New Mexico area, it is known that the potash minerals are concentrated in small subsidiary basins within the main Permian Basin and are concentrated near points of structural deformation. Because of the relatively small amount of drilling that has been done to date in the Trinity River tributary area, it is probable that the best deposits may yet remain to be found.

Reserves

From the great area over which polyhalite has been found in the Trinity River tributary area of western Texas and the thickness of the polyhalite beds in wells, it is apparent that the potash reserves of the Trinity River tributary area are very large. Reserves in the New Mexico potash field were estimated by the Geological Survey in 1940 at 75,000,000 tons of equivalent K_2O. Because the New Mexico potash deposits are shallower and can produce quantities far in excess of present domestic and export demands, it is improbable that the Texas polyhalite deposits will be developed until the New Mexican deposits have been seriously

POTASH

Fig. 19



DISTRIBUTION OF POTASH IN THE TRINITY RIVER TRIBUTARY AREA depleted. The Texas area is further handicapped because with one exception the deposits discovered to date consist principally of polyhalite, an unsatisfactory source of potash under present conditions. A future market for polyhalite might develop, however. For example, agricultural experiments indicate that for certain uses, polyhalite can be employed directly as a fertilizer. Furthermore, polyhalite contains magnesium as well as potassium. The use of light-weight magnesium alloys has increased greatly during the war and this may stimulate research into new sources of the metal. Should a method be devised to extract both magnesium and potassium from polyhalite at a sufficiently low cost, the polyhalite beds may become of value. It should be pointed out, however, that the Carlsbad, New Mexico area contains tremendous reserves of polyhalite which could be obtained from existing mines and with existing equipment. The opening up of the deeper and still undeveloped Texas deposits is therefore likely to be long delayed.

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Common Salt

Common salt, the mineral halite, (NaCl), is found at a number of places within the Trinity River tributary area. It occurs as salt domes or plugs intruded into Cretaceous and Tertiary sediments, as bedded deposits of rock salt in rocks of Permian age, as surface encrustations and brines in salines, and as brines recovered incidental to petroleum production.

Halite is soft (Mohs scale of hardness, 2.5) and light in weight (sp. gr., 2.1 to 2.6). When pure it is colorless but in its natural state it is usually stained by small quantities of included impurities. In nature it is closely associated with gypsum or anhydrite and with small quantities of the soluble sulphates and chlorides of calcium, magnesium, and potassium.

Salt, although common and cheap, is essential to life and the industrial growth of a nation. It is used in large quantities in the preservation of meat and other foods and in the preparation of foodstuffs for market. Livestock also require considerable salt in their diet. However, the greatest use of salt, over 50 percent of the total United States output of 15,214,152 short tons in 1943, was in the chemical industry. Salt is one of the basic raw materials in the manufacture of the alkalies, Na_2CO_3, $NaHCO_3$, and NaOH, hydrochloric acid (HCl), metallic sodium, and chlorine. Increasing amounts of salt are being used in the manufacture of metallic magnesium, synthetic rubber, and plastics. Other industrial uses are in soap manufacturing, textile processing, curing of hides and leather, refrigeration, and in the regeneration of zeolites in softening water.

Salt may be recovered by underground mining methods from bedded deposits or salt plugs. The rock salt is then crushed and screened to the desired commercial sizes. Salt is also produced by injecting water into the salt bearing formation and pumping the brine into pans where it is evaporated to dryness using natural gas, lignite, or solar evaporation. For the chemical industry concentrated brine as pumped from the ground needs no further treatment.

In 1943, Texas produced about 7 percent of the total United States output of salt and ranked fifth among the states in total production. Oklahoma's annual output is less than 10,000 short tons a year. The demand for salt is almost constant except for the development of new industry. The present demand for common salt in the Trinity River tributary area is easily met by established operations and any probable increased demand could also be satisfied. No great expansion in the area using salt produced in the Trinity River tributary area is possible because of competition from established salt producers along the Gulf Coast of Texas and Louisiana on the south and Kansas on the north.

Occurrence of common salt in the Trinity River tributary area

Salt plugs - Within the Trinity River basin salt was produced for many years from brine pumped from the salt dome near Palestine, Anderson County, Texas. The top of the salt was 140 feet beneath the surface and the wells extended about 250 feet into salt. This operation was abandoned in the early 1930's. Salt plugs are roughly circular in outline, vary from 1,000 feet to 2 miles in diameter, and extend to unknown but considerable depth; the top of the salt may occur at any depth beneath the surface. Other known salt plugs within the basin are the Bethel and Keechi domes in Anderson County, the Butler dome in Freestone County, the Oakwood dome in Freestone and Leon Counties, the Moss Bluff dome in Liberty and Chambers Counties, the Lost Lake dome in Chambers County, and the Davis Hill, Hull, South Liberty, and North Dayton domes in Liberty County. The depth to salt of many of these domes may make the production of brine more feasible than the production of rock salt especially as many of the salt domes are close to abundant sources of lignite and natural gas, fuels for the evaporation of the brine.

At the Grand Saline dome, Van Zandt County, Texas in the Trinity River tributary area but outside the drainage basin, the Morton Salt Co. mines rock salt from its Kleer salt mine at a depth of about 1,000 feet. The rock salt is topped at 238 feet but active mining has been below 700 feet. Brine was formerly produced from wells in the northwestern part of the dome. Other known salt domes in the Trinity River tributary area are the Hainesville dome in Wood County; the Steen, Mt. Sylvan, East Tyler, Whitehouse, Bullard and Brooks domes in Smith County; the Brushy Creek and Boggy Creek domes in Anderson County; the LaRue dome in Henderson County; and the Marquez dome in Leon County.

Bedded salt deposits - In Kansas and western Oklahoma the salt bearing beds are in the Permian Wellington formation; but over most of Texas west of a line drawn between Sterling County and western Hardeman County, rock salt probably occurs in slightly younger beds, the Clear Fork and Double Mountain groups of the Permian. The salt beds usually do not crop out at the surface because they either are covered by younger rocks, were not deposited on the eastern edge of the Permian basin, or have been removed by solution. The rock salt beds of the Permian basin in the Trinity River tributary area vary in combined thickness from nothing to more than 1,000 feet. At Colorado City, Mitchell County, Texas, salt brine was produced from a depth of 850 feet; the discovery well for this deposit reported 140 feet of rock salt between 850 and 1,000 feet. In many localities in the tributary area salt beds are within 750 feet of the surface and rarely are they deeper than 1500 feet.

Saline lakes, springs and flood plains - In the early days salt was recovered from saline lakes, springs, and river flood plains of western Oklahoma and northern Texas in the Trinity River tributary area. Saline lakes are still the source for most of Oklahoma's small output of salt.

Oil field waters - Salt water is frequently pumped with petroleum in the oil fields of the area. The disposal of this waste water is a constant expense since it cannot be dumped into surface drainage channels.

Fig. 20

EXPLANATION

- • Known salt dome
- ⊙ Salt dome; producing
- ⊕ Salt dome; past production
- x Salt in surface saline
- ⊗ Salt in salines producing
- (hatched) Area underlain by Parmian bedded salt deposits
- ⊖ Former producing locality of brine from Parmian bedded salt deposits

DISTRIBUTION OF COMMON SALT OF THE TRINITY RIVER TRIBUTARY AREA

Companies Producing Glass Sand

Company	Geologic Age of Sand Deposit
Mill Creek Sand Company Mill Creek, Oklahoma	Oil Creek sand, Simpson group
Sulphur Silica Company Sulphur, Oklahoma	Oil Creek sand, Simpson group
Mid-Continent Glass Sand Company Roff, Oklahoma	McLish sand, Simpson group
Oklahoma Silica Sand Company Hickory, Oklahoma	Oil Creek sand, Simpson group

Glass manufacturing companies in the Tributary area in Texas are the Knox Glass Company at Palestine and the Owens-Illinois Glass Company at Waco, Texas.

There are several glass manufacturers in Oklahoma.

Production of Glass Sand

An appreciable amount of glass sand is produced in the tributary area, principally in Johnston and Pontotoc Counties, Oklahoma, but the production figures are not available.

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Oklahoma

Year	Short Tons	Value
1934	1/	1/
1935	1/	1/
1936	1/	1/
1937	1/	1/
1938	1/	1/
1939	1/	1/
1940	1/	1/
1941	10,743	$42,737
1942	8,305	35,132
1943	7,716	30,496

1/ Included with "other states" or undistributed.

Texas

Year	Short Tons	Value
1934	208,979	$ 612,586
1935	268,809	563,514
1936	316,006	615,815
1937	364,780	623,037
1938	324,449	624,096
1939	352,008	604,663
1940	402,165	792,214
1941	656,569	1,713,508
1942	821,111	2,202,527
1943	1,127,854	3,610,532

Data from United States Bureau of Mines.

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Calcium Chloride

Calcium chloride, $CaCl_2$, is one of the principal dissolved salts contained in brine after the extraction of common salt. In its anhydrous form it is a white, highly deliquescent substance whose commercial utility depends upon its hygroscopic properties or the low freezing point of its solutions. Large quanitites of calcium chloride are known in oil field brines and alkali lake brines of the Trinity River tributary area but, for the most part, the material is not recovered.

Over 50 percent of the total United States calcium chloride output is used by state and local governments for laying dust on highways and in making stabilized roads. Large quantities are also used for ice control on sidewalks and highways, for curing and hardening concrete, for dust proofing coal, coke and other materials, for circulating brines in refrigerating plants, and for an antifreeze in certain types of outdoor mechanical equipment. Other minor uses of calcium chloride are as a laboratory desiccant in drying gas in gas works, as a de-humidifier for air-conditioning rooms holding delicate precision instruments, for making calcium soap lubricants, and for the extraction of lithium from spodumene.

Brine pumped from wells is first evaporated until the sodium chloride has crystallized out, and then by fractional crystallization under controlled composition and temperature conditions, calcium chloride is separated from magnesium chloride and magnesium sulfate. For some purposes calcium chloride with magnesium chloride and sulfate is acceptable, and for this purpose the residual liquor following precipitation of common salt is thus merely evaporated to dryness.

Natural calcium chloride constitutes only a small percentage of the total output, as great quantities are formed as a byproduct in the chemical industry, especially the Solvay process for manufacturing sodium carbonate. Byproduct Solvay-process calcium chloride is formed by the reaction of limestone and sodium chloride. Most of the byproduct calcium chloride is not recovered; the amount recovered depends upon the current demand for the refined product. It has been estimated that 90 percent of the calcium chloride derived from chemical plants and sodium chloride brines is wasted.

The demand for calcium chloride immediately following the war should be good because of postponed road developments by state and local governments. Natural calcium chloride produced from brine in the Trinity River tributary area can compete with the artificial byproduct material only by reason of disparity in freight rates. Manufactured calcium chloride is produced at a number of localities along the Gulf Coast.

Occurrence of calcium chloride in the Trinity River tributary area

In the Trinity River tributary area calcium chloride is found in varying quantities in all brines recovered for the production of common salt, or may be recovered from oil well brines. Analyses of oil field waters from different sources show that the concentration of calcium chloride varies within considerable limits. The high calcium chloride waters may offer opportunities for profitable extraction if other dissolved materials (sodium chloride, bromine, potash, and magnesium chloride) are recovered in the same operation. The Texas Salt Products Co., a subsidiary of The Texas Co., produced evaporated salt, bromine, and calcium chloride from oil field brines at West Tulsa, Oklahoma prior to 1936 but abandoned the operation in that year. The best source within the tributary area for calcium chloride from natural sources is probably waste bitterns from salt refining.

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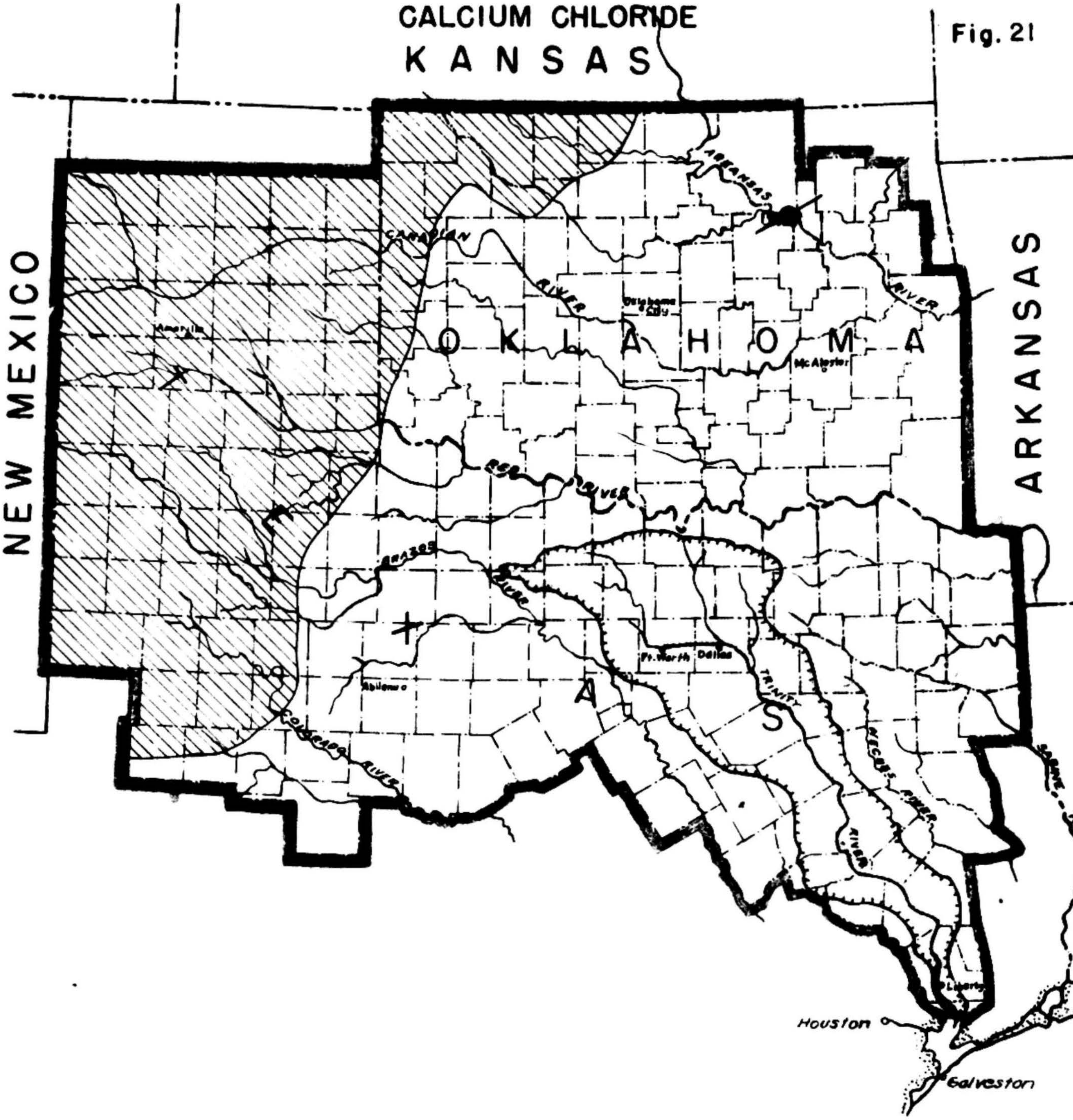
Fig. 21



EXPLANATION

Former producing area

Area underlain by Permian salt bearing beds

DISTRIBUTION OF
CALCIUM CHLORIDE IN THE TRINITY RIVER TRIBUTARY AREA

Magnesium Chloride

Magnesium chloride, $MgCl_2$, is a white, bitter, deliquescent salt which because of its hygroscopic characteristics does not occur as a solid under normal conditions but may be found in bedded deposits under cover. It is generally found with other highly soluble salts of potassium, calcium, and magnesium in sea water, the brines of salt lakes, and the bitterns remaining after the crystallization of common salt.

Magnesium chloride as brine in the electrolytic separation of magnesium metal supplies 85 percent of the United States potential output. In the past the principal sources of magnesium chloride brines in the United States were wells in Michigan and sea water in North Carolina, but since 1941 sea water taken from the Gulf of Mexico near Freeport, Texas has become an important source. Because of its hygroscopic properties, magnesium chloride like calcium chloride can be used to lay dust on roads. Much of the calcium chloride marketed in the United States for this purpose contains both calcium and magnesium chlorides. Magnesium chloride is also used in magnesite stucco and Sorel cement but these uses are in decline.

The producing capacity of metallic magnesium manufacturing plants in the United States expanded 90 times during the war, far beyond the peacetime requirements of the nation. Early in 1944 the magnesium output was curtailed to 60 percent of total capacity. Established plants using seawater or magnesium-rich well brines appear adequate to supply the United States demands for many years.

Occurrence of magnesium chloride within the Trinity River tributary area

Within the Trinity River tributary area magnesium chloride-rich brines are known from Upper Permian horizons near Gail in Borden County, Texas. This occurrence was drilled by the Ozark Chemical Co. of Tulsa, Oklahoma, in 1942 who also investigated methods of recovering commercial products from the brine. High magnesium chloride brines in many other localities underlain by the salt beds of the Permian Basin of north and west Texas are very possible. Magnesium chloride is also found in the brines of shallow wells underlying the alkali lakes of the High Plains. During the war the Union Potash and Chemical Co. at Carlsbad, New Mexico, recovered magnesium chloride in the separation of potassium sulfate from langbeinite. The magnesium chloride recovered in this operation was shipped to Austin, Texas, for conversion to the metal.

Brines recovered incidental to petroleum production offer another source of magnesium chloride; the brines of certain oil fields carry a much higher concentration of magnesium chloride than do others.

Reserves

Reserves of magnesium chloride in the brines of surface and subsurface waters of the Trinity River tributary area are very large but with the perfection of the large scale plants for the extraction of magnesium chloride from seawater or subsurface brines from Michigan, it is improbable that these reserves will be developed. However, considerable magnesium chloride may be produced from the brines as a byproduct in the extraction of other valuable salts.

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Bromine

Bromine is a dark reddish brown, highly corrosive volatile liquid, It is found in seawater and other brines probably as bromides of magnesium and sodium. Seawater contains about 1 pound of bromine in 2,000 gallons of water.

The principal use of bromine is in the manufacture of ethylene dibromide, a colorless, volatile, emulsifiable, poisonous liquid prepared by the action of bromine on ethylene gas. Ethylene dibromide is used in the manufacture of tetraethyl lead for addition to gasoline to improve antiknock qualities. Large quantities are used in the manufacture of war gases (especially tear gas), aniline dyes, and some synthetic rubber. Bromine is also used in photographic reagents, disinfectants, medicine, fumigation, and chemical synthesis.

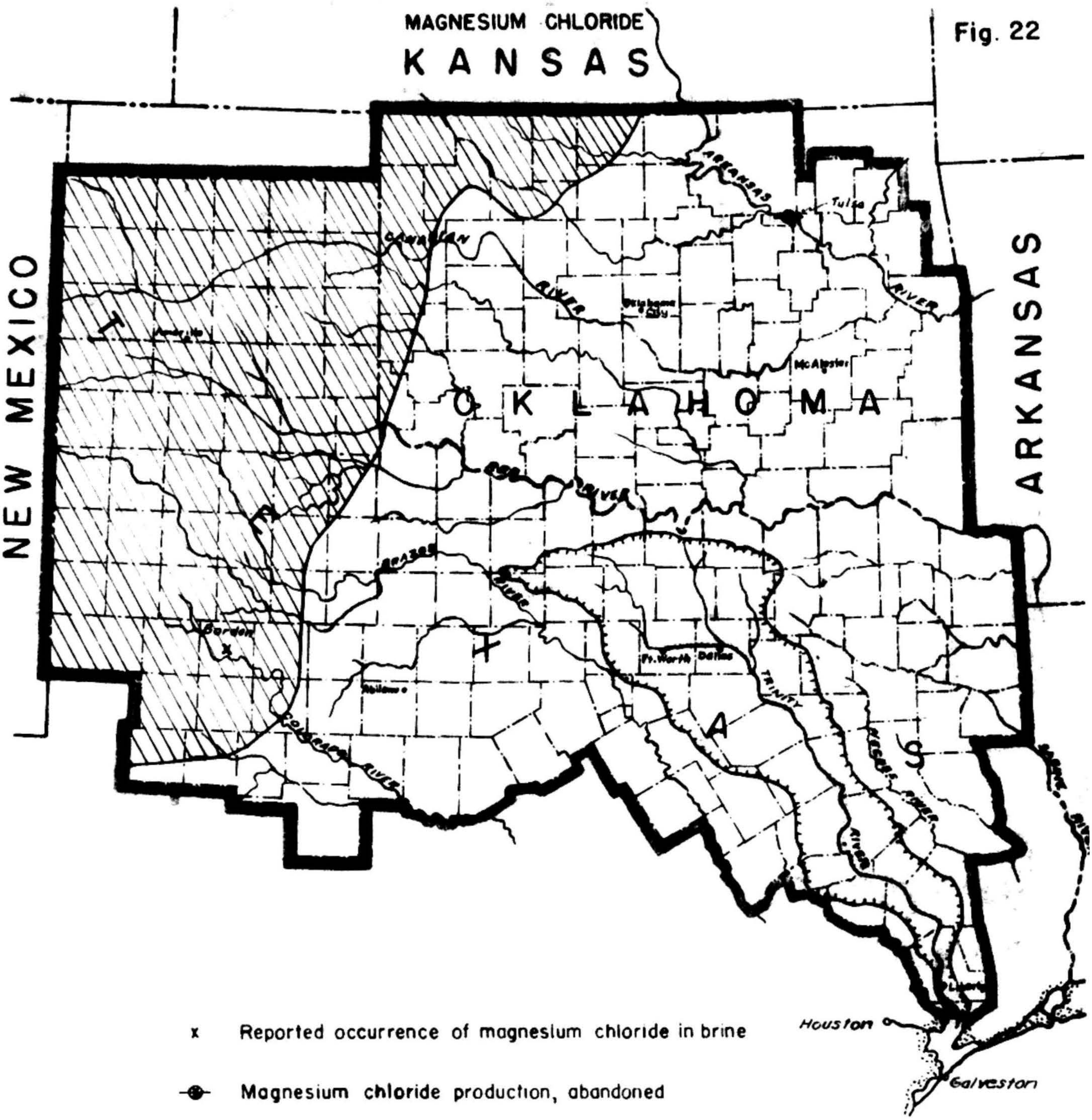
Bromine is separated from brine in a number of ways. In the Ethyl-Dow Corporation process sea water is acidified, oxidized with chlorine, and blown out with compressed air in towers. The bromine is recovered as sodium bromide-bromate using Na_2CO_3; acidification yields bromine. Another continuous process uses an electric current for oxidation of the bromides. A batch process of making bromine uses sulfuric acid and an oxidizing agent (sodium chlorate or manganese dioxide).

The use of tetraethyl lead to improve antiknock qualities of gasoline has increased each year. With the resumption of civilian travel following the war, the demand for leaded gasoline should continue to improve. The large plants to extract bromine from seawater on the Atlantic and Gulf Coasts appear adequate to supply all demands of the immediate future.

Occurrence of bromine in the Trinity River tributary area

In the Trinity River tributary area bromine, probably as magnesium bromide, is present in the alkali lakes of north and west Texas and in oil field brines. Some of the lakes in the High Plains

Fig. 22



x Reported occurrence of magnesium chloride in brine

Magnesium chloride production, abandoned

Area underlain by Permian salt beds; magnesium chloride associated with the salt

DISTRIBUTION OF MAGNESIUM CHLORIDE IN THE TRINITY RIVER TRIBUTARY AREA contain relatively high percentages of bromine. Drill cores from some of the salt domes in southeastern Texas have a strong odor of bromine or iodine. The only output reported from the tributary area was by the Texas Salt Products Company at West Tulsa, Oklahoma, prior to 1936.

Reserves

Bromine reserves in the alkali lakes, oil field brines, and salt domes are probably very large but it is doubtful that they can compete with the efficient large-scale plants using seawater which are located on the Gulf Coast of Texas and Louisiana. It is possible that bromine can be produced in relatively small amounts from brines other than seawater which have been treated for the extraction of other dissolved salts.

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Magnesium Sulfate

Magnesium sulfate, $MgSO_4$, occurs in nature as kieserite, $MgSO_4 \cdot H_2O$, or epsomite, $MgSO_4 \cdot 7H_2O$. Kieserite occurs in bedded salt deposits with other saline minerals; epsomite occurs as an efflorescence on rocks and is especially common on mine walls. Magnesium sulfate commonly occurs in solution in subsurface brines of the Permian Basin of Texas and in the surface waters of the larger alkali lakes of the High Plains.

Magnesium sulfate in aqueous solution is used in coagulating rayon, in tanning hides, in the preparation of pharmaceuticals, and in the preparation of commercial fertilizers. The United States uses between 20 and 30 thousand tons of magnesium sulfate a year.

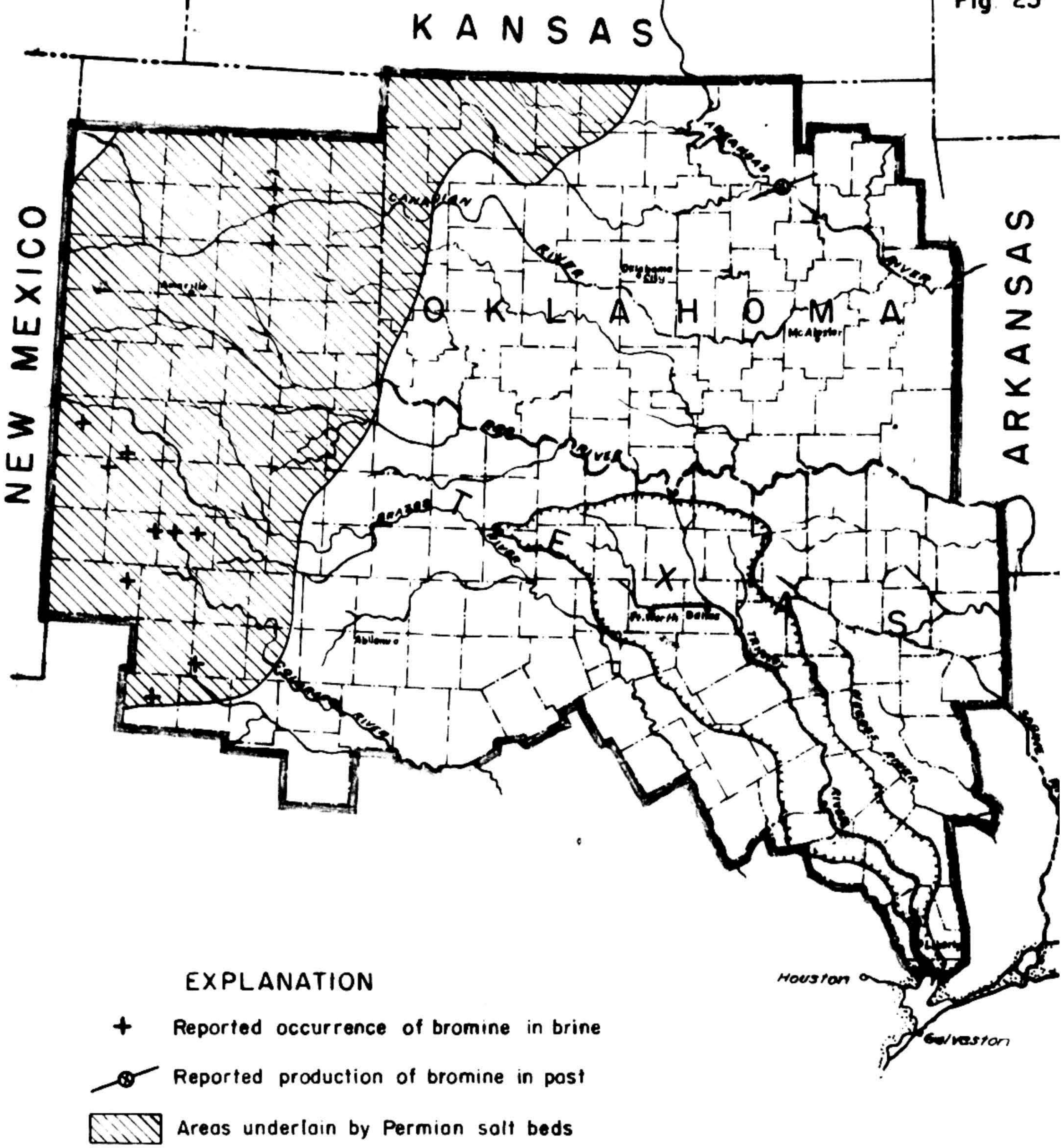
Magnesium sulfate may be made by neutralizing caustic-calcined magnesia with sulfuric acid solution, and this manufactured product competes with the natural magnesium sulfate.

Occurrences in the Trinity River tributary area

In the Trinity River tributary area magnesium sulfate is recovered from shallow well brines in an alkali lake bed near O'Donnell, Texas, by the Arizona Chemical Company, a subsidiary of the American Cyanamid and Chemical Corporation. Brines from other alkali lakes, waste

BROMINE

Fig. 23



DISTRIBUTION OF BROMINE IN THE TRINITY RIVER TRIBUTARY AREA water from petroleum production, and subsurface waters recovered from wells drilled in the Permian Basin of north and west Texas all contain magnesium sulfate to some extent. Recently 44 percent of the dissolved salts of a brine from a well in the Permian rocks of Eddy County, New Mexico, was reported as magnesium sulfate.

Reserves

Undoubtedly large reserves of magnesium sulfate are present in the surface and subsurface waters of north and west Texas and the oil field brines of the remaining parts of the Trinity River tributary area. However, these brines could not be processed for the magnesium sulfate content alone but if sodium sulfate, magnesium chloride, calcium chloride, bromine, and other dissolved salts were recovered, the liquor might be treated at a profit.

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Sodium Sulfate

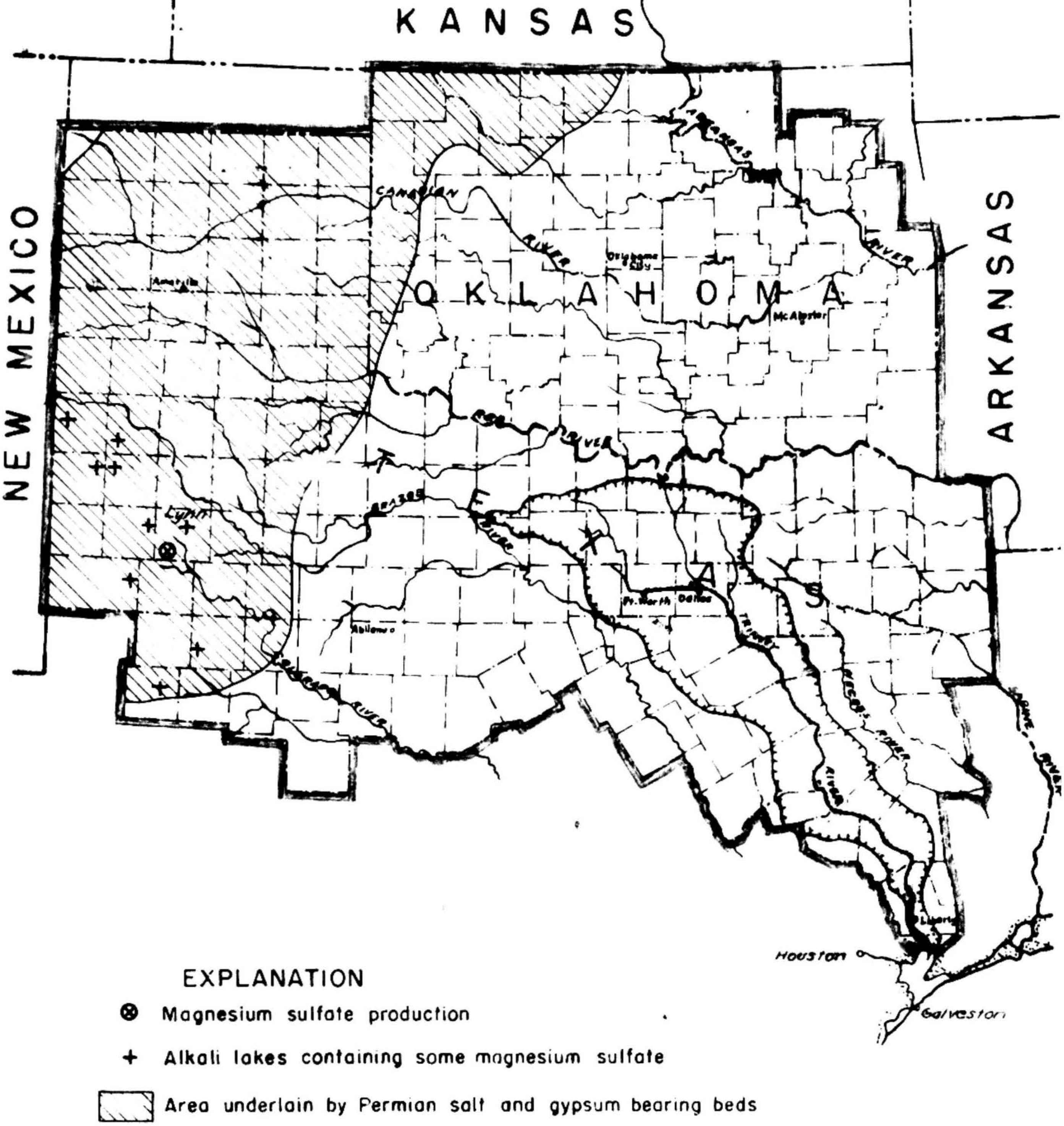
Sodium sulfate, Na_2SO_4, is one of the basic compounds in the chemical industry. In the United States it occurs as brines of alkali lakes in many of the western states. Although some sodium sulfate has always been recovered from this source, until recently most of the commercial sodium sulfate was salt cake, a byproduct in manufacturing hydrochloric acid from common salt and sulfuric acid. In the Trinity River tributary area natural sodium sulfate occurs in most of the alkali lakes of north and west Texas.

A number of sodium sulfate minerals occur in alkali lakes; the more important are thenardite (Na_2SO_4), glauberite ($Na_2SO_4.CaSO_4$), and mirabilite ($Na_2SO_4.10H_2O$). Except thenardite which is white, all of the minerals are transparent, colorless crystals that are bitter or salty to the taste. Much of the sodium sulfate is in the brine which saturates the sand and silt of the lake fill. In a few alkali lake beds, sodium sulfate minerals, principally mirabilite, occur beneath a few feet of clastic sediment.

The greatest industrial use of sodium sulfate is in the manufacture of kraft paper by the sulfate process of making wood pulp. Other uses are in the manufacture of heavy chemicals, rayon and textiles, glass, the standardization of dyes, and as a flux in metallurgy.

Fig. 24

MAGNESIUM SULFATE



DISTRIBUTION OF MAGNESIUM SULFATE IN THE TRINITY RIVER TRIBUTARY AREA

Natural sodium sulfate is produced by pumping the brine from shallow lakes and evaporating to dryness or precipitating the contained solids under carefully controlled temperature conditions.

A recent trend to abandon the sulfuric acid method of manufacture of hydrochloric acid for the gaseous combination of hydrogen and chlorine has resulted in a shortage of salt cake. The deficiency has been made up by imports of large quantities of sodium sulfate from Germany and imports of natural sodium sulfate from Saskatchewan, Canada. The domestic output of natural sodium sulfate from alkali lake brines has increased markedly but the total quantity from this source is only a small percentage of the United States consumption. The development of a large kraft paper industry using the pine forests of the South has created an important market for sodium sulfate produced in alkali lakes of the Trinity River tributary area.

Occurrences of sodium sulfate in the Trinity River tributary area

In the Trinity River tributary area sodium sulfate is reported from alkali lakes in Bailey, Cochran, Gaines, Hockley, Howard, Lamb, Lynn and Terry Counties. Sodium sulfate is also known from underground waters of the Cretaceous rocks of central Texas and the Pennsylvanian rocks at Mineral Wells, Palo Pinto County, Texas. The probable source of the sodium sulfate in the alkali lakes is the underlying Permian gypsiferous rocks of the Permian Basin.

Sodium sulfate is being produced in the Trinity River tributary area by the Arizona Chemical Company, a subsidiary of the American Cyanamid and Chemical Corporation, in plants at O'Donnell, Lynn County, and Brownfield, Terry County, Texas. The product goes almost entirely to the kraft paper industry. The first output of the plants was in 1938.

Reserves

Great quantities of sodium sulfate exist in the brines of alkali lakes and well waters in the western part of the Trinity River tributary area. A relatively new and rapidly expanding market for sodium sulfate exists in the kraft paper industry which uses the pine forests of East Texas, Arkansas, and Louisiana. However, to compete with foreign sodium sulfate which can be imported at Gulf ports at a comparatively low price or salt cake which can be manufactured from sulfur and salt produced along the Gulf coast, the cost of production of the natural sodium sulfate must be kept at a minimum.

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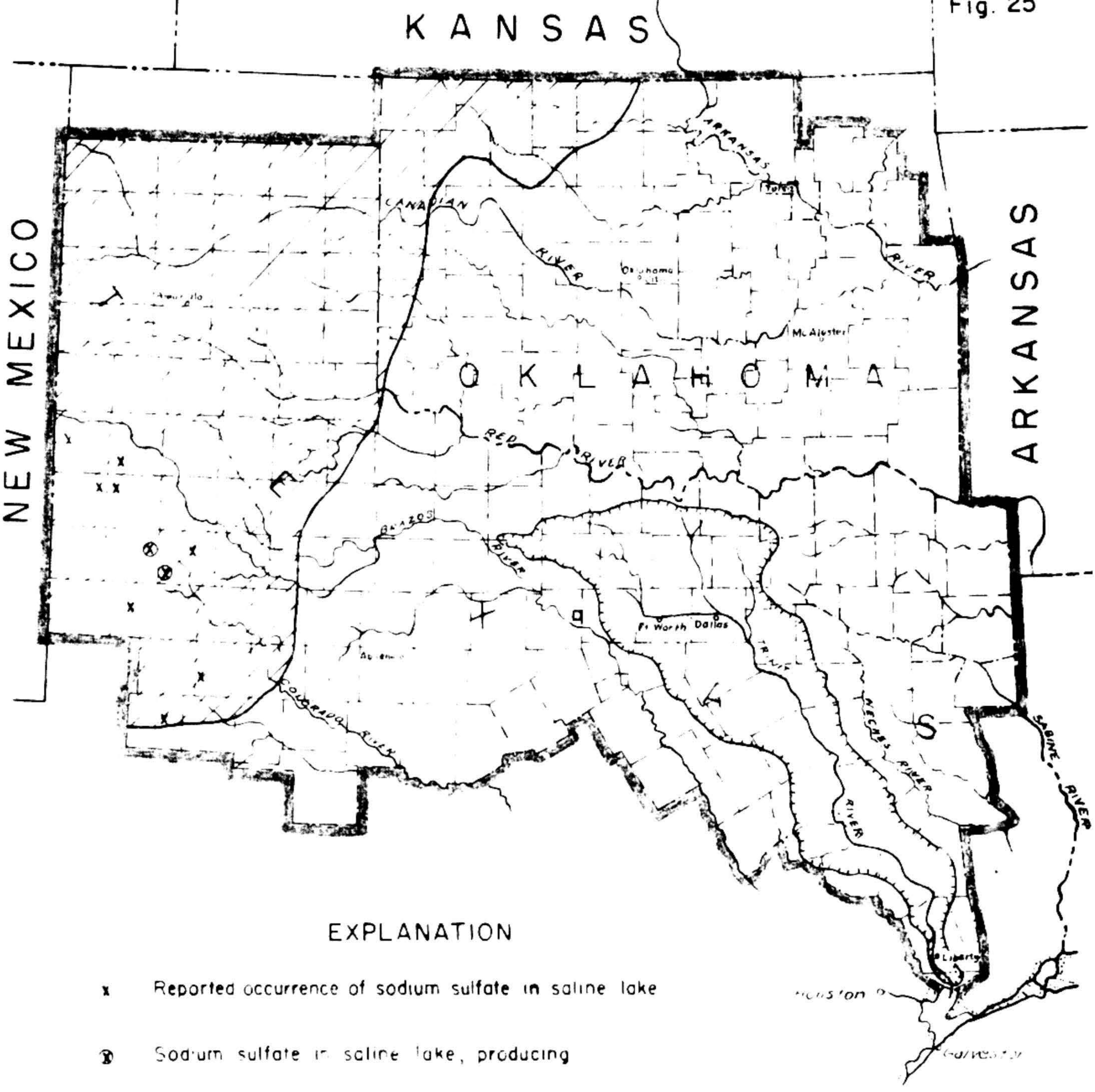
SODIUM SULFATE

Fig. 25



EXPLANATION

x Reported occurrence of sodium sulfate in saline lake

⊗ Sodium sulfate in saline lake, producing

□ Reported sodium sulfate in underground water

Area underlain by Permian salt and gypsum bearing beds

DISTRIBUTION OF SODIUM SULFATE IN THE TRINITY RIVER TRIBUTARY AREA

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SULFUR

D. M. Kinney, United States Geological Survey

Sulfur is a non-metallic yellow mineral which has a hardness of 1.5 to 2.5, a specific gravity of 2.05, and melts between 234° and 248° F. Sulfur is a poor conductor of heat and electricity and is insoluble in water.

Over 70 percent of the United States consumption is made into sulfuric acid and an additional 16 percent is converted to calcium bisulfite and sulfurous acid for the sulfite conversion of wood pulp to paper Principal uses of sulfuric acid are in the manufacture o super-phosphat fertilizer, refining of petroleum products, manufacture of chemicals, the pickling of metals prior to galvanizing and tin plating, and in storage batteries. Native sulfur is used in the manufacture of syntheti rubber, the vulcanizing of rubber, and the preparation of insecticides and fungicides.

The Gulf Coast of Texas produces more than 80 percent of the world's sulfur output and has sufficient reserves to maintain such production for many years. The sulfur is associated with limestone, anhydrite, and gypsum in the cap rock of salt domes, structures which have great importance in the localization of oil in the Gulf Coast area. No sulfur is produced at the present time in the Trinity River tributary area, but the planned development of the Moss Bluff dome almost on the banks of the Trinity River in Chambers and Liberty Counties, should make the area a substantial producer.

In the typical sulfur-bearing salt dome the cap rock is made up of a layer of porous limestone resting on a thicker layer of anhydrite, in part altered to gypsum. The anhydrite in turn rests on the salt. Sulfur impregnates the porous limestone as seams and cavity fillings; a barren cap rock limestone which varies from 5 or 10 feet to 200 feet in thickness overlies the sulfur-bearing rock. The sulfur-impregnated limestone may vary from 25 to 300 feet in thickness and must average 100 feet in thickness to be workable. The actual sulfur content of the porous limestone in commercial deposits ranges between 20 and 40 percent.

The sulfur in the porous limestone cap rock is extracted by the Frasch process in which superheated water (300° F., plus) is pumped into the sulfur-bearing rocks and the molten sulfur is blown to the surface by compressed air. The molten sulfur is then pumped into wooden storage bins where it hardens. Sulfur which also occurs to some extent in the anhydrite layer near the limestone cap rock contact cannot be extracted by the Frasch process because the anhydrite lacks porosity for the circulation of the superheated water. One well is capable of removing the sulfur from one-half acre.

Gulf Coast sulfur controls the world markets. The native sulfur deposits of Sicily have great reserves and are favorably located to supply the industrialized European market, but because of the cost of mining, inefficiencies of extraction, a high tariff, and the impurity of the final product, they do not present serious competition even in the European market. Pyrite (FeS_2) is the greatest competitor of sulfur in the manufacture of sulfuric acid as it is frequently a byproduct of metal and coal mining. Sulfur is also obtained as a byproduct from gases of industrial plants and considerable sulfuric acid is made from flue gases of smelters treating sulfide minerals. The development of the Trinity River north of Liberty would make cheap barge transportation available for sulfur produced from the Moss Bluff dome, thus stimulating the development of the dome and enhancing the value of the deposit.

Occurrence of Sulfur in the Trinity River Tributary Area

Sulfur is known to occur in commercial quantities in only 8 of the more than 200 known salt domes of the Gulf Coast area. In Texas the developed sulfur-bearing salt domes are concentrated between the mouths of the Brazos and Colorado Rivers in Matagorda, Brazoria, Fort Bend, and Wharton Counties, southwest of the mouth of the Trinity River. These domes are limited to a band extending 70 miles inland from the Gulf of Mexico.

In the Trinity River basin the Moss Bluff salt dome in Liberty and Chambers Counties is known to contain sulfur in the limestone cap rock. The Moss Bluff dome is elliptical in ground plan with dimensions of 1½ by 2 miles at a depth of 900 feet. The cap rock extends to within 650 feet of the surface and salt is penetrated at a depth of 1,170 feet. The Moss Bluff dome has proved to be only a small petroleum producer and the area is reported to have been leased and extensively drilled by a major sulfur-producing company. The company is said to be planning development as soon as equipment is available. The great majority of the salt domes in the Trinity River tributary area are more than 150 miles from the Gulf of Mexico and on an empirical basis the sulfur possibilities of these domes are slight.

Reserves

Sulfur reserves at the Moss Bluff salt dome have not been published. However, if a major sulfur-producing company is planning development of the dome, the reserves must be large inasmuch as the capital investment in a Frasch process plant is considerable.

SULFUR

Fig. 26

EXPLANATION

o Reported occurrence of sulfur in salt dome

DISTRIBUTION OF SULFUR IN THE TRINITY RIVER TRIBUTARY AREA

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MINERAL RESOURCES OF THE TRINITY RIVER TRIBUTARY AREA IN TEXAS AND OKLAHOMA

METALLIC RESOURCES

COPPER

A. E. Weissenborn, United States Geological Survey

The uses of copper are too well known to require discussion here; the importance of this metal in the national economy has been all too clearly demonstrated during the war period. This country has for many years led the world in the production of copper, but despite greatly increased domestic production and large imports from foreign sources, supplies were insufficient to meet wartime demands and the use of copper had to be restricted to the most essential military and civilian needs.

Arizona, Utah, and Montana are the principal copper-producing states. Together with New Mexico, Nevada, and Michigan they account for approximately 97 percent of the copper produced in this country. Texas contributes only about 0.01 percent to the total domestic production, and there has been no production of significance from Oklahoma. None of the Texas production comes from the Trinity River tributary area.

Although the Trinity River tributary area has never produced appreciable amounts of copper, it should not be inferred that deposits of copper are unknown in the region. On the contrary, deposits of disseminated copper minerals are widely distributed in the sedimentary rocks of Permian age throughout west Texas and Oklahoma. These deposits are known as the "Red Bed" type of deposits because of their close association with sedimentary rocks predominantly red in color. Other examples of this type are found in New Mexico, Arizona, Colorado, Wyoming, Utah, and Idaho as well as in various places in Europe, Central Asia, Turkestan, South America, and other parts of the world.

Although the Red Bed copper deposits are scattered throughout the world, the copper content is generally so low that deposits have not been an important source of copper. In a few places the deposits have been successfully exploited. The best examples of successful operation in this country are the Scholle, Nacimiento, and Pastura deposits, all in New Mexico. The total production to date from these three localities, however, probably amounts to less than 14,000,000 pounds of copper. This production, although of local importance, is less than a single month's output of one of the large porphyry copper mines, and consequently, is of slight significance in the national economy.

Over a period of many years numerous attempts have been made to mine the Red Bed deposits in the Trinity tributary area, but so far, none have been successful. Of recent years ore from the Pastura deposit in New Mexico has commanded a premium price at the El Paso smelter due to its high silica content. The Pastura mines are approaching exhaustion and should the demand for high silica ore continue, it would tend to encourage the search for siliceous ores from the similar deposits of the Trinity tributary area. The demand for this purpose is limited, however Exploitation of the Red Bed deposits on a large scale would require an increase in the price of copper which cannot now be foreseen, even taking into account the serious depletion of this nation's reserves of copper as the result of wartime demands. Lower freight rates which might result from canalization of the Trinity River are not likely to have much effect on the development of the Red Bed copper deposits.

Occurrence of Copper in the Trinity River Tributary Area

General Geology of the Red Bed Deposits

The sedimentary, or Red Bed copper deposits, are with few exceptions restricted to rocks of Pennsylvanian, Permian, or Triassic age. There seems to be some evidence that the copper minerals in at least some instances were deposited in shallow synclinal basins within these rocks. Although the rocks with which the deposits are associated are dominantly red in color, the particular beds in which the copper is actually found are more apt to be white or light gray. The copper occurs in arkosic sandstones, shales and conglomerates and is commonly associated with plant remains or fossil wood. The mineralogy of the deposits is strikingly similar the world over. Most of the copper was deposited as chalcocite, commonly associated with iron sulphides and is found cementing sand grains, as replacements of plant remains, fossil wood and iron sulphides, or as discrete nodules in sandstone and shale. Chalcopyrite, covellite, and bornite may also be present. In places, especially on the outcrops, the copper sulphides have been more or less completely oxidized and the sulphide minerals altered to malachite, azurite and chrysocolla, or more rarely, to cuprite, tenorite, atacamite and native copper. Vanadium and uranium are found to be associated with the copper in some places. Nickel, chromium, molybdenum, lead, and silver also occur in varying amounts. Barite, calcite, and gypsum are found in the copper-bearing beds, but they are equally abundant in other beds from which copper is absent and appear to have no close genetic relationship to the copper minerals.

Distribution of the Red Bed Copper Deposits in the Trinity River Tributary Area

Copper Deposits in the Permian Rocks - The numerous copper-stained outcrops in the Trinity tributary early attracted the attention of trappers and prospectors and are mentioned in the report of the Marcy Expedition which explored the Red River in 1852. The green-colored outcrops of the Red Bed deposits are not only conspicuous but they tend to give an exaggerated impression of the proportion of copper actually contained in the beds; this has lead to numerous unsuccessful attempts to develop them.

In the Trinity tributary area the sedimentary copper deposits are almost entirely confined to Permian rocks, although the copper-bearing beds are found at several horizons within these rocks. Permian rocks do not crop out anywhere in the Trinity River drainage basin; consequently all the copper deposits of the tributary area lie outside the Trinity River watershed.

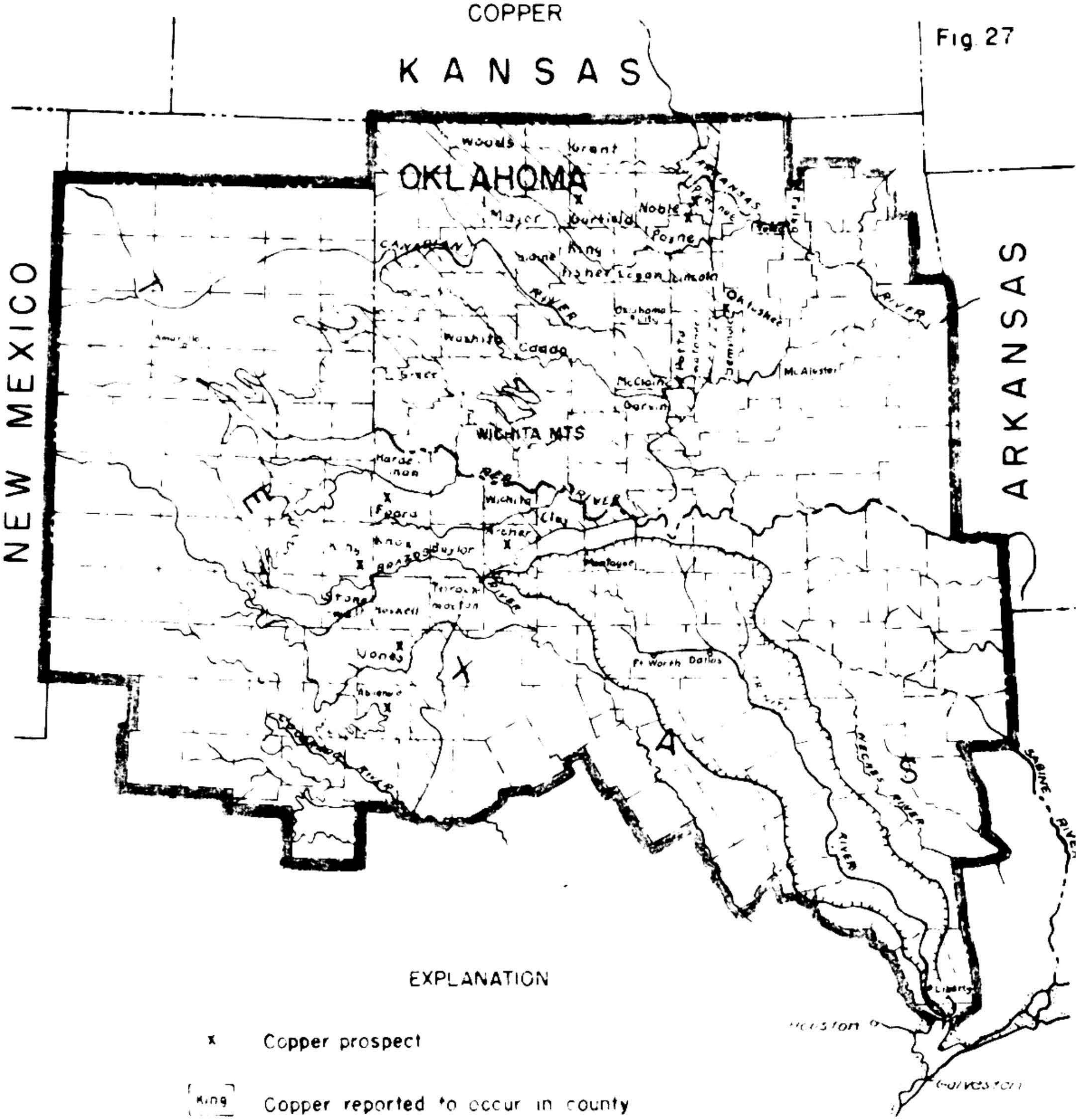
In the tributary area part of Texas, copper deposits are known in the Wichita, Clear Fork, and Double Mountain groups of the Permian. The deposits in the Wichita group crop out principally along the Big and Little Wichita Rivers in Archer, Clay, Montague, and Wichita Counties. The most conspicuous outcrops are near Archer City and unsuccessful attempts were made to mine them many years ago. Copper deposits in sandstones and shales of Clear Fork age are reported in Baylor, Throckmorton, Haskell, Jones, and Taylor Counties, over a distance of approximately 90 miles. The most extensive prospecting appears to have been done in the vicinity of Avoca in Jones County where drilling is said to have disclosed the presence of disconnected lenticular ore bodies throughout a length of several thousand feet. Other areas reported to have been prospected at one time or another are in the vicinity of Seymour in Baylor County, and Buffalo Gap in Taylor County. Copper showings in the Double Mountain group are known in Stonewall, King, Knox, Foard, and Hardeman Counties. Prospecting has been carried on in the vicinity of Buzzard Mountain in King County, Knox City in Knox County, and near the town of Vivian in Foard County.

Copper deposits in Permian rocks in Oklahoma are found in a great many localities, and over a wide area. In Garvin County a few tons of ore have been shipped from a prospect near Paoli, and a small production has been reported from the Byars prospect 4 miles southwest of Byars in McClaine County. The ore is said to have contained considerable silver in addition to the copper, but the operation was not successful and there has been no work done since 1913. Some prospecting has also been reported near Lela in Pawnee County and in the vicinity of Hillsdale in Garfield County. Copper showings have also been observed in Blaine, Caddo, Grant, Greer, Kingfisher, Lincoln, Logan, Major, Noble, Pontotoc, Pottawatomie, Seminole, Washita, and Woods Counties, and doubtless there has been desultory prospecting in countless localities other than those specified.

Copper Deposits in Rocks Other Than Permian - A copper deposit filling a fault in rocks of Pennsylvanian age is found in western Okfuskee County, Oklahoma. Two unsuccessful attempts have been made to mine this ore, the latest being in 1934 when 30 tons of ore were shipped to the El Paso smelter. The deposit is of interest as it is one of the few in the Trinity River tributary area not associated with Permian rocks. C. A. Merritt of the Oklahoma Geological Survey believes that the copper was deposited from meteoric waters which circulated through the fault zone and which presumably obtained the copper from overlying Permian sediments now eroded away.

From time to time, showings of copper have been discovered in veins in pre-Cambrian igneous rocks in the Wichita Mountains of Oklahoma but nothing has been found to date which would indicate that the deposits are of any importance.

Fig. 27



EXPLANATION

x Copper prospect

King — Copper reported to occur in county

/ / Area occupied by Permian rocks, greatly generalized

DISTRIBUTION OF COPPER IN THE TRINITY RIVER TRIBUTARY AREA

Reserves

Although some of the individual deposits appear to have been fairly thoroughly tested, there has been no systematic investigation of the Red Bed deposits of the Trinity River tributary area as a whole, and specific figures of reserves of copper in the Permian beds cannot be given. The statement can be made, however, that the tonnage of copper contained in these rocks is large, but that except locally the grade is so low that the deposits cannot be worked under present conditions, or under any conditions which are likely to exist in the foreseeable future. They should not be regarded as a reserve in the ordinary sense of the term, but rather as a resource which might be utilized in some period of national emergency or in the distant future when other, higher grade deposits in this country are exhausted. This does not preclude the possibility that small deposits, favorably situated, and with a higher copper content that the average might not be mined, particularly if the ore receives a premium for its silica content.

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IRON ORE

H. B. Stenzel and H. C. Fountain, Bureau of Economic Geology, University of Texas, and D. M. Kinney, United States Geological Survey

Iron ore deposits are present in east Texas and in the Arbuckle and Wichita Mountains of southern Oklahoma. The east Texas iron ores have been known for over a hundred years but were not mined on a large scale until the years 1944 and 1945. In these years spectacular industrial developments new to Texas and the great demand for iorn and steel focused public attention on this natural resource. Only a few of the deposits in Oklahoma have been mined and the principal output has been used in the manufacture of special "low heat" Portland cement.

The iron ores of east Texas are of two kinds: the brown ores and the carbonate ore. The brown ores are composed of an intimate natural mixture of several iron-containing minerals and some impurities. This mixture is commonly referred to as limonite. Hence the brown ores are also called limonitic ores. However, according to Galbraith (2) 1/ X-ray examination reveals the limonitic ores to be composed of a fine mixture of about 80 to 85 percent of the mineral goethite ($Fe_2O_3.H_2O$) and 15 to 20 percent of the mineral hematite (Fe_2O_3). The impurities generally consist of sand grains of quartz (SiO_2), pieces of clay or shale, more or less weathered grains of glauconite, and some phosphatic materials.

The limonitic ores assume many different shapes and structures. The nodular or concretionary ores have an endless variety of form as nodules or concretions or honeycombed, botryoidal, stalactitic, and mammillary irregular masses. Colors vary from ocher-yellow to brown to nearly black. Hardness varies from soft and crumbly to medium-hard; usually the lighter the color of the ore the softer it is. The laminated ore usually is in only one horizontal and extensive bed of solid, medium-hard, brittle, brown, thinly laminated limonitic ore.

The second type of east Texas iron ore is the carbonate ore. This ore is composed chiefly of the mineral siderite ($FeCO_3$). The mineral siderite, if pure, is very heavy (sp. gr. 3.7 to 3.9) and medium-hard (Mohs scale $3\frac{1}{2}$ to $4\frac{1}{2}$), and contains 62.1 percent FeO and 37.9 percent CO_2. The carbonate ore contains sand grains of quartz (SiO_2), pieces of lignite, grains of glauconite, and other impurities. It forms dense, horizontal ledges found usually associated in groups, in which the individual ledges are discontinuous.

Iron ores, together with coals, are the fundamental geologic raw materials of heavy industry, which in turn is the backbone of modern technological civilization and the power of nations. Most of the iron ores mined are used for the making of iron and steel; only a very small amount is used for other purposes such as the manufacture of paints, cements, ferromagnesite, hydrogen gas, concrete aggregate, the purifying of gas, as flux at nonferrous smelters, and for heavy

1/ See reference in bibliography.

drilling mud. Less than 0.15 percent of the total iron ore produced in the United States in 1934 went to these minor uses (5).

The iron ores of east Texas are mined in open pits. At the plant of the Lone Star Steel Company the raw ore is taken by dump trucks to the plant near by. There it is dumped at the top of the treating plant, which washes the raw ore and concentrates it. The treating plant is constructed along modern technological lines specially designed for the type of ore handled.

Mining of iron ore and smelting of iron were greatly expanded in the United States during the war years, 1941-1945. During these years the demand for ore and steel was unprecedented by peacetime standards. It is generally predicted that during the postwar years steel production in the United States will be larger than in the years before the war (about 46,500,000 tons), but also considerably smaller than during the war (about 80,000,000 tons) (5). How much of the increased peacetime production of iron ore will be shared by the east Texas mines is not clearly predictable. Such major iron ore producing centers as the Lake Superior and Birmingham districts will continue to supply most of the ore needed for the national economy. In comparison with these large producers of iron ore, the output of the east Texas region is very small. Even at the peak of its production, in 1944, the east Texas region produced 303,682 gross tons of crude ore out of a total of 111,020,145 gross tons for the entire United States, or merely 0.27 percent of the total (5).

Demand for steel products has accumulated during the war in every civilian category. This pent-up demand is certain to assure great production of steel and iron ore for several years to come. In the region covered by and adjacent to the Trinity River tributary area the chief uses of civilian steel products will be in the form of automobiles and other vehicles, railroad rolling stock and rails, construction materials for buildings, highways, and bridges, and materials for the petroleum industry. It is estimated that the petroleum industry of the United States will consume annually 2,400,000 tons of steel largely in the form of drill pipe, line pipe, and casing (5).

East Texas iron ores were shipped in 1944 to blast furnaces in the Birmingham district of Alabama and in Houston, Texas. The iron ores are in an advantageous position as to shipping distances insofar as the steel produced in the region can be manufactured locally into shapes used by consumers in the trade territory in the construction, oil, and other industries.

Occurrence

The east Texas iron ores are part of, or are derived from, the Weches greensand member of the Mount Selman formation of the Eocene Claiborne group 2/. This greensand member with its attendant iron ores

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2/ "Weches formation" instead of "Weches greensand member of the Mount Selman formation" is used in some recent geologic reports.

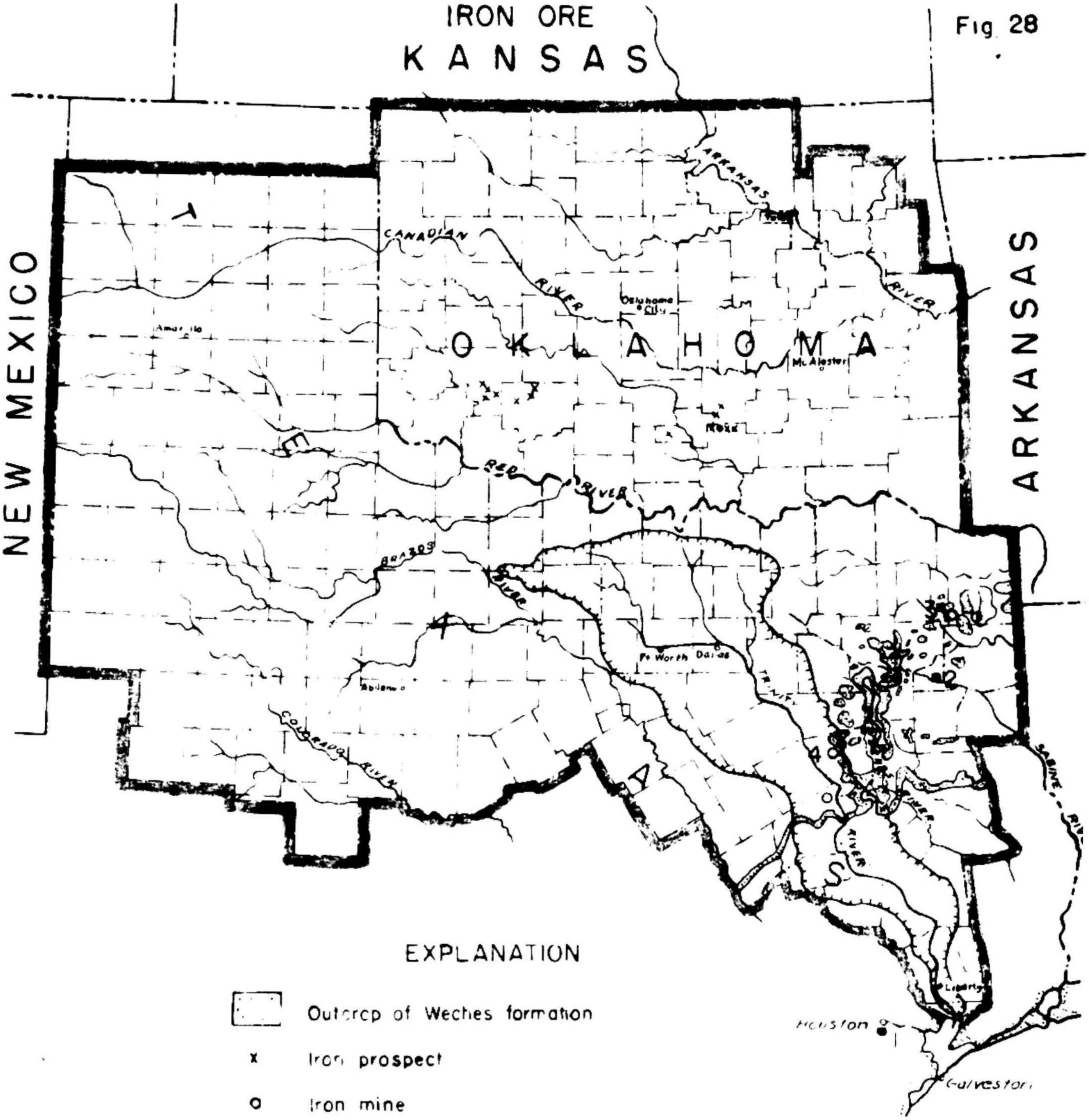
extends through the following counties: Cass, Morris, Marion, Harrison, Upshur, Wood, Smith, Van Zandt, Henderson, Rusk, Cherokee, Anderson, Nacogdoches, Houston, and Leon. The iron ore region may be divided into two basins. The North Basin is separated from the South Basin roughly along a line about 15 miles north of and parallel with the course of the Sabine River. This line runs approximately through the town of Gilmer in Upshur County.

The North Basin ores are chiefly of the nodular or concretionary type; the South Basin ores are chiefly laminated ore. Carbonate ore occurs in both basins. The nodular or concretionary ores are distributed throughout the weathered part of the Weches strata in the North Basin. The laminated ore of the South Basin forms a nearly continuous ledge of varying thickness at the top of the weathered Weches formation, where the Weches and the Sparta formations are in contact. The nodular or concretionary ores and the laminated ores are products of the weathering in place of the Weches strata. These strata in the fresh, unweathered state contain many iron-bearing minerals, of which the most common are glauconite (a complex iron-alumina silicate), siderite ($FeCO_3$), and pyrite or marcasite (FeS_2). Through the processes of weathering these minerals have been changed into the limonitic iron ore; at the same time the iron content of the mass has been concentrated and partly segregated so that the resultant ores are richer in iron than the unweathered rocks of the Weches. In conformity with the nature of the weathering processes, chiefly leaching and oxidation, the resultant limonitic iron ores are found above the ground water table, that is, above the zone of continuous saturation with ground water. Hence the limonitic ores are mined in open pits above the ground water table, and encroachment of ground water is not a problem.

In the North Basin and in the northern part of the South Basin the iron ore is found in more or less isolated hills or larger plateaus that are erosion remnants of a once continuous cover of Weches rocks. These erosion remnants are usually the highest hills of the area and form the divides between major streams and creeks. The larger of the isolated hills and the plateaus are covered by a loose, white-gray sand soil that is derived from the weathering of the Sparta formation, which caps the Weches strata. In the isolated hills the Weches is usually thoroughly weathered; but on the larger plateaus the weathering extends only along the outside fringe and, as usual, the limonitic ores are found only in the weathered portions. Toward the south, that is, in the south part of the South Basin, the Weches strata gradually dip underground and become covered by successively younger sedimentary rocks. This condition sets a limit to the southward extent of the Weches and its attendant ores.

The Oklahoma iron ore deposits are present in the Wichita Mountains of Kiowa and Comanche Counties and in the Arbuckle Mountains of Murray, Johnston, and Pontotoc Counties. The deposits of the Wichita Mountains are predominantly titaniferous magnetite deposits, although one deposit of hematite is known from Comanche County. The deposits in the Arbuckle Mountains are principally brown iron ore.

Fig. 28



EXPLANATION

Outcrop of Weches formation

x Iron prospect

o Iron mine

■ Steel plant

1. Sheffield Steel of Texas, Houston

2. Madaras Steel Corp. of Texas, Longview

3. Lone Star Steel Co, Daingerfield

4. McCrossin Engineering Co., Rusk, Texas

DISTRIBUTION OF IRON ORE IN THE TRINITY RIVER TRIBUTARY AREA

The deposits of titaniferous magnetite in the Wichita Mountains are irregular masses in anorthosite gabbro, a heavy, dark igneous rock of pre-Cambrian age. The magnetite has been concentrated to a limited extent in the residual soil overlying the anorthosite areas and is frequently coated with limonite and hematite. Run of mine material averages about 15 percent iron. The average titanium content is about 8 percent. As ore with a titanium content of over 1 percent is not acceptable for use in iron furnaces, the deposits are of no present value as a source of iron ore. The deposits have been tested by pits, trenches, and shafts.

The hematite deposit in the Wichita Mountains is a bedded deposit about 40 feet above the base of the Reagan sandstone of Cambrian age. The hematite bed varies from a few feet to 21 feet in thickness and can be traced for at least a mile along the outcrop. The hematite ore averages about 30 percent iron. It was mined for a short time for paint manufacture in Oklahoma.

Brown iron ore is found in the Arbuckle Mountains of Murray, Johnston, and Pontotoc Counties. The ore is associated principally with the limestone and dolomite of the Arbuckle group, although some deposits are found in the Simpson group and the Viola and Hunton limestones. The masses of brown iron ore may adhere to country rock or occur as loose fragments in residual soil overlying unweathered rock. The iron deposits commonly have been localized by faults or folds.

Little is known of the size of the brown iron ore deposits, although some extend over several acres and a shaft 20 feet deep was still in ore. However, individual deposits are believed to be small. A few deposits were worked in 1939 and 1940 to supply the Oklahoma Portland Cement Company with iron ore for the manufacture of special "low heat" Portland cement. A small amount of the output went to iron foundries in Oklahoma. Probably less than 5,000 tons of iron ore were mined from the deposits in Johnston and Pontotoc Counties.

Reserves

The wide distribution of the Weches greensand member of the Mount Selman formation 3/, and its attendant ores indicates that the iron ore reserves of east Texas are huge. An estimate of the reserves was made by the United States Geological Survey in 1938 (1), and is given in the following table.

3/ The term "Weches formation" instead of "Weches greensand member of the Mount Selman formation" is used in some recent geologic reports.

ESTIMATED RESERVES OF IRON ORE IN EASTERN TEXAS

County	Probably available now or in near future (Long Tons)	Possibly available, but too thin or low-grade for large scale operations (Long Tons)	Total Reserves (Long Tons)	Area covered by probably available ore (Acres)	Area covered by possibly available ore (Acres)
North Basin					
Cass:					
East of 93°25'	41,979,000	5,215,000	47,194,000	8,000	2,200
West of 93°25'	18,451,000	3,185,000	21,636,000	2,600	1,500
Total:	60,430,000	8,400,000	68,830,000	10,600	3 700
Morris	28,338,000	500,000	28,838,000	3,000	500
Marion	5,313,000	1,819,000	7,132,000	600	1,500
Upshur (Estimated)	4,000,000	1,000,000	5,000,000	800	200
Total North Basin	98,081,000	11,719,000	109,800,000	15,000	6,000

(Continued)

ESTIMATED RESERVES OF IRON ORE IN EASTERN TEXAS

(Continued)

County	Probably available now or in near future (Long Tons)	Possibly available, but too thin or low-grade for large scale operations (Long Tons)	Total Reserves (Long Tons)	Area covered by probably available ore (Acres)	Area covered by possibly available ore (Acres)
South Basin					
Cherokee:					
Near Rusk	16,503,000	---	---	4,250	---
Near Dialville	12,954,000	---	---	3,600	---
Massell Mountain	2,626,000	---	---	675	---
Mount Haven	4,376,000	---	---	750	---
Near Reese	1,945,000	---	---	500	---
Other Areas		7,000,000	---		2,000
Total:	38,404,000	7,000,000	45,404,000	9,775	2,000
Henderson:					
Near Brownsboro	1,634,000	3,209,000	4,843,000	280	1,100
Other Areas		2,918,000	2,918,000	---	1,500
Total:	1,634,000	6,127,000	7,761,000	280	2,600
Anderson		12,643,000	12,643,000	---	6,500
Other Counties		5,000,000	5,000,000	---	500
Total - South Basin:	[illegible]0,038,000	30,770,000	7[illegible],[illegible]08,000	10,055	11,500
Grand Total:	139,118,000	42,489,000	1[illegible],608,[illegible]00	25,655	17,600

178.

This estimate is regarded at present as essentially correct except that newer geological findings have disclosed a much greater amount of carbonate ore present than had been known at the time this estimate was made. Geologists of the Lone Star Steel Company estimate that in the tract of land near the company's furnace in Morris County, total ore reserves contain about as much carbonate ore as limonitic ore. This discovery in effect doubles previous estimates of total reserves in the area surrounding the Lone Star Steel Company plant. The older estimate gives about 28,000,000 long tons of iron ore probably available now or in the near future in all of Morris County. However, on account of the recent discovery of the extent of the carbonate ore, it seems that this figure would fit approximately the reserves contained in southeastern Morris County in the vicinity of the Lone Star Steel Company mines alone. Additional exploratory work, particularly for carbonate ore, may make it necessary to revise upward the estimates for some of the other deposits.

The tonnage of titaniferous magnetite available in the Washita Mountain area is probably very large, although the tonnage available for immediate recovery from residual deposits is limited. The anorthosite gabbro country rock's percentage of magnetite is very low and the unaltered rock could not be mined at a profit even if a market for titaniferous magnetite existed. Only one deposit of hematite is known and it is too low-grade for metallurgical use, although some of it might be mined for paint pigment. The brown iron ore deposits in the Arbuckle Mountain area have large reserves but the deposits are low-grade and are small and scattered. The best market for the brown iron ores is probably in the manufacture of special Portland cements.

Producing Companies

Companies producing iron ores or iron and steel in the Trinity River tributary area and the location of their plants and mines are given below:

Lone Star Steel Company, Daingerfield, Texas. Products: Raw and beneficiated iron ore, coke.	Mine in southeastern Morris County, Texas. Ore washing and beneficiation plant, coke ovens, and blast furnace in southern Morris County, Texas. Blast furnace not in operation.
Madaras Steel Corporation of Texas, Longview, Texas.	No mines. Experimental steel plant planning to produce steel castings near Longivew, Texas.

McCrossin Engineering Company, Rusk, Texas. Planned Products: Charcoal, pig iron, methanol, acetic acid, wood tars, and other charcoal byproducts. Construction of plant suspended. — Mines near, Rusk, Cherokee County, Texas.

National Lead Company, Baroid Sales Division, Texarkana, Texas. Product: Oil well drilling mud conditioner. — Mine in Suratt survey, near Linden, Cass County.

Sheffield Steel of Texas, Houston, Texas. Products: Ingots, blooms, billets, sheet bars, etc. — Mines near Linden, Cass County, and Jacksonville, Cherokee County, Texas. Blast furnace and rolling mill in Houston, Texas, in production.

Production

The production of iron ore for the six-year period, 1939 to 1944, in the Trinity River tributary area is given in the following table. Iron ore was not mined in the area in the years, 1920 to 1939.

Year	Crude Ore Mined (Gross Tons)	Iron Content (In Percent)	Ore Shipped From Mines (Gross Tons)	Beneficiated Ore Shipped From Mine (Gross Tons)	Active Mines
1939	10,361	51.32	6,511		
1940	5,453 (a)	51.50	8,665 (a)	27,879 (b)	Linden mine, Cass County
1941	19,718 (c)	52.50	11,278 (d)		Linden mine, Cass County
1942	46,212 (e)	52.51		19,423 (e)	Linden mine, Cass County
	(18,377 (e) short tons of usable iron ore produced.)				
1943	None		17,792 (e)		No mine active in east Texas
1944	303,682	46.50		275,531	3 mines

All data from United States Bureau of Mines publications (5, 6)

(a) Includes Oklahoma.
(b) Includes Tennessee.
(c) Includes South Dakota and Virginia.
(d) Includes Oklahoma, Tennessee, and Virginia.
(e) Includes Virginia.

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MANGANESE

D. M. Kinney, United States Geological Survey

Manganese is an essential raw material in the manufacture of steel. The manganese is used in making ferromanganese and spiegeleisen which are added to the melt to remove oxygen and sulphur and to add the proper amount of manganese and carbon to the steel. A small amount of electrolytic manganese is now used in steel manufacture. Even under the stimulus of high prices during the war, domestic production was unable to supply more than 13 percent of the United States requirements, although a larger percentage could have been produced had the need arisen and had lower grade ore been used. Under ordinary conditions metallurgical ore must average 48 percent of manganese and contain less than 0.25 percent of phosphorus. During the war ore averaging only 35 percent of manganese was utilized and material containing as little as 20 percent of manganese and carrying as high as 1.0 percent of phosphorus were purchased by the Government and stock-piled.

Manganese commonly occurs in nature as one of the oxides or as a mixture of the oxides. The oxides of manganese are black minerals of variable hardness; the common manganese oxide minerals can only be identified with certainty by their X-ray patterns. Manganiferous calcium carbonate ($Mn,CaCO_3$), and rhodochrosite ($MnCO_3$), are associated with the oxides in many places.

In 1942, 95 percent of the manganese ore in the United States was used in the manufacture of manganese alloys--90 percent of this quantity was used in making ferromanganes, 5 percent in spiegeleisen, and 5 percent in silicomanganese. Other uses of manganese are as a depolarizer in dry batteries, in the manufacture of hydroquinone, in the manufacture of manganese sulphate for fertilizer, as a coloring agent in paints and ceramics, and as a dryer (oxidizer) in varnish, japan, and printing ink. The material for use in dry batteries must have a high available oxygen content, with minimum iron and be free from arsenic, copper, nickel, and cobalt.

Steel furnaces which would serve as a market for manganese produced in the Trinity River tributary area are located in Houston, Texas, Birmingham, Alabama, Kansas City, Missouri, and East St. Louis, Illinois. Manganese oxide mined in the Trinity River tributary area might also be used locally as a ceramic coloring agent in giving brick a gray, black or mottle gray, and black surface.

Occurrence of Manganese in the Trinity River Tributary Area

In the Trinity tributary area manganese deposits are known at several localities near Bromide in Johnson and Coal Counties, Oklahoma, at the eastern end of the Arbuckle Mountains, and from the Ouachita Mountains in northeastern McCurtain County in the southwestern part of the state. Manganese is reported from Triassic sandstone in Dickens County, northwest Texas, but the deposits have no commercial possibilities. No manganese deposits are known from the Trinity River drainage basin.

Near Bromide the manganese deposits are small replacement bodies in the Chimneyhill limestone of Silurian age. The replacement deposits have been localized along faults and consist of a mixture of dark, reddish-brown, manganiferous calcium carbonate and black manganite with some manganocalcite and rhodochrosite as veins and cavity fillings. This ore averages more than 35 percent of manganese. Other deposits consist of manganocalcite, hematite, and hausmannite which average less than 20 percent of manganese, and manganiferous ankerite, which contains between 6 and 18 percent of manganese. In places these low-grade deposits have been concentrated to small high-grade ore deposits.

The manganese deposits in the Ouachita Mountains are in the lower part of the Arkansas novaculite, a hard, white, cherty rock of Devonian or Mississippian age. The manganese occurs as the oxide on bedding planes, along joints, as thin veins cementing brecciated novaculite, or as pockets in the novaculite. The manganese oxide, in small amounts, is disseminated generally through the lower part of the Arkansas ovaculite, but very infrequently has it been concentrated sufficiently to make a workable deposit. The ore averages about 0.35 percent phosphorus and is high in silica.

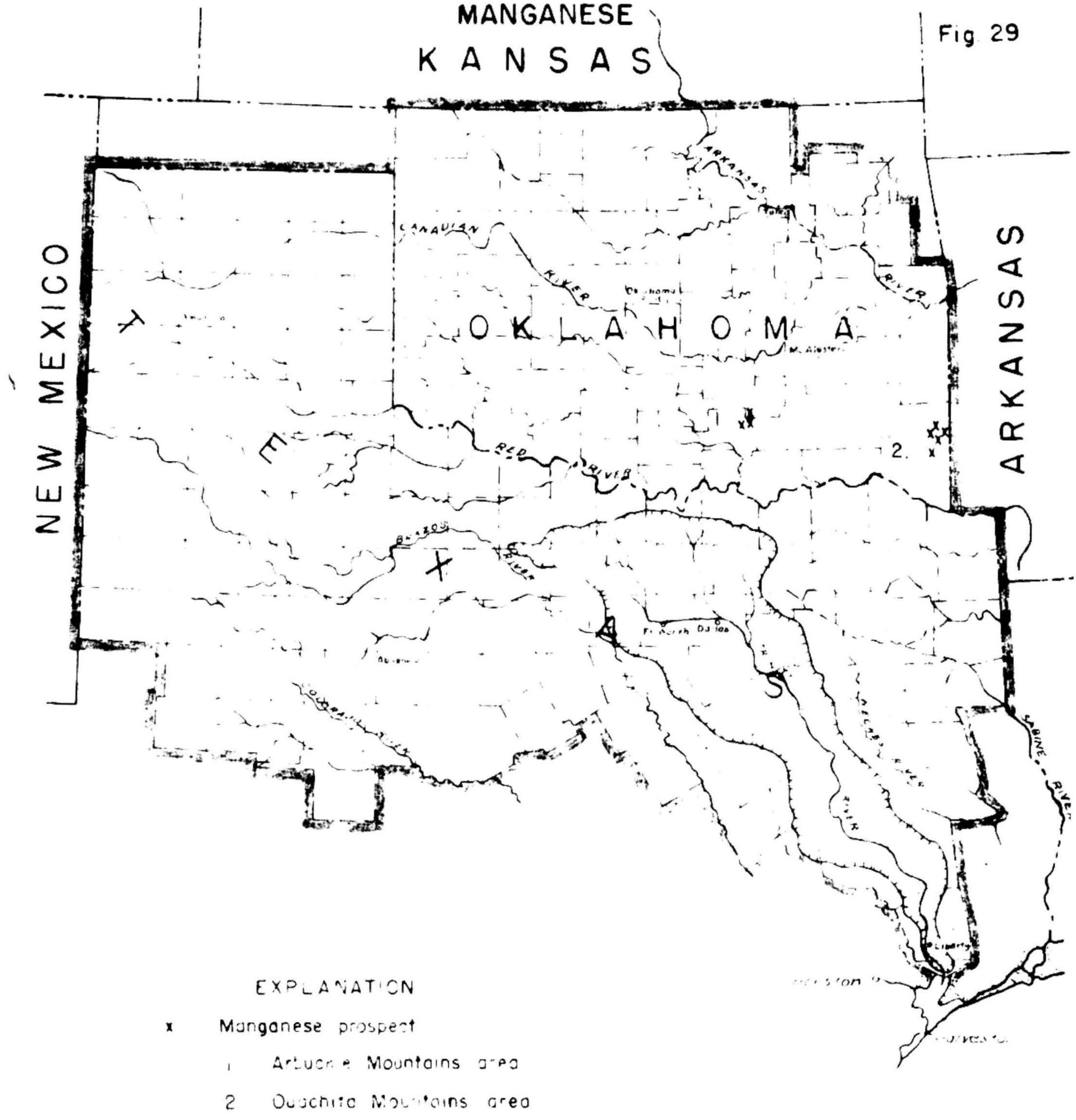
Reserves

The manganese deposits near Bromide have been estimated by D. F. Hewett of the United States Geological Survey to contain 5,000 tons of material assaying more than 35 percent of manganese. This estimate might be doubled if material assaying as low as 15 percent manganese were included in the ore estimate. The quantity of manganese oxide in the Arkansas novaculite of the Ouachita Mountains is probably very large. However, the deposits are believed to be too disseminated to constitute ore as the manganese oxide rarely constitutes as much as 20 percent of the rock.

Production From the Trinity River Tributary Area

1935	No Production
1936	No Production
1937	No Production
1938	No Production
1939	No Production
1940	No Production
1941	40 Short Tons
1942	31 Short Tons
1943	265 Short Tons
1944	No Production

Fig 29



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ZINC AND LEAD

A. L. Jenke, United States Geological Survey

Zinc and lead are mined in the important Miami-Picher area of Oklahoma, northeast of the Trinity tributary area. There has been no production of significance of these metals from either the Texas or Oklahoma parts of the tributary area although scattered low-grade deposits are found at various places in Oklahoma. There have been numerous attempts to develop these deposits since about 1900 but all have been unprofitable.

Occurrences of zinc and lead in the Trinity River tributary area

The most important occurrence of zinc in the Trinity River tributary area is the Davis zinc field in the Arbuckle Mountains of Oklahoma, about 7 miles southwest of Davis, Murray County. The deposits are found in crystalline limestone and dolomite in the Arbuckle limestone of Upper Cambrain or Lower Ordovician age which crop out in a zone about 15 miles long and 500 feet to one half mile wide. The beds dip from 40 to 50 degrees to the northeast and exhibit considerable evidence of minor folding and faulting. Sphalerite (ZnS) with minor amounts of galena (PbS) occurs finely disseminated throughout both the limestone and dolomite and at places forms irregular replacement masses in brittle, fractured dolomite. The chief working at the Hope-Sober open pit, one of the larger mines, was along a vertical shear zone striking northeast, along which the sphalerite and other minerals had been concentrated. Within 5 to 8 feet of the surface the sphalerite has been altered to smithsonite ($ZnCO_3$). The zinc mineralization is closely associated with a band of hematite boulders which can be traced the length of the outcrop; the zinc content of the rock decreases away from the band of hematite boulders. The zinc ore has been mined from open pits and shallow prospects, only a few of which reach 40 feet in depth.

Another occurrence in the Arbuckle mountains is near Ravia in Johnston County where both lead and zinc have been found in numerous shafts, some of which extend to depths as great as 90 feet. This deposit is in some respects geologically similar to those in the Davis zinc field.

Lead is reported in the Wichita Mountains in Comanche County, Oklahoma. In 1902 rumors of deposits of gold, silver and other metals brought on a brief mining boom and considerable prospecting was done but no workable deposits were ever found. Galena and chalcopyrite with small amounts of silver occur in the Clark and Bennet prospect 8 miles southwest of Meers and some exploration was done, but the property has been idle for many years. The mineralization is associated with basic dikes in pre-Cambrian granite. In the Lawton area, galena with traces of zinc, copper and silver minerals is found in fault zones in the pre-Cambrian granite. A number of unsuccessful attempts have been made to develop these deposits.

Lead and zinc minerals have been found in a number of places in the Ouachita Mountains in McCurtain County, southeastern Oklahoma. Several attempts have been made to mine these deposits but all have ended in failure due to the low grade and small size of the deposits.

The best known prospects are north of Eagletown and in the vicinity of Watson. At the Johnson copper prospect near Eagletown, chalcopyrite, galena, sphalerite and pyrite, together with their oxidation products are found in a vein in shattered quartzitic sandstone and shale of the Stanley shale of Pennsylvanian age. The deposits were prospected in 1917. Near Watson, sphalerite and galena are found in brecciated zones in sandstone and a considerable production is reported to have come from this locality many years ago. A third locality in the Ouachita Mountains is about 5 miles northeast of Glover where sphalerite-bearing veins are found in the Cambrian Collier shale.

Reserves and Production from the Trinity River tributary area

Except for a few trial shipments there has been no production of either zinc or lead from the Trinity River tributary area in either Texas or Oklahoma, and no deposits are known to occur in the Texas part of the area. The known deposits in the Wichita and Ouachita Mountains in Oklahoma are too small and low-grade to be of much significance, and geological conditions are such that it does not appear likely that larger or richer deposits will be found in the future in these areas. The Arbuckle Mountain deposits appear to be somewhat more promising. They have never been successfully worked and are unlikely to be worked under present conditions but might be considered a reserve for the future. They have not been sufficiently developed to permit estimates of grade and tonnage.

The Miami-Picher field in northeastern Oklahoma, one of the most productive zinc and lead areas in the United States is just outside the Trinity River tributary area. A small amount of drilling has been done in Cherokee County within the Trinity River tributary area in an attempt to pick up a possible southward extension of the Miami-Picher field. The drilling to date has not demonstrated the extension and no reserves can be assigned to this part of the area. However, the area has been very incompletely prospected.

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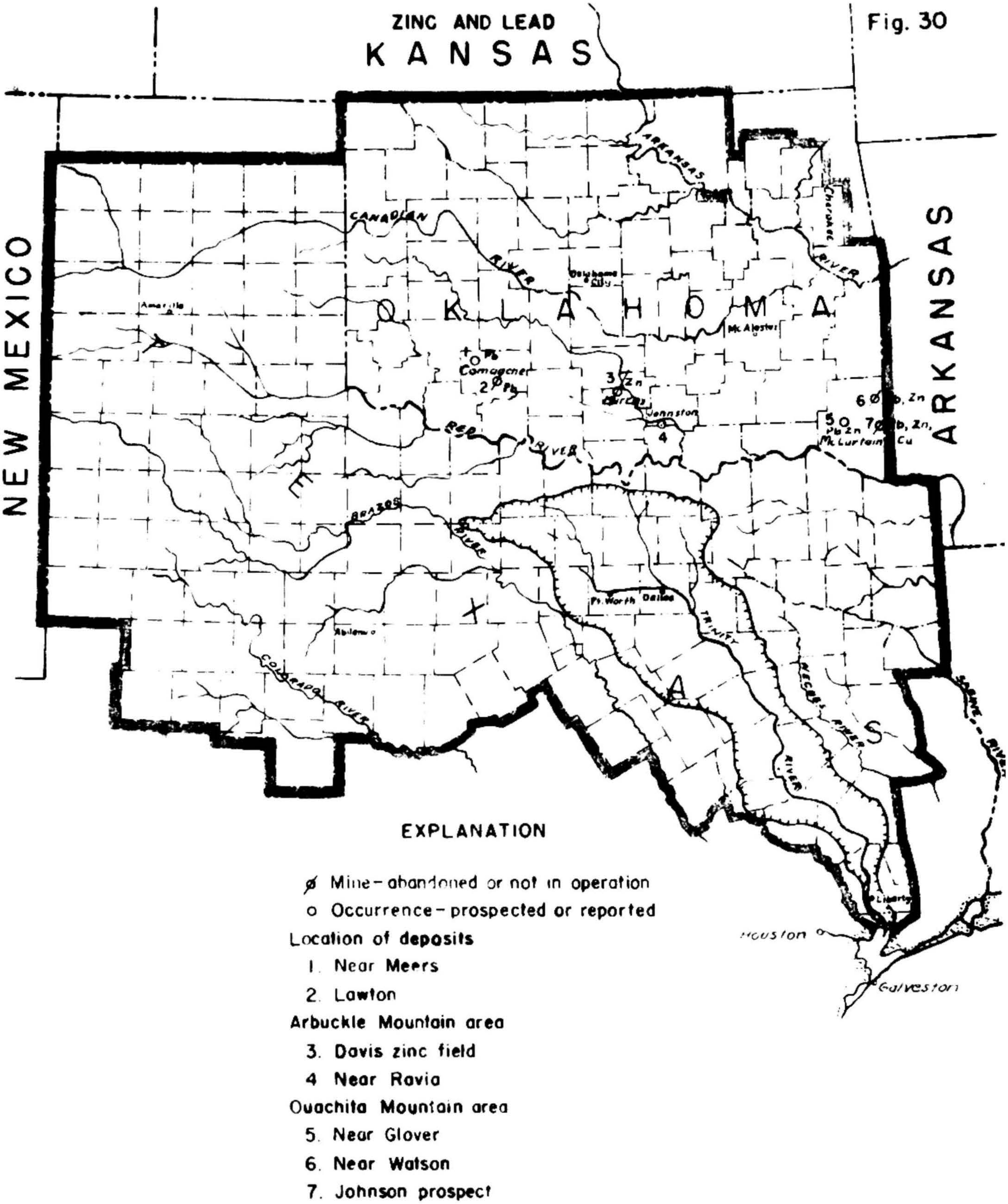
Fig. 30



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