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PRELIMINARY REPORT

ON THE

STRUCTURAL MATERIALS

OF

OKLAHOMA

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SCIENTIFIC STAFF

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INTRODUCTION

By Chas. N. Gould

The object of this report is to attempt to set forth in a brief manner our present knowledge of the most important structural materials in Oklahoma. The time has not yet come when anything resembling a complete report on the subject can be written. The State is yet too young, and altogether too little systematic work has been done, to attempt anything, but a preliminary discussion of the subject. Up to the present time, practically nothing has been written on building material in the State, not because material is lacking, but because accurate information on the subject has never been collected.

Waste of Timber

We Americans are a wasteful people. In no civilized nation, that the sun shines upon, is there such a prodigious waste of raw materials as in America. In nothing, has the wastefulness of our people been so potently shown as in the waste of timber. The United States originally possessed the most magnificent forests of hardwood in the world, but with ruthless hand we have destroyed them, until today our forests are practically exhausted. The United States Bureau of Forestry is authority for the statement that, at the present rate of consumption, the timber of America will last but a single generation. That is, in a little more than thirty years our timber will be exhausted. Unless the American farmer learns to plant trees, the people of this country will soon be without timber.

Heretofore, in America, the man, who has cut down and destroyed a beautiful tree, has been considered a public benefactor. Even yet, in many parts of the United States, great hardwood trees are every year deadened in order to make room for crops. In eastern Oklahoma today tens of thousands of great oak and hickory trees stand rotting in the fields, bleak monuments to the lack of thrift and to the unthoughtfulness of our people. At the present rate of consumption, and destruction, unless some method is devised to re-forest our land, our grandchildren will have no timber with which to build a house, and some other material will have to be substituted.

Conditions such as these, which are today actually confronting us, can but bring vividly to our minds the absolute necessity of applying some speedy remedy. Two remedies suggest themselves: first, the planting of timber, and second, the matter of substituting for timber some other cheap and durable building material. The object of this report is to discuss the second of these two remedies as they apply in Oklahoma. The discussion of the planting of timber, while of the utmost importance, must be deferred until some future date.

If our timber is practically gone, it is obvious that, some other form of building material must be substituted. There are at the present time four mineral products used extensively as structural material, namely: stone, clay products, gypsum and Portland cement. That all of these products are lying dormant in the hills of Oklahoma is shown in this report.

Stone

Since the beginning of historic time, stone has been utilized for building, and will always be used for certain kinds of structures. A stone building is handsome, lasts for ages, and, under ordinary conditions, is not easily destroyed by fire . There are, however, certain reasons, principally those of economy, which lead to the belief that for ordinary purposes stone will not be used in Oklahoma, at least for some time to come. Even in England and other countries of Europe, where civilization is much older than ours, many of the smaller buildings are still erected of wood, or of some material other than stone. In this report the location of the chief kinds of stone in the State are discussed and certain suggestions made regarding their utilization. Fortunately Oklahoma possesses inexhaustible deposits of the various kinds of building stone.

Clay Products

The same objection urged against stone may also be used against brick and other clay products. A brick house is much more expensive than a wooden one, but it is also more durable. The fact remains, however, that if other material can be secured, brick will never take the place of wood for the construction of a large class of buildings. Clay tile and terra cotta for decorative and ornamental purposes, and for roofing will doubtless be used more and more in Oklahoma as time goes on ,but the probabilities are that clay products will never become sufficiently cheap to be used for ordinary construction purposes.

It is not the intention in this report to discuss at great length, either the location of clays in Oklahoma or their adaptation to commercial uses. This subject falls within the province of a report, shortly to be published by Mr. L. C. Snider, Assistant Director of the Survey, who has written a chapter on clay for this report. Suffice it to say here, that Oklahoma possesses a very large amount of valuable clays and shales which are suitable for the manufacture of a very great variety of clay products. With this clay, there are very large deposits of coal, oil and gas; fuels that may well be utilized in the manufacture of the clay. However, these matters will be discussed at length in Mr. Snider's report.

Gypsum

Of all building materials, gypsum products may be manufactured most cheaply, and if it were not for the fact that up to the present time ordinary gypsum plaster or stucco has not been suitable for outside finish in a humid climate, this material would doubtless supercede most other building materials. Gypsum plaster and stucco have been used for hundreds of years in arid or semi-arid climates like Egypt, Mexico and southern California, but attempts to utilize this material in a region like Oklahoma, with a rainfall of 20 to 40 inches, have proved unsuccessful. Perhaps the best example of a building of this kind is the structure now standing in Jackson Park, Chicago, utilized for the Field Columbian Museum. It was the Fine Arts building at the Chicago World's fair in 1893. The outer construction is of staff, which is gypsum plaster mixed with excelsior or some other fibrous material. The building is now greatly dilapidated, and only by continual repair is it rendered at all habitable.

The American chemist who finally solves the problem of making gypsum plaster durable for an outside finish in a humid climate, without materially increasing its cost, will have solved the building problem of the future. Various preparations and combinations of the material, which are claimed to fulfill these conditions, are on the market, but so far none of them have proved entirely satisfactory. Either the cost is so high as to be prohibitive or the material will not stand the tests.

The subject of the location of the gypsum deposits in Oklahoma, and the proper utilization of the material, will not be discussed at great length in this report, for the reason that the writer is now collecting data for a separate report on the subject. This report should be written within the next few months and when finished a complete discussion of our present knowledge of the gypsum resources of the State will be available.

Portland Cement

If neither stone, clay, nor gypsum products are suitable for a large class of structural purposes, and if wood will soon be no longer available on account of its scarcity, some other building material must be sought. There are those who believe that this material has been found in Portland cement, which during the last few years has taken the place of practically all other materials in certain forms of structure. In the chapter in this report devoted to this subject, written by Mr. Nelson, the use of Portland cement and the location of the cement material in Oklahoma will be discussed.

Necessity for Development

One of the chief reasons for the publication of this report on structural materials at the present time is to attempt to point out to the people of Oklahoma the necessity of the development of the raw products of the State.

With deposits of all sorts of structural material, lying dormant in our hills, in quantities which for practical purposes are inexhaustible, Oklahoma is today utilizing very little. In the matter of building stone, Oklahoma has granite, gabbro, porphyry, basalt, limestone, marble and sandstone in quantities which can never be exhausted. Yet Oklahoma imports practically all the granite and other igneous rocks used for building and monumental purposes from eastern states or from Europe. In one cemetery we may find monuments of Scotch granite, Scandinavian granite, Vermont granite and Georgia granite, but rarely do we find monuments of Oklahoma granite. For all the stone imported into the State we pay the market price plus the freight.

Oklahoma has marble, equal to much of the best of the eastern marble, yet today very little of it has been utilized. Oklahoma has limestone for building purposes and for manufacturing into lime, equal to the best known, yet practically all our building stone is imported from Misouri and Indiana and our lime from Texas, Mis-imported from Missouri and Indiana and our lime from Texas, Mis-burned in Oklahoma. Oklahoma sandstone is equal to the best of the Ohio and Kentucky sandstone, yet little of it is being utilized except for local use.

There are, at the present time, twelve gypsum mills in Oklahoma, yet notwithstanding that fact, a considerable part of our stucco, wall plaster and other gypsum products come from either Kansas or Texas, although neither state contains as much gypsum nor as much fuel as does Oklahoma.

In the matter of Portland cement and concrete rock, conditions are somewhat different. There are now three Portland cement mills in the State, located at Dewey, Ada and Hartshorne, and others are in contemplation. Notwithstanding this fact, however, much of the Portland cement used in the construction of Oklahoma buildings comes from Kansas, Texas and adjoining states. Fortunately the greater part of the concrete rock used in the construction of buildings is derived from deposits near at hand. This material is chiefly crushed limestone or granite and coarse gravel.

Nor are our clays and shales being utilized. With deposits of as good brick and tile clay as may be found in any state, and fuels which are practically inexhaustible, including coal, oil and gas, Oklahoma is today manufacturing only a small part of the clay products used in the State. Each year, approximately a million dol-

lars is sent to Kansas to pay for brick. In northeastern Oklahoma there is a gas main passing from the Oklahoma gas fields into Kansas. For the use of this gas the people of Oklahoma get practically nothing. The gas is used to burn Kansas mud into brick and the brick are shipped into Oklahoma. For these brick the people of the State pay the market price in addition to the freight. Oklahoma clay is as good as Kansas clay, and Oklahoma has ten times as much fuel as Kansas ever will have, yet in the matter of brick we are constantly paying tribute to Kansas.

Oklahoma is manufacturing practically nothing in the way of sewer tile, drain tile, roofing tile, fire proofing, hollow ware, and terra cotta, although we have vast deposits of clay suitable for the manufacture of all of these products. Our money is going to Kansas, Missouri and Illinois to pay for the things which should be manufactured at home.

One of the chief objects of the Geological Survey is to locate these and other valuable materials in the State, and endeavor to assist in their development. The Director of the Survey stands willing at all times to assist individuals and companies in exploiting any legitimate resource of the State.

CHAPTER II

GEOLOGICAL HISTORY OF OKLAHOMA

By Chas. N. Gould

During geologic time that part of North America now included in the State of Oklahoma has been alternately submerged below the ocean and elevated above it many times. During the periods of submergence beneath the water, various kinds of deposits were laid down on the ocean bottom. When the country was raised above the water these deposits hardened and became solid rock. When the land stood out of the water for any length of time, the action of the elements rain, wind, water and frost, wore away the rocks and carried them through rivers into the ocean.

Geologic Time Scale

Geological time is divided by geologists into the following eras: Archean, Algonkian, Paleozoic, Mesozoic and Cenozoic. These eras are again subdivided into periods and the periods into minor subdivisions. The rocks deposited during a period of time for called a system, for example the rocks deposited in the Cambrian period make up the Cambrian system. In the following table, the systems and such minor subdivisions as are well represented in Oklahoma are shown. The oldest rocks are placed below:

Cenozoic	Quartenary	Pleistocene
	Tertiary	Miocene Pliocene
Mesozoic	Cretaceous	Upper Dakota Lower Comanche
	Jurassic	
	Triassic?	
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
Archean		

Rocks Exposed in the Arbuckle and Wichita Mountains

The oldest rocks in Oklahoma are the granites, presumably of Archean age, and are exposed in the Wichita and Arbuckle mountains. Granite is usually considered a part of the original crust of the earth, and granite or some form of igneous rock, underlies all the stratified rocks; that is to say, if a hole were drilled deep enough anywhere on the surface of the earth it would encounter the igneous rock. We may assume that all of Oklahoma is underlain with some form of igneous rock, probably granite, which, however, is now exposed in but a few places. About the middle of Cambrian times the sea surrounded the granite peaks and a deposit of sand derived from the granite was laid down along the shore line. This sand now appears as a ledge of coarse-bedded sandstone, known as the Reagan sandstone. Lying upon the granite, in the Wichita and Arbuckle Mountains, the sandstone is composed largely of coarse feldspar and quartz-fragments and is generally too coarse to make a good building stone.

The sea in which the Reagan was deposited, deepened, or the land surface was lowered so that the granite was entirely submerged. In this sea a great mass of limestone and dolomite was deposited, which so far as known is one of the thickest limestone formations in the world. This is known as the Arbuckle limestone. Its exact thickness is unknown, but is estimated by Mr. Taff, formerly of the United States Geological Survey, who has studied the formation, to be somewhere between 6,000 and 8,000 feet. Limestone of the same age as the Arbuckle, very similar to it in character and almost equal to it in thickness occurs in the Appalachian Mountains and in other parts of the country. These deposits are believed to be continuous although they are so deeply buried under younger formations as to make it impossible to trace any connections. If this is true, Oklahoma at the time of the deposition of the Arbuckle limestone, must have been a portion of a great sea which covered most of the United States. These conditions must have endured for an immense length of time, probably for hundreds of thousands or even millions of years, to permit the accumulation of such a great thickness of limestone and dolomite which, necessarily, is deposited very slowly. The Arbuckle limestone is usually hard and firm, and would under ordinary circumstances make a good building stone. It has been so extensively folded and crushed, however, that usually the bedding planes have been destroyed and the rock fractured in all directions. It is extremely difficult to find a locality where regular blocks may be secured.

Early in Ordovician time, after the deposition of the Arbuckle limestone conditions changed from that of a deep sea to a shallow sea, and a deposit consisting of shale, sandstone, and thin-bedded limestone was laid down. This formation, which is about 2,000 feet thick is known as the Simpson formation. So far as known there is very little good building stone in this formation, the limestone being too thin and the sandstone either too soft or too brittle. The sandstone of this formation is a very fine quality of glass sand.

About the middle of Ordovician time conditions again changed, this time from a shallow to a deep sea and another heavy ledge of limestone was deposited. This formation, known as the Viola limestone, is about 800 feet thick, and consists of heavy bedded white or blue limestone. This has not been quarried for building stone, because in most places it is too much broken, but doubtless localities can be found where good stone might be secured.

During the early part of the Silurian period the Sylvan shale was deposited. It is 100 to 200 feet thick and may be used for the manufacture of Portland cement or for various other clay products.

Above the Sylvan is a formation known as the Hunton limestone, which consists of three members, a limestone at the base, then a shale member, then another limestone at the top. The upper and middle portions of the Hunton are of Helderbergian or lower Devonian age . The entire thickness of this formation is usually less than 200 feet. The limestone members at the base and top frequently contain good building stone, but none has been quarried.

After the deposition of the Hunton limestone, the region was elevated above the ocean and erosion took place. In many places much of the upper part of the Hunton was carried away, and occasionally all of it has been removed. Then, in late Devonian time, the region again sank and there was laid down in still water a deposit of mud and silt, which, on hardening, became a hard, brittle shale, containing many concretions and bands of chert. The formation is known as the Woodford chert and contains no building stone.

Limestone was deposited locally on top of the Woodford chert. This limestone is known as the Sycamore limestone, and has been quarried for building stone at Dougherty. Above the Woodford and Sycamore are shales and sandstones of Carboniferous age, which will be described later.

The formations so far described are well exposed in the Arbuckle Mountains, in Murray, Johnston and Pontotoc counties. The Reagan, Arbuckle and Viola formations are exposed in the Wichita Mountains also, and the others are almost certainly present although deeply buried and not now exposed. The Arbuckle, Simpson, Viola, Sylvan, and Woodford all doubtless extend back from the mountains in all directions, and as already mentioned in the case of the Arbuckles, they are probably continuous with formations exposed in other regions.

After these rocks had been deposited there occurred one of those periods of emergence, which have occured at intervals throughout geologic time. The regions occupied by the Arbuckle

and Wichita Mountains were elevated in the form of two vast domes, each about 60 miles long and 20 miles wide. The amount of upheaval was probably about two miles above their present level. As soon as this uplift occurred and the rocks stood out of water, the agents of erosion, wind, rain, frost, and heat began to wear down the mountains. The upper rocks were first destroyed, and carried into the ocean. Afterward the rocks more deeply buried were attacked and carried away. In time all the sedimentary formations were worn away in places exposing the granite core of the mountains. This granite now stands out as high, jagged peaks in the Wichita Mountains, while in the Arbuckles it is exposed in the country around Tishomingo, and in the East and West Timbered Hills south and west of Davis. Surrounding the granite and flanked upon all sides of it are the various sedimentary formations mentioned above lying in regular order, beginning with the Reagan and ending with the Sycamore. In passing from the Washita River near Davis to the East Timbered Hills, a distance of four miles, one will walk over the uplifted cut-off edges of about two miles of sedimentary rocks.

Rocks Exposed in the Ozark Uplift

The regions heretofore described are in southern Oklahoma. In the northeastern part of the State, conditions were somewhat similar. In this region which is the southwestern extension of the Ozark Uplift, a number of formations, consisting of limestone, sandstone and shale, were laid down under varying conditions, either in the ocean or along the shore. The Yellville limestone and dolomite (not exposed in Oklahoma but near by in Arkansas) was deposited about the same time as the Arbuckle limestone.

The Burgen sandstone was laid down about the same time as the Simpson formation, the St. Clair marble about the same time as part of the Hunton limestone, while the Chatanooga shale corresponds in age to the Woodford chert.

The St. Clair marble is exposed in some deep hollows near Marble City, where it has been quarried for marble. The Burgen sandstone outcrops along the Illinois River a few miles north of Tahlequah and is a good quality of glass sand. Several shale members in this region might be used for the manufacture of brick, tile and pottery.

The most important formation in this part of the State, however, is a ledge of limestone and chert, some 300 feet thick, known as the Boone chert, which was deposited in Mississippian time. It is of about the same age as the Sycamore limestone in the Arbuckle Mountains. This is the formation in which the lead and zinc of the Joplin and Miami districts occur. The limestone quarried at Carthage, Missouri, comes from this formation also. The Boone formation is exposed on the surface in Ottawa, Delaware, Adair, Cherokee and Mayes counties, where it forms the surface of the upland plateau lying between Grand River and the Arkansas-Missouri line.

Above the Boone is a shale formation, the Fayetteville shale, and above the Fayetteville a limestone known as the Pitkin limestone. This limestone is hard and durable and would make a splendid building stone. The Fayetteville and Pitkin are both thought to be of Mississippian age.

After the deposition of the formations just described which occupy much of southern Missouri as well as northeastern Oklahoma and northern Arkansas, there occurred an upheaval, very similar to the one which brought up the Arbuckle and Wichita Mountains. The rocks were elevated in the form of an immense dome. Erosion immediately began its work on the uplift and in many places the Pitkin, Fayetteville and much of the Boone formation have been removed, while in some of the deeper valleys along the White River in Arkansas the older formations down to the Yellville limestone are exposed.

Pennsylvanian Rocks

All the depositions and upheavals heretofore described occurred in early geologic time, before the close of the middle Carboniferous or Pennsylvanian time. In the Arbuckle Mountains, the Sycamore limestone is probably of Carboniferous age and in the northeastern part of the State the Boone, Fayetteville and Pitkin are Mississippian in age. In the Ouachita Mountains the Jack Fork and Caney formations are Mississippian or Pennsylvanian.

About the time that these uplifts occurred, or possibly earlier, there was a great shallow basin or arm of the ocean occupying what is now east-central Oklahoma. This basin seems to have been connected with another arm which extended north through what is now central Oklahoma, Kansas and Nebraska. The basin must have extended far to the west, but we have no means of knowing just how far. The streams rising in the uplifted mountain regions just described, emptied their accumulated sediments into this basin so that in time there were laid down immense deposits of sand and mud. Great plants grew in the swamp-like basin and the vegetation accumulated in immense quantities. As time went on the mass of vegetation which was laid down in the basin became coal. The sand hardened into sandstone and the mud formed shale. These formations are more than five thousand feet in thickness and belong to the Pennsylvanian or Coal Measures age. The rocks of this age now occupy about one-third of the State and consist largely of alternate ledges of shale, sandstone and coal, although in the northern part of the State, farther from the mountain uplifts, there are a number of ledges of limestone. The shales are much more abundant than the other rocks, and occupy perhaps three-fourths of the thickness of all the formations. The quality of the shale is usually suitable for making brick, tile, and

sometimes pottery and Portland cement. Sandstone is the next most abundant rock and occurs alternately with the shale. The high hills, bluffs, and cliffs in this part of the State are formed largely by heavy ledges of sandstone. Some of these ledges are twenty to fifty feet thick. The sandstone is usually gray to brown in color, is regularly bedded and makes an excellent building stone. It is found in inexhaustible quantities in more than twenty counties in the eastern part of the State and has been quarried in hundreds of localities. There is not a town in eastern Oklahoma which does not contain buildings constructed of this brown sandstone. The coal in the region occurs in regular beds contained between ledges of sandstone and shale. There are in all more than twenty beds of coal in this region, of which about ten are known to be of workable thickness.

Among the Pennsylvanian rocks of northern Oklahoma there are a number of ledges of limestone which lie interbedded among the sandstones and shales. Great numbers of shells and other forms of marine life, preserved as fossils, make up the greater part of the limestone ledges . These ledges enter Oklahoma from Kansas and pass southward, usually bearing off a little to the west, about as far as the Arkansas River, where they usually thin out and finally disappear. Only a very brief description of the various ledges need be given here.

The lowest limestone of Pennsylvanian age enters Oklahoma a few miles west of Grand River in central Craig County, and passes southwestward near the towns of Centralia, Chelsea, Claremore and Catoosa and crosses the Arkansas River south of Broken Arrow. This formation was formerly known as the Fort Scott limestone, but is now called the Claremore. Above this formation shales occur and above the shales another ledge of limestone known as the Pawnee, which parallels the Claremore a few miles to the west, passing southward toward the Arkansas River. Then come other shales and a ledge of limestone known as the Altamont, which unites with the Pawnee at Oolagah and the two are known as the Oolagah limestone. Above is another thick bed of shales, which is succeeded by another limestone—the Lenapah, which passes from Kansas southwest through Nowata, Lenapah and Tulsa as far as North Canadian River. Other limestone ledges lying west of the Lenapah are known as the Hogshooter, Dewey, Avant and Piqua. Eastern Osage County is occupied largely by ledges of shale and sandstone and no other important limestone is found while passing westward until a point four miles west of the town of Pawhuska is reached where there is a very heavy limestone formation known as the Pawhuska formation, composed of three members which cap the hills of that region.

Western Osage County is occupied by the southern part of the Flint Hills of Kansas. The rocks consist of alternating layers of limestone and shales and sandstone all of which dip westward.

There are a number of ledges of limestone in western Osage and eastern Kay counties, the most important of which are the Wreford, Fort Riley, Winfield, and Herrington limestones. These formations cannot be traced farther south than Noble County.

Permian Rocks

Lying west of, and above the sandstone, shale and limestone of Pennsylvanian age, is a great series of red shales known as the Redbeds. This series of rocks, consist of unknown thicknesses of red clay shales, containing occasional ledges of some other material, usually gypsum, sandstone, or dolomite. These rocks occupy all the country from about the eastern line of old Oklahoma westward across the State, surrounding the Wichita Mountains, and extending across the Panhandle of Texas, as far as New Mexico. The Redbeds seem to have been deposited during a time of withdrawal of the sea and also of extremely arid climate. They contain very few fossils and their red color is apparent proof that little organic matter was buried with them. Very few ledges can be traced for any distance, so that the thickness of the Redbeds is not known. The extensive gypsum deposits in western Oklahoma belong to the Permian Redbeds.

After the rocks of the Pennsylvanian and Permian age had been deposited, all that part of America now occupied by Oklahoma was raised above the ocean and for a long period of time remained out of the water, in fact so far as we know, only the southeastern part and certain regions of western Oklahoma have again been submerged since Permian time.

Triassic or Jurassic Rocks

With the possible exception of a few unimportant formations of doubtful age which outcrop along the Cimarron River in the extreme northwestern part of Cimarron County, there are no rocks of either Triassic or Jurassic age in the State, which indicates that all of Oklahoma was a land area through those periods.

Cretaceous Rocks

During the Cretaceous period, that part of Oklahoma which lies south of the Arbuckle and Ouachita Mountains, all of eastern Texas, and southern Arkansas was submerged and a number of different formations were deposited.

The oldest Cretaceous formation in Oklahoma is known as the Trinity sandstone, which is composed largely of coarse sand and clay. The Trinity, which is from 400 to 600 feet thick, was probably deposited along the margin of a sea which at one time marked the southern base of the Arbuckle Mountains. This formation, as exposed on the surface, extends from near Ardmore to the Arkansas line and dips south passing beneath the next younger formations. After the deposition of the Trinity the water deepened and a limestone formation was deposited. It is about twenty-five feet thick, usually white in color and is known as the Goodland limestone. After the deposition of this limestone there was a shallowing of the sea and a series of mud and calcareous shell rock was deposited to a depth of thirty to fifty feet.

The sea again deepened and the Caddo limestone was deposited. This formation is about 150 feet thick and consists of clay, calcareous marls and white or yellow limestones. There was another shallowing of the sea and a series of clays and sand, with thin beds of limestone were laid down. This formation is known as the Bokchito and is about 150 feet thick. The sea again deepened and the Bennington limestone 80 to 100 feet thick was laid down. The Cretaceous limestone is fairly good for building, although in some cases it is rather soft.

Above the upper limestone members there was laid down a deposit of sand and clay. This sandstone is known as the Silo sandstone. It is usually black or dark brown in color and has been used for building stone.

At the time that southeastern Oklahoma was covered by a Cretaceous sea, there seems to have been an embayment of another sea extending from Kansas and Colorado south across the western part of the State. In a number of the western counties there are deposits of shell rock containing fossils of Cretaceous age lying on the unevenly-eroded surface of the Redbeds. These were probably laid down at about the same time as the Goodland or Caddo limestone of southern Oklahoma. There is no means of determining just how far this sea extended but deposits have been found in Woods, Harper, Woodward, Dewey, Custer, Roger Mills and Washita counties.

In the extreme northwestern part of Oklahoma along the valley of the Cimarron River there are rocks of Cretaceous age also. These consist largely of sandstone and shales, the upper members being the Dakota sandstone of the same age as the Silo. This formation is found very abundantly in Kansas, Nebraska, and other states in the northern part of the Great Plains.

Tertiary Rocks

During late Cretaceous times Oklahoma stood out of the water and so far as we are able to learn it has remained a part of the unsubmerged continent ever since. During Tertiary times, however, the Rocky Mountains, which were then much higher than at the present time, were being eroded and washed away, and the material derived from them, consisting of sand, clay and gravel, was carried by streams and spread out on the western part of what is now the Great Plains. Much of western Dakota, Nebraska, Kansas and Oklahoma, northern Texas and eastern New Mexico, Colorado, Wyoming and Montana contain deposits of Tertiary age derived from the waste of the Rocky Mountains. In Oklahoma Tertiary deposits occur in the three western counties, Cimarron, Texas, and Beaver, and in a number of other counties in the western part of the State. There is very little building stone of any importance on the High Plains.

CHAPTER III

QUALIFICATIONS OF STONE

By Chas. N. Gould

In the selection of a stone for building purposes, four general qualifications should be considered: first, cost; second, inherent quality of the stone; third, color; and fourth, possibilities of decay.

Cost

The cost of the stone depends upon a number of conditions, of which the most important are the ease or difficulty with which the stone may be quarried, and the distance which it must be transported.

Other things being equal, sandstone and limestone, which are regularly bedded, and break with an even fracture, are easily quarried. Granite, which is an extremely hard stone, not bedded, and which breaks with an uneven fracture, is difficult to quarry, and for that reason is expensive. The general characteristics of the various building stones found in Oklahoma will be discussed at length later in this report.

The matter of transportation is always vital. Stone is both heavy and bulky, and in case the material has to be carried for any considerable distance, freight rates are usually prohibitive. In case there are no quarries near at hand containing suitable stone, municipal, county and state authorities are often obliged to transport stone for long distances. As a typical example of this fact may be cited the case of Oklahoma County, which a few years ago sent approximately $100,000.00 to Bedford, Indiana, to pay for stone used in the construction of the court house. The price paid for this stone was approximately 90 cents per cubic foot. There is scarcely a building of any size in the State that does not contain stone from the Bedford quarries. or from Carthage, Missouri. Other stone comes from Silverdale, Kansas, or from Honey Grove, Texas. These instances seem to indicate that the high cost of transportation is not always effective in preventing the use of stone.

In additon to the expense of quarrying and the cost of transportation, there must also be taken into consideration, the question of dressing the stone. Granite and gabbro, which are very hard and tenacious rocks, are worked with difficulty, while limestone, marble and sandstone are usually more easily dressed. For this reason a granite building will cost much more than one constructed of marble, limestone or sandstone. There are but few buildings in Oklahoma constructed entirely of granite, the most conspicuous examples being the old Chickasaw Capitol and the bank building at Tishomingo. Many public buildings in the State, such as banks, school houses and court houses, have columns, sills and capstones of granite, and in a few cases doors, walls and certain interior decorations have been made of this stone, but in general a relatively small amount of granite has been used. There are in the State hundreds of buildings constructed of either sandstone or limestone. This fact of itself, would indicate that the cost of granite construction is greater than that of other stone.

Inherent Qualities of Stone

All stone possesses certain inherent qualities which render it desirable or undesirable for certain uses. Of these inherent qualities the one most universally in demand in building stone is known as durability. This may be defined as the capacity which a stone possesses to withstand the forces tending to mar or destroy it. The durability of stone depends largely upon four general qualities: first, mineralogical composition; second, hardness; third, strength; and fourth, texture.

Mineralogical Composition: All rocks are composed of certain definite chemical substances known as minerals. These minerals are often found in the form of crystals: for instance, quartz is a very hard mineral having usually a definite crystal shape; calcite is a mineral which resembles quartz superficially, but is very much softer and has a different crystal form. Quartz is not easily acted upon by water, but the crystals may be broken by pressure to form sand grains, and these sand grains, when cemented together, form sandstone. Calcite, on the other hand, is readily acted upon by water containing certain acids, and is thus readily dissolved. It may be redeposited under certain conditions to form limestone.

In discussing the mineralogical composition of rocks two chief classes, igneous and sedimentary rocks, will be considered. Igneous rocks are those which have been formed within the earth and are composed usually of certain definite minerals in their original crystal form. Some typical igneous rocks are granite, basalt, gabbro, porphyry and diorite. Sedimentary rocks are those which have been deposited as sediments, usually in some prehistoric ocean, and may be divided into three general classes, limestone, sandstone and clay. Of each of these there are many divisions and sub-divisions.

Among the chief igneous rocks which may be used for building stone in Oklahoma are granite, gabbro, diorite and porphyry. Of these, granite and gabbro are the most readily accessible.

Granite is a composite rock made up of crystals of three different minerals: quartz, feldspar and either hornblende or mica. These minerals usually give to the rock a speckled or mottled ap-

pearance, the color of the rock depending upon the color of the minerals composing it. A great part of the granite in Oklahoma is reddish or mottled in color. In the Wichita Mountains, which are composed almost entirely of granite, the prevailing color of the rocks is dark red, although gray and pink granites are found. In the Tishomingo region, in the south central part of the State, the granite is composed principally of rather large crystals of quartz and feldspar. The prevailing color there is a reddish-gray or pink.

In the disintegration of granite, feldspar is broken more rapidly than quartz. In fact, quartz is acted upon by water so very slowly, that it may be said never to disintegrate. Feldspar, however, breaks up by the long-continued action of water containing certain acids, and the residue goes to form clay. The disintegration of granite is an extremely slow process, so that for practical purposes it may be said that granite is indestructible. A granite building will stand for ages and scarcely show the effect of the action of the elements.

Gabbro is acted upon by water somewhat more rapidly than granite, but for all practical purposes it may also be said to be indestructible. While, so far as known, there are no accurate data on the subject, the statement may be made that gabbro will last for many centuries without the action of water being apparent.

Generally speaking, the sedimentary rocks are much less durable than the igneous rocks. This is largely due to the fact that the igneous rocks still contain their original crystal composition, while in the sedimentaries the crystals have been broken up and the constituent parts are held together by some form of cement.

The sedimentary rocks of Oklahoma consist largely of clay, sandstone and limestone. Clay is composed of extremely fine particles of decomposed rock material, chiefly silica, or broken up quartz grains, and alumina, which is derived originally from feldspar and other igneous rocks. Under certain conditions of stratification, clay is known as shale. The chief distinction between the two kinds of rocks is that shale is composed of layers, or in other words is distinctly stratified, so that it may be readily split, while clay is typically a homogeneous, unstratified mass of soft rock. The chemical composition of clay and shale is the same and the two may be used indiscriminately in the manufacture of Portland cement and of most clay products.

Sandstone is composed typically of grains of quartz which have been broken up and ground smooth by the action of water, held together by some form of cement. The important factor of a sandstone is not the character of the grains, but the character of the cement. The most important of the cementing materials are silica, calcium carbonate or lime, and iron oxide. Of these, silica is perhaps the most important. That is to say, a sandstone cemented with silica is harder, more durable, and therefore more valuable than a stone cemented with either of the other materials. Calcium carbonate, or lime, may, or may not be a valuable cementing material. Under certain conditions it forms a good cement, holds the sand grains in close union, and makes a valuable stone. Under other conditions, however, it is easily acted upon by certain acidulated waters and is less valuable. A sandstone cemented with iron is usually less valuable than the others, because of the fact that iron oxide is red in color and likely to stain the building, the red color being considered objectionable.

Limestone is composed of calcium carbonate or calcite. The greater part of the limestone contains fossils, usually shells or bones of prehistoric animals that lived at the time the limestone was deposited. It is believed that the greater part of the limestone of the world was originally made up largely of fossil shells. In many cases, the fossils have been entirely obliterated since the rocks have formed, so that no trace of them remains. On the other hand, there are certain limestones which consist entirely of fossil shells, loosely cemented together.

There are a great many varieties of both sandstone and limestone. Coarse sandstone composed of quartz grains or grains of granite, is known as arkose. A rock composed of rounded pebbles, which may, or may not be quartz, is known as conglomerate or pudding stone. If the pebbles are angular, that is, if they have never been ground smooth, the rock is called breccia. A very fine grained sandstone, used for razor hones, is known as novaculite.

Of the limestones there are also many varieties. Some are named from the character of the fossil composing them. Crinoidal limestone is composed of crinoids, coral limestone of corals, and shell limestone of shells. Oolite is a limestone composed of small concretions or spherules, usually not larger than a pin head. Travertine is a form of limestone usually deposited by streams that carry large amounts of calcium carbonate in the water.

There are all sorts of gradations between the various kinds of sedimentary rocks, for instance, shaly limestone, or sandstone, sandy shale or calcareous sandstone. Practically all of the varieties of limestone and sandstone mentioned above as well as many others, are found in various parts of Oklahoma.

Hardness: The hardness of a rock is the resultant of a number of factors, of which the most important are the hardness of the minerals composing it, the character of the cementing material, and the size of the component parts. A rock may consist wholly of quartz grains, the hardest of common minerals, and yet, on account of the small amount of cementing material, it may be so soft as to crumble between the fingers. A good example of a rock of this kind is the glass sand found in the Simpson formation in the Arbuckle Mountains of Oklahoma. This rock is composed of almost pure silica, but under a sharp blow of a hammer a piece of the stone breaks down into a pile of white sand grains. Such a stone is known as saccharoidal sandstone. Other parts of the same

ledge are cemented with silica, and the rock is so hard that it can scarcely be broken with a hammer. The difference in hardness is due entirely to the abundance and character of the cementing material.

The hardest rocks in Oklahoma are the granites and gabbros, which, as stated above, are igneous rocks. The softest rocks, found in many localities, are the clays and shales. Between these two extremes lie the sandstones and limestones. Some sandstone is extremely hard, and some very soft, and so with limestone. Certain ledges are so hard that the rock is difficult to work, while other ledges are so soft that the stone is not suitable for building purposes.

Strength: Strength is a very important consideration in the selection of a stone. By strength, we mean the capacity which a stone has to withstand stress or pressure applied at the surface. Many conditions enter into the nature of the strength of a stone, the chief of which are the mineralogical composition, the amount and character of the cementing material, the size of the grains, and the presence or absence of cleavage or bedding planes. The average strength of igneous rocks is greater than that of sedimentary rocks. A rock saturated with water is not as strong as one that is dry. If a rock has been shattered by blasting or by any other cause, the strength will be impared.

Texture: In selecting a building stone, texture is an important factor, not only in the matter of durability, but also with regard to color and general appearance. Uniformity in size, color and the matter of the composition of the constituent parts should be carefully noted. Many rocks, particularly limestone and sandstone, are not uniform throughout, but contain various-colored impurities, such as pyrite, marcasite and grains of quartz or calcite, of unusual size or color. All rocks also contain pore spaces, or openings which admit the air and water. In many cases lines of lamination or bedding planes are prominent, which will, within a few years, wear into conspicuous deformities in the stone. The soft constituents will decompose first, leaving noticeable depressions in the surface of the rock. In certain limestones in Oklahoma there are concretions of flint. It so happens that limestone weathers rapidly, while flint disintegrates very slowly if at all, so that in a building constructed of this material the surface of the limestone will wear away leaving the concretions of flint projecting.

All of these irregularities should be avoided. Only a stone which is uniform in texture should be used for building purposes. Both the durability and beauty of the building depends upon the uniformity of the texture.

Color

From an artistic standpoint, no property of stone is more important than color, and one of the great difficulties in constructing handsome buildings is to obtain stone which is perfectly uniform in color. Stone varies widely in shade and tint, even in the same quarry. Iron is the great coloring matter of the rocks, the greater part of the blacks, browns, reds and yellows and intermediate tints, being due to the presence of certain compounds of iron. In general, a stone which contains little or no iron will be white but a very small percentage of the mineral will color the rock, and in case it is unevenly distributed throughout the stone the color effect is bad. In many cases, the color of a rock, when freshly quarried, may be almost perfectly white, but after a few months exposure the color may change to a cream color, buff, or light brown, or the stone may be mottled or streaked with irregular patches. This is due largely to oxidation of the iron.

Color, rather than strength and durability, is often the most important factor in determining whether or not a stone shall be used for a particular building. Generally speaking, white or brown stone, either limestone, marble or sandstone of a uniform color is desirable. Some years ago brown stone was in great demand. At the present time white or light-colored stone has the preference. No one can tell, however, how soon the fashion will change again and red or brown stone will become the prevailing color.

Other things being equal, it is perhaps not good policy to construct a building of white limestone or marble in the business portion of a large city, for the reason that a building of this kind soon loses its original color and becomes gray and dingy from the smoke and dirt that fill the air. Suburban residences and those in rural districts are less readily affected by smoke and dust. Generally speaking, the chief things to be considered in selecting stone for a building in a large city, are strength and durability rather than color.

The various building stones of Oklahoma are variously colored. For instance, the sandstone of the western part of Oklahoma is a deep brick-red as may be seen in many business blocks in cities in the western counties. The sandstone of eastern Oklahoma is gray or light brown. The northern Oklahoma limestone such as is used in buildings in Newkirk, is a light gray or cream color. The stone from the newly-opened quarry at Bromide is nearly pure white, while the marble from Marble City is white or light gray. The granite from the Wichita Mountains is mostly red or black, and that from the Arbuckle Mountains is chiefly pink or light gray.

Possibilities of Decay

It is a matter of very great importance in the selection of stone, particularly for outside work, that the climatic conditions be kept well in mind. A stone which will last for centuries in a favorable climate will decay and go to pieces in a generation in an unfavorable one. The ideal climate for the preservation of stone is one that never falls below freezing, and which contains a relatively

small amount of moisture. In order for a stone to withstand alternate freezing and thawing in a moist climate, like ours, it must be of the most durable kind. A classic example of the decay of stone due to the effect of climatic change is that of the granite obelisk, known as Cleopatra's needle, now standing in Central Park, New York City. This monument had remained in Egypt from the time of the Romans until it was removed to New York in 1883. Since that time it has been disintegrating so rapidly that the greater part of the hieroglyphics engraved upon it have been almost obliterated. In order to preserve the stone it has been found necessary to cover the obelisk with a preparation of paraffin and creosote.

There are a number of factors which must always be considered in discussing the forces tending to bring about the decay of stone, but only the most important need be considered here, namely, temperature changes, abrasion, growing organisms and water. These will be discussed very briefly.

Temperature Changes: A stone may be injured by changing temperature in either one of two ways. First, by the expansion and contraction of the rock itself induced by the heating of the particles, and second, by expansion and contraction due to freezing and thawing of the water contained in the pores of the rock.

Heat expands and cold contracts. It is well known that, particularly in dry climates, a stone may be heated during the day time to a temperature of more than 100 degrees Fahrenheit, while at night the temperature may be below freezing, or in the winter time many degrees below zero. This change of temperature is sufficient to expand and contract the different particles of which the rock is composed. While the actual amount that any particular crystal will expand or contract is extremely small, the aggregate is considerable, and, although the amount is so small that it can scarcely be measured, it readily becomes effective when distributed throughout rock masses. Experiments have shown that the actual expansion in different kinds of stone is approximately as follows:

Granite	.000004825 in. per foot for each degree F.
Marble	.000005668 in. per foot for each degree F.
Sandstone	.000009532 in. per foot for each degree F.

The annual range of temperature in many localities is as much as 150 degrees F. and it is readily computed that, according to the amount of expansion produced in granite, this range would make a difference of a little more than one inch in a block of granite 100 feet in length.

Another point must be taken into consideration, namely, that most rocks are composite in their nature. That is, they are made up of a number of different kinds of minerals. Granite for instance, is composed of quartz, feldspar, and either mica or hornblende. Now it so happens that the co-efficient of expansion of these three minerals is different. In other words one will expand more than another, at the same temperature . So it happens that when a piece of granite is heated all the parts do not expand alike. This has a tendency to break up the rock mass into its constituent crystals.

Not only are rocks broken by the alternate heating and cooling of the rock masses themselves, but water greatly aids in this work. Water is almost universally present in the rocks. Even the most dense of the shales or granites contain very minute pores through which the water percolates. Many rocks also contain joints and crevices varying in thickness from a very small fraction of an inch to several inches, through which the water enters. Now it is well known that water expands on freezing so it will be readily understood that if a rock contains water, either in pores or in crevices, and this water freezes, it will exert a double influence on the rock, and if the freezing and thawing be repeated often enough will eventually fracture it. There is little doubt that this class of expansion and contraction is in most cases much more effective in rock disintegration, than that produced by heat alone, without the aid of water.

Abrasion: Mechanical abrasion is a very important factor in rock disintegration. It is accomplished mainly by wind and water taken together with other agents of abrasion. While it is true that neither wind or water taken alone have any great abrasive effect on the rock, it must be remembered that both wind and water when moving rapidly carry tools, usually sand and small pebbles. A stream of water flowing down a hill soon picks up small particles of rock, which are carried along, and these particles aid the stream in cutting away a bank. So the winds as they cross the land, pick up the sand grains and small pebbles, and hurl them with considerable force against objects with which they come in contact. In a number of places in Oklahoma glass in windows on the south side of houses along the north bank of streams have been etched by the sand. Monuments in many of our cemeteries, particularly those constructed of marble, are already beginning to show the effect of the wind-blown sand. In many cases the lettering has already become indistinct, and the polish has been dulled.

Growing Organisms: A factor of considerable importance in rock disintegration is found in small organisms which are often found attached to rocks. Of these lichens, algae and mosses are particularly important. These low forms of plant life have the ability to exist by clinging to the surface and taking up the moisture. This softens the rock, making it an easy prey to other agents of erosion. In soft limestone or shales the tiny rootlets often penetrate the rock mass itself. The organic acids given off by decaying plants aid in the decomposition of the rock.

Water: Perfectly pure water has very little chemical effect on rocks, but water is rarely very pure. It usually contains diluted solutions of various acids. Even rain water as it falls from the clouds absorbs certain gases, chiefly carbon dioxide and sulphurous acid, in passing through the air.

As the water carrying acids percolates through the rocks it dissolves considerable quantities of mineral matter, and that aids in the dissolution of the rocks. In some cases rocks are acted upon very slowly by percolating water, while other rocks like limestone and calcareous shales are worn away comparatively rapidly.

CHAPTER IV

GRANITE OF OKLAHOMA

By Chas. H. Taylor

Introduction

It is not the intention to present in this chapter an exhaustive discussion of the geologic and petrographic relations of the igneous rocks of Oklahoma.

Only a small area in the western part of the Wichita Mountains has been studied in detail, therefore the relations of the different rocks in this area to those of the remainder of the mountains cannot be stated with certainty. The writer is preparing a more detailed report of the igneous rocks of the Wichita Mountains, which will be published soon.

All the articles relating to the igneous rocks of Oklahoma have been freely drawn upon. Professional paper No. 31 of the U. S. Geological Survey has been especially useful in the description of the areas not visited by the writer. G. W. Kneisley's unpublished manuscript has also been freely consulted. Credit is given in the text wherever it is due.

General Discussions of Granite

For convenience in discussion, we will consider under this head several varieties of igneous rocks popularly known as granite, but according to scientific classification not true granite.

Definition: In the popular sense a granite is any igneous rock with granular texture, i. e., one which is made up of minerals, the individuals of which can be made out with the eye or with the aid of a hand lens. According to generally accepted scientific classifications a granite is a granular igneous rock composed chiefly of orthoclase feldspar and quartz, with hornblende or mica, or with both hornblende and mica. There are also often present other minerals, generally of minor importance in classifying granites, but, as we shall see later, some of these may be of importance when the granite is considered from an economic standpoint.

Mineral Composition: The feldspars are by far the most abundant group of minerals found in the igneous rocks in Oklahoma. For convenience the group is separated into two divisions known as the orthoclase feldspars, and the plagioclase feldspars. The orthoclase

feldspars are orthoclase and microcline; both are potassium silicates, but differ somewhat in physical properties. The plagioclase feldspars are aluminium silicates with sodium or calcium or both. Beginning with those containing most sodium and ending with those containing most calcium they are, albite, oligoclase, andesite, laboradorite, bytownite and anorthite. The orthoclase feldspars are found in relatively short thick crystals having two good cleavages at right angles to each other. The cleavage faces may be recognized even in a rather fine-grained rock by the plane, shiny surfaces presented. They are as hard as ordinary steel, have a specific gravity of about 2.60, are usually gray or pink, often white, and rarely blue. The plagioclase feldspars are often striated, that is, traversed by fine lines or grooves, and are white to dark bluish gray in color.

Quartz, silicon dioxide, is the second most abundant mineral in igneous rocks. It appears in irregular or rounded grains, filling the spaces between the feldspars, and has no cleavage, but has a distinct conchoidal fracture, that is, breaks like glass with concave or convex surfaces. Quartz has a hardness greater than good steel or glass, a specific gravity of 2.63, and is usually colorless or gray, rarely pink or blue.

The hornblendes, a group of complex silicates, include several varieties which usually can not be distinguished from each other without the polarizing microscope, when in igneous rocks. They occur in prismatic crystals or irregular grains. The crystals are usually rather thick, but may be long and slender. The hornblendes have two good cleavages making angles of 124 degrees and 56 degrees to each other, they are a little harder than steel, and brittle, have a specific gravity of about 3.25, and are black, greenish black, or green.

Mica, which is perhaps next in abundance in the igneous rocks of Oklahoma, is a complex aluminum silicate with magnesium or potassium, and more or less iron, lithium, fluorine and hydrogen. In igneous rocks we usually recognize only two varieties. All dark colored micas are called biotite and all light colored ones are called muscovite. The dark color is usually due to the presence of iron. The micas are found in flakes or tabular masses, which have a perfect cleavage. Thin elastic flakes may be easily split off. Mica can be scratched with a knife, has a specific gravity of 2.80 to 3.00 and ranges in color from white in muscovite to black in biotite, with intermediate shades of brown and green.

The pyroxenes are another group of complex silicates found in igneous rocks. They are much like the hornblendes except that the two good cleavages make angles of nearly 90 degrees to each other. Unless this cleavage can be observed they cannot be distinguished from the hornblendes, except under the polarizing microscope. It is now customary to designate different varieties of granite by the minerals of the last named groups, which are present; for instance, a granular rock containing orthoclase feldspar, quartz and biotite would be called a biotite granite. If it contained both hornblende and biotite it would be called a hornblende-biotite granite. The granite at Cold Springs is a hornblende-biotite granite. The one quarried at Tishomingo is a biotite granite.

Besides the foregoing minerals, which are usually chief in all common igneous rocks, we find a number of minerals generally classed as accessory to igneous rocks. Of the original minerals of igneous rocks which may be classed as accessory we should notice pyrite, magnetite and hematite. Pyrite is a brass-yellow, hard, brittle mineral, with high specific gravity. It is usually found in round or irregular grains in the igneous rocks of Oklahoma. Magnetite is found in rounded and irregular grains, has a specific gravity of 5.18, is nearly as hard as steel, brittle, and iron black in color. Hematite, as found in Oklahoma rocks, is always in very fine red or brown dust included in other minerals, usually the feldspars.

Chemical Composition: Very few analyses of igneous rocks from Oklahoma have been made. For this reason the chemical composition of igneous rocks will not be dwelt upon, except to state that the chemical composition generally runs much the same for rocks of the same mineral composition and any properties governed by chemical composition will usually be suggested by the mineral composition.

Texture: Texture relates to the size, form and arrangement of the mineral grains or crystals. It is one of the most important factors to consider in selecting building or ornamental stone, for the strength, durability, and beauty of the stone are largely dependent on the texture. Equi-granular rocks are those in which the mineral grains are of equal size. If some mineral grains are distinctly larger than all the rest the rock is said to be porphyritic. The larger crystals or grains are called the phenocrysts and the remainder is called the groundmass. The grain, that is, the size of the mineral grains, is a very important factor in the texture of building stone. It is customary to consider a rock coarse-grained if the average diameter of the mineral grains is above 1 centimeter or 0.40 inch. In medium-grained rocks the average diameter of the minerals ranges from 0.50 centimeter to 1 centimeter, or 0.20 to 0.40 inch. If the mineral grains are less than 0.50 centimeter or 0.20 inch the rock is called fine-grained. These terms will be used in this sense in this paper. Often long, slender crystals of feldspar penetrate other minerals, somewhat resembling nails driven into a board. Such texture is called ophitic. Many of the dark-colored, fine-grained rocks have an ophitic texture.

Physical Properties: The mineral composition and the texture of the rock are the largest factors in determining the physical properties. The importance of some of the physical properties will be noted, but not enough data has been secured to discuss all of these with reference to Oklahoma granite. The physical properties

which should be noted are: porosity, expansion, elasticity, cohesion, flexibility, weight, hardness and color.

The porosity is the space between the minerals, (occupied by water or air) computed in percentage of the whole volume of the rock. The porosity of granites is always small, seldom attaining 0.8 per cent.

Minerals in rocks expand when the temperature is raised and contract when the temperature is lowered. This change in volume is not enough in the rock to be a detriment to a building as a whole, but in regions of sudden changes in temperature the differential changes in volume disintegrate the rocks, as explained under weathering.

Cohesion is the resistance to fracture or crushing. A measure of the cohesion is usually termed the crushing strength. The crushing strength of granites, the rock being supported beneath its entire base, ranges from about 10,000 to 44,000 pounds per square inch.

Even the lower figure just given, is far in excess of that required by any building yet constructed. Of far more importance is what may be termed the transverse crushing strength. This is the pressure a rock will sustain in the middle when supported at the ends. No experiments have yet been made in this line on Oklahoma granites ,though they might be used as a valuable criterion for judging the value of a stone.

Flexibility is the resistance to fracture under displacement of form. A quick hard blow will break a piece of quartz more readily than a piece of feldspar, that is, the quartz is more brittle than the feldspar. Mica is still less brittle. The brittleness of a stone is largely determined by the texture and the kind of minerals composing it. Some rocks with slender, interlocking crystals are much more flexible than those without this texture. Some of the gray granites of the western part of the Wichita Mountains have an ophitic texture and this aids in making them tough or flexible. The red coarse-grained granite from Granite is one of the most brittle rocks found in the State, chiefly because the mineral grains are equi-dimensional and therefore cannot interlock. The abundance of quartz would also make this granite brittle.

The hardness of a rock will be determined by the hardness of the constituent minerals. Any of the granites of Oklahoma are hard enough for building stone or ordinary road material. Fresh granite when used as road material, will break up into small fragments, because of its brittleness, rather than wear out.

The weight of a stone is usually compared with the weight of an equal volume of water and the ratio is termed the specific gravity. Granites range from 2.60 to 2.77 in specific gravity, which means that granite is 2.60 to 2.77 times as heavy as pure water. It is an easy matter to determine, approximately, the specific gravity of a stone. Weigh any small piece, then suspend it in water and weigh it again. The difference will be the loss. Divide the original or weight in air by this loss, the quotient is the specific gravity. If the weight per cubic foot is desired, multiply the specific gravity the weight of a cubic foot of the stone. The weight of a stone is important to know in estimating shipping weight and strength of structures. Oklahoma granites range from 2.63 to 2.77 specific gravity. A few varieties of rock, not true granites, have a higher specific gravity.

Common colors in granite are light to dark gray, pinks and various shades of red. So far no granites in the lighter shades of gray have been found in quantity, in Oklahoma. Medium grays, dark grays, pinks and several varieties of red are plentiful. The color is important and often significant of the lasting properties of a granite. The color of the feldspar often determines the color of the granite. Biotite, hornblende and magnetite usually are responsible for the dark shades. The "Black Granite" at Cold Springs is dark colored because of the presence of the last named minerals. The granite of Granite City is red because of the presence of finely divided red hematite in the feldspar. The brilliant red granite from Mountain Park gets its color from the red hematite in spaces between the crystals and in the cracks in the crystals. Since some of these minerals, which determine the color of a stone alter readily under the influence of the weathering agencies, one can often predict the change that will take place when the rock is exposed to the atmosphere.

Varieties of Granite: Since the texture and mineral composition are the chief factors in determining the qualities of a rock these two characteristics form a convenient basis of classification of rocks. Since according to common usage all the granites contain quartz and feldspar a descriptive classification of granites need contain the names of only the non-essential minerals. If a granite contains mica, hornblende, or pyroxene it may be called a mica, hornblende or pyroxene granite, or any combination of the above terms. If we care to specify farther the kind of mica, hornblende or pyroxene we may introduce the varietal name e. g., biotite-augite granite. If we wish also to state the texture in the name, we may say it is an even-grained, biotite-hornblende granite. The size of grain as explained above should also be stated. Thus the Cold Springs granite is a fine-grained, biotite-hornblende granite. The Tishomingo granite is a slightly porphyritic, coarse-grained, biotite granite.

As all of the igneous rocks found in Oklahoma are not true granite it is thought best to introduce at this point a brief definition of those of this class, which we need to note in studying the granite of the state. Of these the chief varieties are diorite, gabbro and rhyolite.

A diorite is a granular igneous rock, composed of plagioclase feldspar, hornblende and often some mica. If some quartz is present it is then known as a quartz diorite. If the feldspar is about half plagioclase and half orthoclase it is a monzonite. A gabbro is

labradorite) and pyroxene or mica. If the rock is almost entirely of feldspar it is known as anorthosite. A rhyolite is a rock having the same minerals present as granite, but it is very fine grained or some of it may be glass. Rhyolites are often porphyritic.

Structure: Structure relates to the large features of the rock, such as joints, rift, and grain. Joints are the fractures or cracks in the rock, which divide it into blocks. The joints are usually open near the surface, but are closed when a depth of a few feet is reached. Joints may be vertical, horizontal, or inclined. There may be two sets at right angles to each other, or a greater number at various angles. If joints are properly spaced so that the rock comes out into suitable-sized blocks they serve a useful purpose, but they may be so spaced as to destroy the rock for building purposes. If no joints are present quarrying is much more difficult. Horizontal or slightly inclined joints are often called sheet joints. Sheet joints often run approximately parallel to the slopes of the hill. Such is the case at Mountain Park and at some of the hills at Granite.

Rift and grain are terms often used by quarrymen to denote a tendency of the rocks to split in a rather constant direction. They are generally supposed to be due to a system of microscopic, parallel fractures causing foliation. The cracks pass through some minerals and around others, or pass through all indiscriminately. The rift is sometimes parallel to sheet joints, but often crosses them. The grain is at right angles to the rift and is due to the same cause, but is not so noticeable.

Quarrymen take advantage of the rift and grain, where it is developed and are able to operate more economically because of its presence. In some of the quarries in Oklahoma they have been followed, but in others quarrymen have not observed any difference in the ease of splitting. Microscopic examinations of a number of the granites show that there are in many cases, systems of parallel fractures, but their relations to the direction of jointing has not been observed.

Rock Varieties: It is not an uncommon thing to find tabular masses of some other variety of rock cutting an area of igneous rock. These are called dikes, and in Oklahoma are of several varieties, ranging in thickness from less than an inch to more than 20 feet. The varieties of dike rocks, which have been observed, are, aplite, pegmatite, normal granite, diorite and diabase.

The aplite dikes differ from the normal granite in that they are fine grained and are almost pure quartz and feldspar. The pegmatite dikes are coarse-grained and often contain large crystals of quartz or feldspar and also may contain rare minerals. The aplite and pegmatite dikes are numerous in the vicinity of Cold Springs. The aplite is usually light gray in color, and medium to fine-grained. Pegmatite dikes are known at Cold Springs and Lugert. At the former place there is a dike four feet wide of a coarse-grained pegmatite containing large tourmaline crystals and zircon in abundance.

Normal granite dikes are also common especially near the contact of the gray granite and the gabbro. At Granite City 8 parallel dikes of gray granite varying in thickness from 1 inch to 1 foot can be seen in the space of a few rods. In this case the granite carries an abundance of a blue hornblende known as riebeckite. The diorite and diabase dikes are the latest intrusions in the Wichita and Arbuckle mountains, and can scarcely be distinguished from each other except under the polarizing microscope. These dikes are all fine- to medium-grained and dark in color.

Segregations are knots or masses of a fine-grained, dark colored rock often found inclosed in the normal granite. Such segregations are darker because of the concentration of hornblende or magnetite or other dark minerals. There is no way of predicting where these will occur. They do not weaken the stone, but disfigure it for building purposes.

Intrusions consist of fragments of other rocks, which may have fallen into the molten rock and on cooling were included. Like the segregations, their occurrence cannot be predicted, but they are generally localized. Unless the included rock is almost identical to the inclosing rock, the inclusion would disfigure a building stone. In some cases large boulders may be included, which in themselves are large enough to pay for quarrying. Inclusions are known in the western part of the Wichita Mountains.

Weathering of Rocks: The disintegration of a rock because of changes of temperature, freezing and thawing of water, solution, oxidation, etc., is known as weathering. The rate at which a rock disintegrates depends on the mineral composition and the texture of the rock and the climate in which it is exposed. A moist warm climate favors change by oxidation or solution. If the rock contains minerals bearing much iron, such as magnetite, pyrite, hematite, biotite and some of the hornblende, and pyroxenes, it is likely to change from a gray or greenish-black to a yellow or brown color on exposure to the weather. This change of color is due to the alteration of the above minerals and the formation of a brown or yellow iron oxide, which is dissolved out and carried to the surface. Pyrite, magnetite and biotite are especially likely to undergo this change. It is therefore important to know if a stone contains these minerals in large quantities. The feldspars also often alter to a white mica or to kaolin. This will give a gray or lighter colored shade to the rock. It is therefore impossible to predict what the color of the unaltered rock will be unless the mineral composition is known.

DISTRIBUTION OF GRANITE AND RELATED IGNEOUS ROCKS IN OKLAHOMA [1]

Since the igneous rocks of Oklahoma outside of the Arbuckle and Wichita mountains have not yet proven of any commercial value our attention will be directed to these two areas. The location of the granites of the State is indicated in the map shown in Fig. 1.

The Granite and Related Rocks of the Wichita Mountains

The Wichita Mountains, which are located in southwestern Oklahoma, consist of a group of isolated hills. The rocks are according to Taff, older than the earliest sedimentary rocks found in the State, and are probably Archean. They consist of granites of various types, rhyolite, quartz monzonites, quartz diorites, diorites, diabase, gabbro and anorthosite . For a general distribution of the main types of rocks in the Wichitas, see the geologic map, Fig. 2.

The several varieties of rocks according to Taff may be separated into four groups, "distinguished by their large mass or abundant occurrence and also by their age relations." "These in the order of apparent age are gabbro and related anorthosite, granite and related aplite, granite porphyry and associated rhyolite, and diabase dike rock." The quartz monzonite, quartz diorites and some of the diorites have been found, by more detailed study in the region around Cold Springs, to grade into granite. The large area of porphyritic granite (granite-poryphyry) in the eastern part of the mountains has not been studied in detail, but there are isolated masses of a porphyritic granite about Headquarters Mountain, which are older than the main mass of granite. The last group noted by Taff also includes some diorite.

Gabbro and Related Anorthosite: [2] "For the most part the gabbro is exposed in valleys or in the plain which surrounds the mountains. Such is its occurrence along Medicine Creek southeast of Saddle Mountain, in the broad elevated valley between the Wichita and Quana mountains, and in the plain between the Wichita and Raggedy mountain groups. On the southern side of Medicine Creek the gabbro rises in the lower northern slopes of the Wichita Mountains beneath the granite. The position of the gabbro with regard to the granite is similar on the southern and western sides of the Wichita group. On the north and south the gabbro of the Raggedy Mountains is separated from the granite masses by the "Red Beds" deposits, but in the plain eastward it is connected with the gabbro of the Wichita group.

1. For a more general description of the Wichita Mountains the reader is referred to Professional Paper No. 31, U. S. G. S.
2. Op. Cit, Pages 60-61.

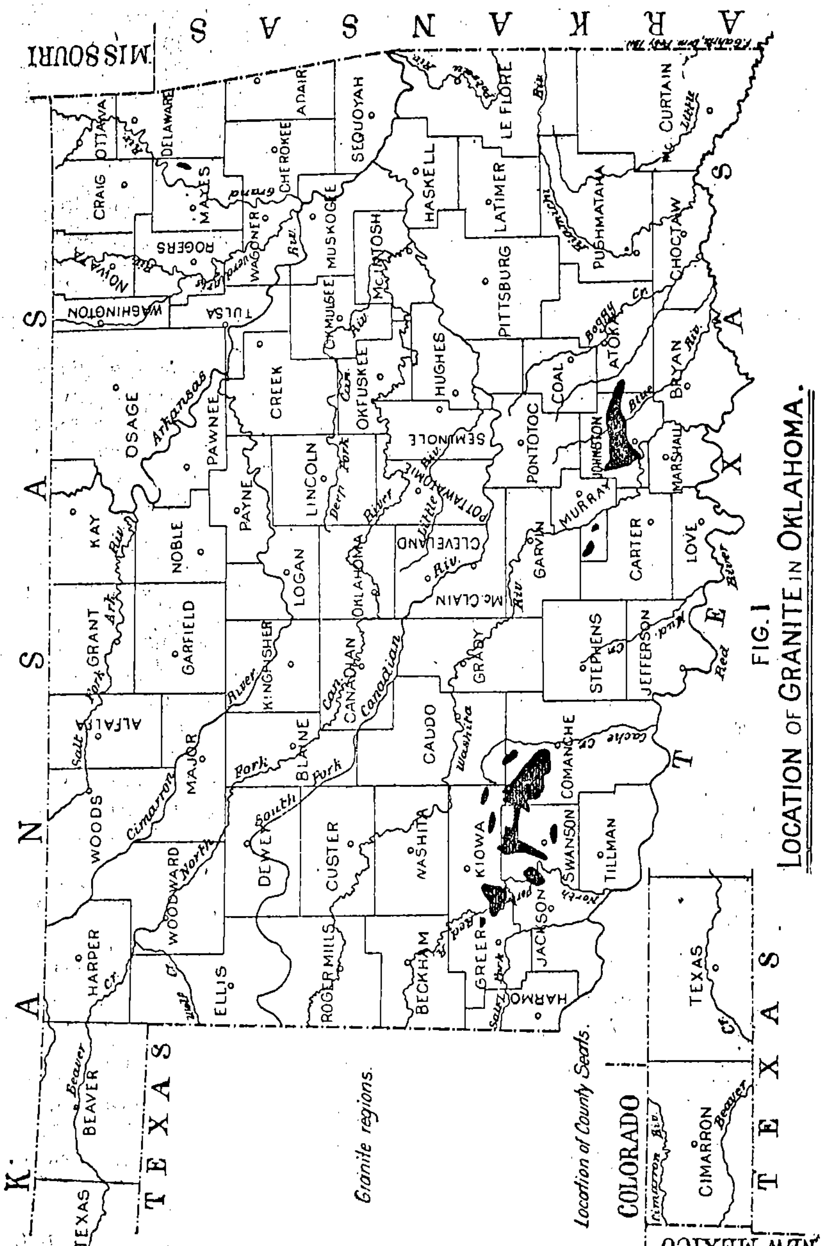


FIG. 1
LOCATION OF GRANITE IN OKLAHOMA.

"The gabbro of the Raggedy group makes mountains of considerable size, but their general aspect is different from that of the mountains formed of the granite. The gabbro disintegrates more readily, and even the large-size boulders are less angular than those of granite. The general effect is a roundness of contour and profile of the hills, and in the valleys or plain the rock is generally disintegrated.

"The prevailing physical aspect of the gabbro is that of a dark-gray to black, rather coarsely crystalline rock. The gabbro proper consists of labradorite, augite, and magnetite with a little biotite and accessory titanite. It is a typical gabbro, fairly fresh or with the augite altered to uralitic hornblende.

"The rocks which on close study have proved to be anorthosite were collected as phases of the gabbro, and occurred near the contact with the granite or near dikes of granite or aplite. Between the anorthosite and the gabbro a continuous gradation can be made out, even in hand specimens. The specimens of anorthosite collected show a reddish, greenish, or bluish-gray rock, with lath-shaped crystals of labradorite.

"Petrographically the relation between the gabbro and anorthosite rocks is close, and in the field it is doubtful if lines can be drawn separating them. In the several specimens of anorthosite examined, labradorite is the only constituent, with the exception of a mere trace of magnetite. Beginning with a faint trace, the augite increases in quantity until it is almost equal in amount to the labradorite. With the increase of augite or its alteration product, uralitic hornblende, there is a corresponding increase in the magnetite. The various stages can be readily seen.

Granite and Associated Aplite:[1] Granite is the principal mountain-making rock in the Wichita region. Its area is greater than that of all the other igneous rocks combined, and is about equal to that of the others and the older Paleozoic sediments. It makes all of the high land of the Wichita, Quana, Devils Canyon, and Headquarters mountains, and a large part of the Raggedy group.

"The relations of the granite to the gabbro indicate that the granite is younger and that it intrudes the gabbro. Both occur in large masses, as shown, and the gabbro is cut by a great number of granite or aplite dikes, which in many cases can be traced from the granite mass.

"In physical aspect this granite varies from dark red to light pink and from moderately coarse to finely granular. A representative of a large part of the granite mass is found in Mount Scott, which consists of a rather deep-pink, even-textured, and moderately fine-grained rock.

"The granite in its various phases is rich in orthoclase and quartz, with relatively subordinate amounts of the dark silicates, hornblendes, augite, or biotite. The majority of the specimens

1. Loc. Cit, Page 60.

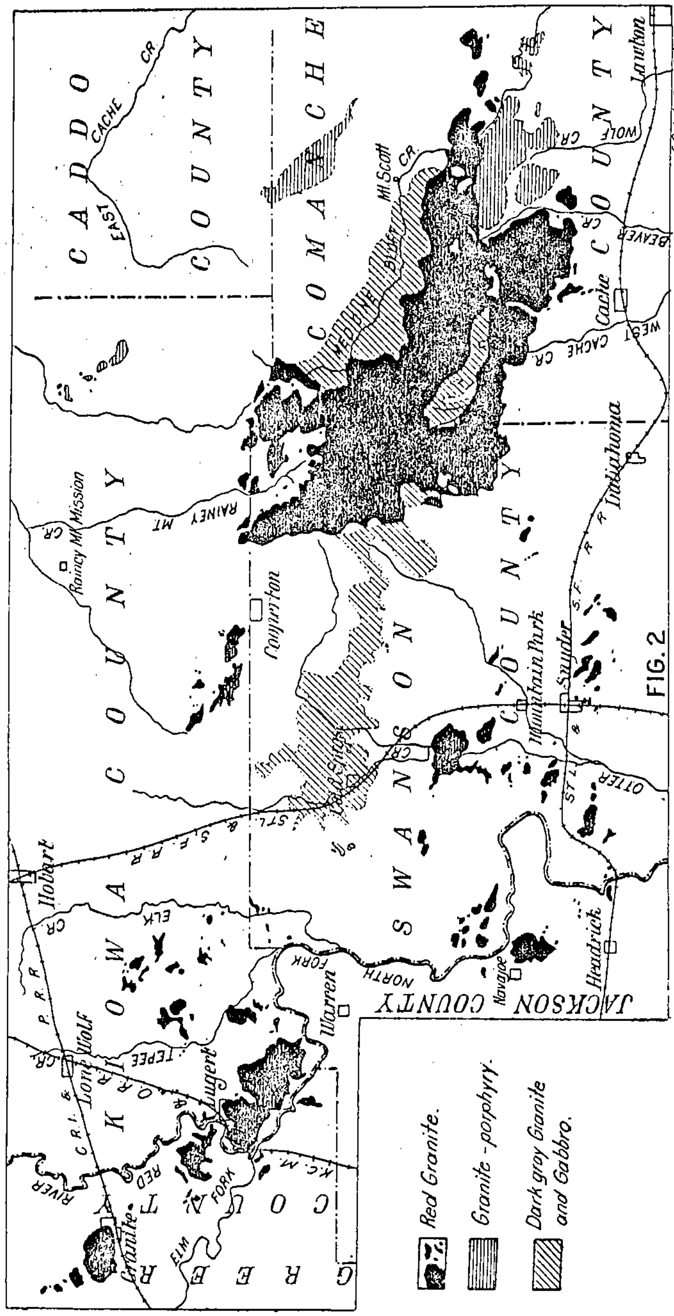


FIG. 2
LOCATION OF GRANITE IN WICHITA MOUNTAINS.

studied are from dikes cutting the gabbro or very near the contact of the granite with the gabbro. A specimen from the top of Mount Scott may be taken as typical of the granite as a whole. It is a medium coarse-textured rock, to which the feldspar gives a dominant red color, which is varied by small spots of a dark greenish mineral and grains of quartz. The microscope shows that orthoclase and quartz occur in nearly equal amounts and together make up by far the greater part of the rock. A little hornblende also occurs, and accessory magnetite, apatite, and zircon. Although not evident in hand specimens, the rock is seen to have a crude porphyritic structure when examined under the microscope. The feldspar occurs in large phenocrysts, surrounded by quartz and feldspar in micropegmatitic intergrowths. The dark, turbid character of the feldspar is to be attributed to finely divided hematite which fills the crystals as a dust.

"Parts of the large granite masses also show variations in texture. In the northwestern foothills of Saddle Mountain the granite has a finer texture and is porphyritic, but is slightly different from that occurring commonly in the Carlton Mountains. A similar phase of the granite occurs in the northwestern hills of the Headquarters group, at the extreme northwestern end of the Wichita range.

"Variations of the granite from the average type are found chiefly near its contact with the gabbro. A particular instance was noted in the SE. 1-4 sec. 21, T. 4 N, R. 14 W., where the granite mass rests against the gabbro. Hand specimens show the rock to be strongly porphyritic, and it may be called spherulitic granite-porphyry. A similar contact phase of the granite with gabbro occurs near the center of the south side of sec. 16, T. 4 N., R. 14 W.

"In the description of the structure of the Wichita range it was observed that there are zones of fracturing and jointing in the granite. In such localities the rock on weathering breaks up into relatively small, angular bowlders. The prevailing surface features of the granite, however, are coarse and rugged, the rocks having broken deeply into large angular bowlders between widely set joints, and then became rounded on long weathering. The slopes of Mount Scott are typical of the granite surface of large masses. The lower slopes of the knobs and mountains are strewn with immense bowlders, many of which descend to the borders of the plain. The large bowlders become well rounded on long surface exposures, and some of these in old age are reduced by exfoliation.

"The granites in T. 4 N, R. 17 W., are more basic and hence darker colored and finer grained than those farther south and west. In the vicinity of Cold Springs and Roosevelt, where they have been quarried, the dark gray granite forms the large hills, while intermediate lowlands are mostly of anorthosite.

"The granite is cut by diorite and aplite dikes, and in the zone of contact with the anorthosite it includes bowlders of diorite and diabase. Under the microscope the gray granite is seen to be a medium to fine grained, biotite-hornblende granite with considerable magnetite and occasionally some pyrite. In places the true granite grades insersibly into quartz-monzonite and rarely into a typical quartz-diorite."

The granites at the west end of the mountains are much freer from dikes of all kinds than farther east. There are two types of granite which make up the greater part of the exposures, a medium grained red granite, which appears to be the older, and a coarse grained red granite of a little lighter shade. The coarse grained red granite consists of feldspar 53 per cent, quartz 44 per cent, magnetite 2 per cent, and hornblende 1 per cent. The coarse grained rock weathers more readily than the fine.

Granite Porphyry and Associated Aporphyolite: [1] "A class of rocks apparently closely related to the granite composes practically all of the Carlton Mountains, the igneous mass lying between the limestone hills in the vicinity of Blue Canyon north of Mount Scott, and some hills near the northwest end of the limestone areas east of Rainy Mountain Mission. They vary from brick red to shades of light pink. The porphyritic character is variable. Specimens may be selected which have a near resemblance to certain parts of the granite, but on the whole the masses designated granite- porphyry are different from those described as granite.

"Megascopically the rock appears to be rather coarse-grained and largely porphyry. With the exception of the feldspar phenocrysts, there usually seem to be no real crystal grains, the remainder of the rock consisting of small quartz grains. A microscopic examination shows that, with the exception of a very little altered hornblende, the rock is composed almost entirely of spherulitic aggregates of feldspar and micropegmatite, often grouped about small crystals of feldspar. A little quartz also occurs, in grains.

"In some instances the feldspars have a faint zonal structure, but these and a small proportion of the others, presumably plagioclase, are undeterminable on account of their decomposition. The greater part of the feldspar is orthoclase. The above description applies to the rock of Carlton Mountain, on Medicine Creek, near the western side of sec. 28, T. 3 N., R. 12 W.

"Another porphyry, distinct from that just described, is found in the east end of Carlton Hills, at the east end of Medicine Bluff. It is a dull-pink rock, with phenocrysts of feldspar and quartz, in a dense or finely granular ground mass. The feldspar phenocrysts are all orthoclase, frequently twined according to the Carlsbad law, and from 3 to 4 millimeters in length. The ground mass, largely feldspathic, and in part possibly micropegmatitic, is now very much decomposed, and looks not unlike the devitrified base of a surface glassy flow. With the exception of a little doubtful hornblende

1. Op. Cit, Pages 63-64.

there are no dark silicates to be made out. The feldspars are all charged with a fine reddish dust, probably hematite.

"In Blue Creek Canyon, sec. 11, T. 4 N., R. 13 W., a rock is exposed, which was believed to be a phase of the granite-porphyry, but which on microscopic examination proved to be aporhyolite. Rocks having similar physical aspects occur in the Carlton Mountain area, about 1 mile north of Signal Mountain. Specimens of the same rock also were collected from East Wooded Hills of Arbuckle Mountains, Indian Territory. As in the Arbuckle Mountains, the aporhyolite occurs in close association with the granite-porphyry, but the contact relations were not made out.

"In hand specimens the Wichita aporhyolite appears to be a partially decomposed porphyry of a darker hue than the average Carlton Mountain porphyry. In thin sections it is seen to be a fluidal, vesicular, much-altered rock, containing phenocrysts of feldspar, a little quartz, possibly secondary, and rarely a very little plagioclase. The base, which was once glassy, is now completely devitrified, but still shows in certain bands a perfect perlitic structure. The vesicles, of which there are many, are now filled with secondary silica.

"On weathering the porphyry breaks into small bowlders and fragments, and the hills composing it have distinctly rounded forms. At Medicine Bluff, 1 1-2 miles northwest of Fort Sill, the granite-porphyry is exposed in a vertical cliff 100 to 400 feet high, showing rude columnar structure, doubtless due to close parallel and cross jointing. The distinct, closely placed parallel joints may be seen at a considerable distance to extend nearly vertically from the top of the bluff to the bed of Medicine Creek. Whether this structure is common in other parts of the granite-porphyry of the Wichita Mountains cannot be determined on account of the mantle of weathered surface rock. It is presumed that similar structural conditions occur, since the characteristic weathering of the porphyry into small angular blocks is universal."

Dikes: The various types of granite and gabbro are cut by many dikes of diorite, aplite, pegmatite and diabase. The diorite dikes were intruded first and are younger than the granite of the western end of the mountains. Intrusion of aplites and pegmatites followed and last of all there was an intrusion of diabase-diorite dikes.

The diabase and diorite dikes have been prospected a great deal for minerals. The dikes range from a few inches to 20 feet in width and are usually nearly vertical or else steeply inclined. The aplite dikes are more resistant to weathering than the other rocks and often stand out as ridges. The diorite and diabase dikes are least resistant and generally are found in valleys or depressions and expose no firm rock. The aplite dike rocks are fine grained light gray, and are composed of quartz, orthoclase and occasionally a small amount of biotite or hornblende. The diorites and diabases are fine to medium grained, dark to greenish black rocks, composed of plagioclase feldspar, hornblende and biotite with often as much as 5 per cent of quartz. Ophitic texture is often well developed.

The Granite and Related Rocks of the Arbuckle Mountains

The Arbuckle Mountains are located in south-central Oklahoma. Unlike the Wichitas, the greater part of the rocks in the Arbuckles are not granites, but consist of sedimentary rocks, chiefly limestone, sandstone and shale. Granite occurs in three general areas in the Arbuckles, where more than 100 square miles of granite is exposed. This rock is, in general, a coarse-grained, pink granite which has been quarried and used for building purposes. Two smaller areas located in western Murray County are known respectively as the East and West Timbered Hills.

The location of the granites of the Arbuckles is shown on the map, Figure 3.

Igneous rocks are exposed in three areas in the Arbuckle Uplift. The largest of these in the eastern portion is composed for the most part of granite, of a small amount of rocks related to granite, and of intrusive dike rocks, chiefly diabase. The other two areas, which are situated near each other in the western part of the mountains are composed of granite porphyry and aporphyolite, containing also basic dikes.

Granite and Associated Igneous Rocks: [1] "The granite is a reddish or pinkish rock, moderately coarse in texture * * * dikes of basic rock penetrate the granite in many directions * * * the surface of the granite is nearly flat and is in large measure concealed by materials resulting from its own disintegration.

"The typical granite is in general, a biotite granite, rich in microcline and poor in ferro-magnesian silicates * * * The feldspars are principally orthoclase or microcline with plagioclase, albite and oligoclase almost always associated * * * .

"Porphyry and associated basic dikes: The porphyry of the Arbuckle Mountains occurs in two areas * * * which rise slightly above the general level of the Arbuckle table land * * *. These igneous rocks, of Pre-Cambrian age consist of granite porphyry and aporhyolite of various shades of pink, red and brown * * *. In places the aporhyolite like the granite porphyry is strongly porphyritic."

The Igneous Rocks on Spavinaw Creek [2]

"There is a small area in the eastern part of Mayes County, one of the northeastern counties in the State, where granite is exposed. It occurs in the form of a dike, on the north side of Spavi-

1. The following excerpts are taken from Mr. Taff's article in Professional Paper No. 31, U. S. G. S. Pages 17-20.

2. Dr. C. N. Gould, state Geologist, Oklahoma; unpublished manuscript.

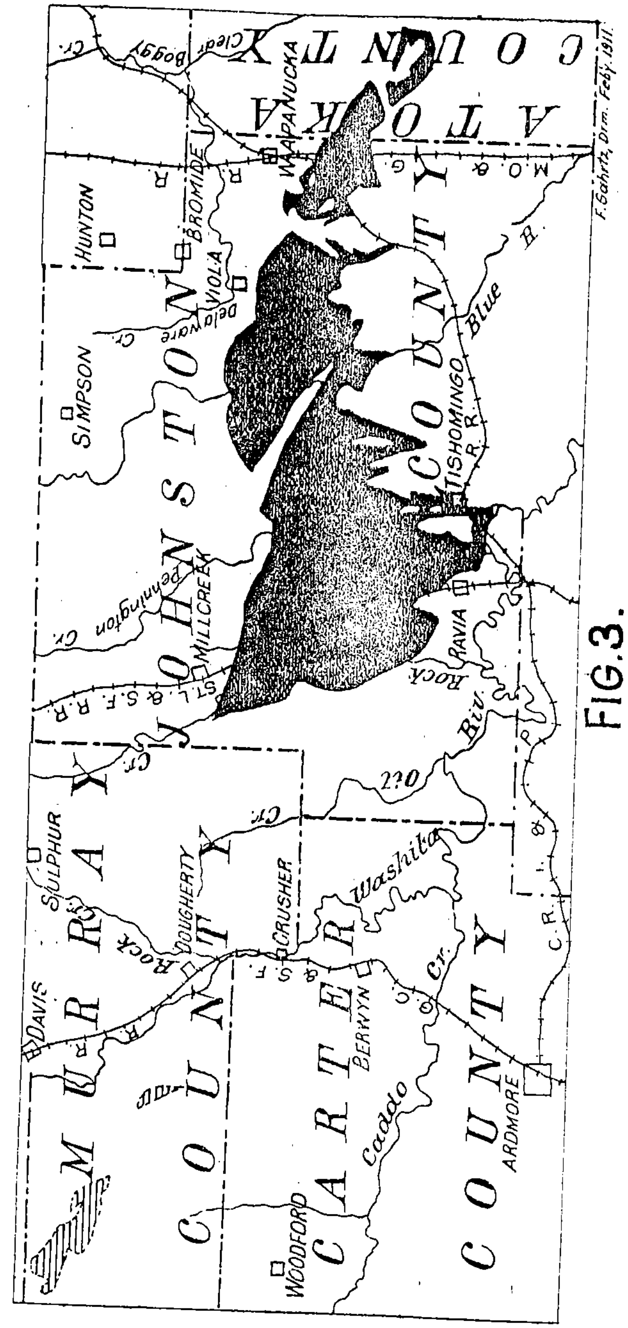


FIG. 3.
LOCATION OF GRANITE IN ARBUCKLE MOUNTAINS.

Granite   Granite-porphyry.

0 5 10 20

naw Creek, about six miles above its mouth and a mile below Spavinaw postoffice. The granite is exposed along the axis of a fold for a distance of about a quarter of a mile. The width of the dike is usually less than 75 feet.

The rock is a porphyritic granite, light-red in color, composed of feldspar, quartz, hornblende and magnetite. Chemical analysis shows more than 70 per cent of silica, with more than 20 per cent of iron and alumina oxides.

This rock would make a durable and handsome building stone. It is found in sufficient quantity to justify quarrying, if transportation were available. If a railroad is ever built along Spavinaw Creek, this rock will probably be developed."

Detailed Description of Granite at Quarries

Granite City Area: At Granite City in the northwestern part of the Wichita Mountains, two types of granite have been quarried, on, a medium-grained and the other a fine-grained red granite. The medium-grained granite makes up by far the larger part of the granite hills north and west of Granite City. It has been quarried at five different points on the south side of Headquarters Mountain within a mile of the city limits. There are several other places within a mile o fthe city limits. There are several other places where good quarries could be opened.

The following companies are now operating quarries at Granite:

Ten specimens of the coarse-grained granite studied under the microscope show that this rock contains on an average 55 per cent orthoclase, 42 per cent. quartz and 1 per cent. each of hornblende, biotite and magnetite. The orthoclase consists of short tabular crystals, .5 to 1 centimeter in average diameter. It is often intergrown with quartz. It contains brilliant red hematite in splotches, broad streaks and in cracks and also evenly disseminated throughout the crystal. The quartz is in irregularly rounded, clear, glassy grains from 1 to 5 millimeters in average diameter. Fractures in the quartz are sometimes filled with red hematite. The hornblende and biotite are in irregular brown and green masses and are altering to green chlorite and red hematite. The magnetite occurs in rounded grains from .05 to 1 millimeter in average diameter. It is often associated with the biotite and hornblende, but in some cases it is scattered through the orthoclase. Though special precaution was used to get fresh specimens, all showed that the orthoclase had altered considerably to kaolin.

The fresh unaltered granite is pale red color on fractured surface, but weathers to a lighter shade to a depth of 10 to 15 feet. Much of this altered rock has been put on the market. It is hard and brittle, and takes a good polish. Samples tested in the University laboratoy, at Norman, showed a crushing strength of 11,200 to 16,800 pounds per square inch. The specific gravity is about

2.65. The hammered face does not present a marked contrast in color to the polished or fracture face.

At all of the quarries the granite is cut by vertical and nearly horizontal joint planes. The strongest system of vertical joints has a nearly north-south direction and is strikingly persistent.

Their influence on topography and drainage is plainly evident. These joints are not regularly spaced, but a majortiy range from 4 to 8 feet apart. There is also a system of approximately east-west joints, which are persistent, but are spaced somewhat farther apart than the north-south system. In all this area there is a system of inclined or nearly horizontal joint planes, which give rise to what has been called sheet structure. These planes are approximately parallel to the surfaces of the hills. They are spaced from 6 to 10 feet apart, but are not parallel. They converge and diverge, thus cutting the granite into broad, flat-lying lenses which overlap. Since these join planes generally dip away from the hills they aid greatly the quarrying. In some of the quarries one or more dikes of a fine-grained, dark hornblende granite cut the red granite. These dikes range from one inch to fourteen inches in thickness and dip northeast at an angle of 25 degrees.

In practically all of the quarries segregations of a dark, greenish-gray basic granite are found. These range from mere specks up to 2 feet in diameter. Under the microscope they are seen to be made up of a fine-grained mass of quartz, orthoclase, green hornblende and magnetite. It will be noted that they are of the same composition as the normal granite with hornblende greatly increased. They spoil the appearance of the granite when present, but do not cause much waste.

The fine-grained granite has been quarried at only one place, though it appears in several places in the southwest part of Headquarters Mountain. It is much the same composition as the other red granite, but consists chiefly of an intergrowth of quartz and feldspar, contains about 5 per cent. of albite and is much finer grained. Because of the finer grain it weathers less readily, takes a smoother surface in polishing, is a dark brownish-red on polished surface and is not so brittle as the other.

This granite occurs as angular masses included in the medium-grained red granite. These masses range from a foot to a few rods in diameter, but they are so fractured it would not be profitable to attempt to quarry from them.

Mountain Park Area: Granite has been quarried at two places on the hill about one mile northwest of Mountain Park. At the point of the granite area nearest the railroad a grayish-pink, fine-grained granite has been quarried. This rock has not been studied microscopically, but with the aid of a hand lens it shows feldspar, quartz, and hornblende. It weathers into subangular gray to pinkish-gray bowlders. It is jointed favorably for quarrying, but the inclined sheet jointing shown farther west does not yet manifest itself. Though the color is not entirely pleasing, this ought to be a good structural stone.

About one-half mile to the northwest of this point, a quarry has recently been opened on the Parsons Bros.' property. The granite here is a rose-red, medium-grained rock, containing about 75 per cent. feldspar and 25 per cent. quartz, the quartz grains being decidedly smaller than the feldspar. The quarry has not yet been sufficiently worked to show how the rock will change with depth. The weathered surface zone has a gray mixed with rose, which make a decidedly pleasing polished surface. The rock takes a fine polish and shows up well. It is a tougher rock than that at Granite City. Basic segregations are present.

Slightly inclined joint planes are sufficiently persistent to make quarrying easy. Vertical joints are not regular in spacing or direction, but are fairly favorable to quarrying. The rocks showed a crushing strength of 20,600 pounds per square inch and have a specific gravity of 2.65.

Cold Springs Area. There are two varieties of rock that have been quarried at Cold Springs. Gray granite is quarried at three points, one near the railroad station, another one-half mile north of the northeast corner of the townsite, and the third aong the railroad about midway between Cold Springs and Roosevelt. Anorthosite has been quarried at two places in South Cold Springs. The gray granite is found in areas of 100 acres or more in the vicinity of Cold Springs, but these areas are usually cut by aplite and diorite dikes. However, areas of 10 acres or more may be found free from intrustions.

The rock appears in the field as a gray to pink, fine-grained, even textured rock, which weathers into subangular bowlders. It is cut by north-south and east-west, almost vertical joints irregularly spaced. No system of horizontal joints cutting it into sheets has been developed.

The microscope shows the rock to vary in composition to correspond to a noticeable variation in color. An average for the quarry at the station shows the following: Orthoclase, 40 per cent.; quartz, 30 per cent.; hornblende, 10 per cent.; albite, 7 per cent.; biotite, 5 per cent.; oligoclase, 2 per cent.; magnetite, 3 per cent.; augite, 1 per cent. The feldspars are altering to muscovite and kaolin and the biotite and hornblende are altering to chlorite. The feldspars are tabular in shape and range from .1 to 1 millimeter in maximum diameter. The quartz is in irregular rounded grains of about the same size. Though it is rather basic, it is plainly a hornblende-biotite granite. It is a medium tough rock, has a specific gravity of about 2.77 and takes a good polish. The polished surface is much darker than the fractured or hammered surface. It letters exceptionaly well. Segregations are usually absent. Small veinlets of a lighter rock some time traverse the rock. On exposure to the moist atmosphere it has been seen to become slightly discolored because of the alteration of magnetite to a brown iron oxide.

At the quarry northeast of Cold Springs, the rock is a little lighter shade of gray, and is composed of the following: Orthoclase 50 per cent., quartz 35 per cent., hornblende 8 per cent., biotite 6 per cent., albite 3 per cent. In texture and physical properties it is much like the rock described above. A rather well-defined system of horizontal jointing is developed here, which aids in quarrying.

The granite at the quarry between Cold Springs and Roosevelt is much like that at Cold Springs and need not be described.

The anorthosite is a dark bluish-gray, medium to coarse-grained rock, made up almost entirely of labradorite feldspar, though in some places it contains as much as 5 to 10 per cent. augite. In such cases it becomes a gabbro. The rock is rather tough, has a high specific gravity, and takes a beautiful bluish-black polish. Joints are irregular. In most cases a well defined schistosity is developed, making the stone split readily in one direction. Where this is best developed the crystals are on an average one-fourth as thick as broad, and have remarkably perfect parallel dimensional arrangements.

CHAPTER V

SANDSTONE

By Chas. N. Gould

Composition

Sandstone is composed of grains of sand, cemented together. The individual grains are usually composed of a mineral known as silicon dioxide, or quartz. Other minerals, however, such as feldspar, hornblende, and limestone, to mention only a few, are frequently found as ingredients of sandstone. As a usual thing the individual grains, which go to make up the sandstone, have been worn smooth and round. In some cases, however, the grains are more or less angular. The size of the individual grains varies from those so small as to be scarcely seen by the naked eye, up to those several inches in diameter. If the grains are large and rounded, the rock is called a conglomerate; but if the grains are angular, the rock is called a breccia.

The individual sandstone grains are usually held together by one of three cements, either lime, iron or silica. Lime is the most unstable of all the cements, and so a sandstone cemented with a lime is usually rather soft and fragile. Iron is considered a much better cementing material than is lime. The iron is usually in the form of an oxide, which is either brown, black, or red in color, so that sandstone cemented with iron is frequently a black, red or brown rock. Sandstone cemented by silica is much harder and more durable than that cemented by either lime or iron. Sandstone of this character is frequently spoken of as quartzite, although technically quartzite is a sandstone, that has been metamorphosed by the action of heat and presure.

Geologists believe that practically all the sandstones now found on or near the earth's surface were formed in one of two ways. In most cases they were shore line deposits along some ancient sea. The rocks of the coast ground up by the action of waves, were deposited as beach sand. This sand has since hardened forming sandstone. The second method of sandstone formation was sand dunes. In many cases dunes are being formed today by the action of winds, and it is believed that this process has been in operation throughout all geological time. The loose sand of the sand dunes is afterwards cemented and forms sand rock.

Sandstone, when cemented, is usually a hard and resistent

stone. If, however, the cementing material is lime, or if the rock contains no great amount of cementing material, the stone may be soft and easily crushed. In certain cases there is little cementing material of any kind in the stone, in which case it will fall to pieces when struck a sharp blow. This sort of sandstone is known as saccharoidal.

The color of sandstone depends largely upon the presence of the cementing material. Much of the sandstone in western Oklahoma contains a large per cent of iron, and is red in color. In the southeastern part of the State the color of much of the sandstone is black or dark brown. The sandstone in the eastern counties is usually light colored, being either light brown or gray. This stone contains relatively small amounts of iron.

Distribution in Oklahoma

Sandstone is the most widely distributed building stone in Oklahoma. There is scarcely a county in which it does not occur in quantity, and in most counties it is by far the most abundant building stone. In general, eastern Oklahoma contains a gray or light-brown sandstone; western Oklahoma, red sandstone; while the southern part of the State contains a black or dark-brown stone. Fig. 4 shows the location of the various kinds of sandstone in Oklahoma.

Sandstone in the Mountain Areas

Arbuckle Mountains: Sandstone occurs in each of the three mountain ranges of southern Oklahoma, which have been discussed in the chapter under Geology. The Arbuckle Mountains contain two members made up largely of sandstone, namely, the Reagan and the Simpson formations. The Reagan sandstone of Cambrian age, which lies just above the granite, is composed largely of rather coarse-grained porphyry and granite fragments. As a usual thing this rock is inaccessible to market, and it rarely occurs under conditions which make it suitable for quarrying.

The Simpson formation, which lies just above the heavy bedded Arbuckle limestone, contains three or sometimes four heavy beds of sandstone. This rock is often fine-grained and in most cases it is saccharoidal, that is, it crumbles easily on being struck a sharp blow, so that it would not make a good building stone. In a number of cases, however, the Simpson is fairly coarse-grained and has been used locally for outbuildings and fences. The Simpson outcrops around the edge of the Arbuckle Mountains and is exposed in Murray, Johnston and Pontotoc counties.

Wichita Mountains: In the Wichita Mountains the only sandstone of any prominence is the Reagan. This formation occurs along Blue Creek canyon in northern Comanche County and near some high porphyry bluffs in southern Caddo County. So far as known it has never been used for building purposes.

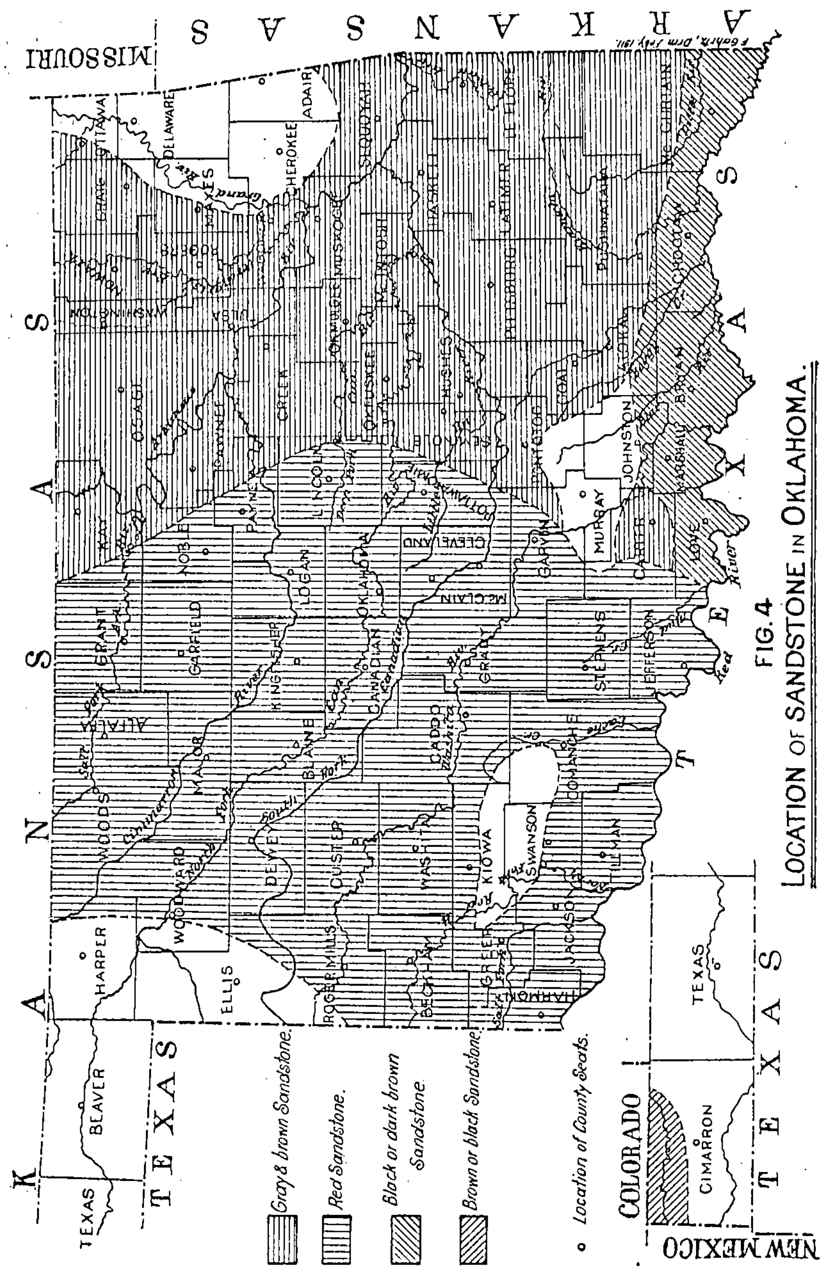


FIG. 4
LOCATION OF SANDSTONE IN OKLAHOMA.

Ouachita Mountains: The higher peaks of the Ouachita Mountains, in the southeastern part of the State, are composed largely of ledges of massive sandstone. The geologic age of this rock is not yet definitely determined, but is probably Mississippian or Pennsylvanian. Practically all the rocks in these mountains, exclusive of some ledges of chert near Talihina and Atoka, consist of alternating ledges of heavy sandstone and shale. These rocks were once deposited on the bottom of a former ocean, but the region has since been much faulted and folded, so that, at the present time, the greater part of the rocks stand practically on edge or are inclined at high angles.

In these mountains, it is the hard sandstone, which resists erosion, that makes up the ridges. The intervening valleys are largely shale valleys. The principal sandstone formation, which has been named the Jack Fork sandstone by Mr. Taff, occurs in the mountains of the same name, also in the Kiamichi, Winding Stair, and other unnamed high mountain ranges in this region.

The ledges of sandstone vary in thickness from a few inches up to many feet. In some places they have been worn down by erosion, but in many cases the ledges stand out as prominent cliffs and bluffs. McKinley Rocks, a well known mass of sandstone 200 feet high and half a mile long, standing on the summit of the Kiamichi Mountains south of Tuskahoma, is a good example of an exposure of eroded Jack Ford sandstone.

Very little use has been made of the sandstone in the Ouachita Mountains. Buildings, at such towns as Antlers and Talihina, have been constructed of this rock, but relatively speaking only a small part of this stone has been utilized. It is a durable and handsome stone and when developed will be of great value to the region.

Ozark Uplift: In the Ozark Uplift in the northeastern part of the State, there is relatively little sandstone. The Boone formation, which is a limestone, occupies the greater part of the country. In a few deep valleys, however, sandstone occurs. At a bend of the Illinois River, some five or six miles northeast of Tahlequah, the Burgen sandstone, which is 100 feet or more thick, is found. This is however, inaccessible to market and will probably never be utilized. It is in many cases, nearly pure white and might be used for the manufacture of glass.

In the southern part of the Ozark Uplift, sandstone comes in above the Boone chert. This is particularly true in the hilly country known as the Brushy Mountains, in southern Adair and northern Sequoyah counties, where there is an extensive plateau formed of sandstone.

Pennsylvanian Sandstone of Eastern Oklahoma

The rocks of eastern and east-central Oklahoma consist largely of alternating layers of sandstone and shale of Pennsylvanian age. They have been divided by Mr. Taff into a number of formations, which, however, need not be discussed here. The general statement may be made, that throughout this region, sandstones, which are harder than the intervening shales and which withstand erosion, form the tops of the cliffs and scarps. The valleys and lower parts of the cliffs are usually composed of shales. In the country lying between the Ouachita Mountains in the southern part of Oklahoma and the Ozark Mountains in the northeast corner of the State, including most of Sequoyah, Haskell, McIntosh and part of Pittsburg, Latimer, LeFlore and Muskogee counties, the rocks have all been folded so that the various ledges now stand on edge. Within this region there are several prominent hills and mountains, for instance, Cavinal, Sugar Loaf, Poteau, Beaver, Tucker, Sanbois, Panther, Kiowa, and Belle Star. These hills are all formed of heavy ledges of sandstone.

Farther north and west, the greater part of the rocks lie level or dip to the west. In this region the sandstone ledges form the tops of the hills and cliffs. The following counties contain many prominent ledges of sandstone: Craig, Nowata, Washington, Osage, Mayes, Rogers, Tulsa, Wagoner, Creek, Okmulgee, Muskogee, Okfuskee, Hughes, and Seminole.

Although throughout this entire region, occupying nearly one-third the area of Oklahoma, there is scarcely a community in which sandstone has not been quarried locally, no extensive quarry, from which sandstone has been shipped for considerable distance, has been opened so far.

In the early settlement of the Indian Territory many of the first buildings were constructed of sandstone; the barracks and officer's quarters at Fort Gibson, the Creek Council House at Okmulgee, the Seminole Council House at Wewoka, the Osage buildings at Pawhuska, and many of the agency buildings and practically all the school buildings were erected of sandstone.

Such towns as Vinita, Broken Arrow, Wagoner, Pryor Creek, Muskogee, Okmulgee, Weleetka, Okemah, Dustin, Wetumka, Checotah, Eufaula, Holdenville, Canadian, Coalgate, Lehigh, Atoka, Wilburton, McAlester, Hartshorne, Alderson, Poteau, Wister, Sallisaw, Stigler, Porum and Quinton contain business blocks and residences in which handsome and durable sandstone has been largely used. Many of the early farm houses in this part of the State were also built of sandstone.

The fact that this stone is so abundant and easily quarried is of extreme advantage to the communities in which it is found. Although, at the present time, gas-burned brick are being used, because brick buildings can be constructed more cheaply than those of sandstone, the fact remains, that the presence of this sandstone is a very considerable material asset to the State.

Permian Sandstone of Western Oklahoma

The greater part of the sandstone in western Oklahoma is red

in color. Neither in quality nor amount is it equal to the sandstone in the eastern part of the State. Nevertheless, in many regions it is of sufficient importance to justify quarrying.

Western Oklahoma is the region of the Redbeds. The greater part of the rock consists of red clay shales. In certain places these shales contain ledges of sandstone or gypsum. The sandstone, however, is frequently soft and not suitable for building purposes. There is scarcely a town in western Oklahoma, however, which does not contain buildings constructed of the soft red sandstone. Quarries have been opened near most of the towns and in many cases are still in operation. Brick, however, has taken the place of stone for the majority of building, and at the present time, comparatively little of the red sandstone is being used.

Some of the earliest structures in the old territory of Oklahoma were constructed of this stone. The first building of the Central State Normal at Edmond, some of the older buildings of the Agricultural and Mechanical College at Stillwater, as well as buildings at Norman, El Reno, Guthrie, Kingfisher and Oklahoma City, were constructed of this sandstone.

At the present time, there is little incentive towards the development of sandstone industries in western Oklahoma. Brick shale is abundant in all counties and is being made into brick at several towns in the region. Gas-burned brick from Kansas and northeastern Oklahoma can be imported more cheaply than sandstone can be quarried. For these and other reasons the sandstone industry is not now active.

Cretaceous Sandstone

Southern Oklahoma: There is a region in southeastern Oklahoma, containing considerable quantities of dark red or black sandstone. This area includes Bryan, Marshall, Choctaw and McCurtain counties. Sandstone outcrops in many localities and has been used for building purposes at Madill, Durant, Woodville, Bokchito, Bennington, and Hugo. In some ways this stone resembles the red sandstone of western Oklahoma, but is usually darker in color and much harder.

Northwestern Oklahoma: There is a small area in the Cimarron valley near Kenton, where sandstone is found. It is light brown to black in color and has been utilized locally for buildings. It is a durable and handsome stone and if transportation were available might become an important source of revenue.

CHAPTER VI.

LIMESTONE

By Chas. N. Gould

Distinction Between Limestone and Marble

The distinction between limestone and marble is not always easy to draw. Technically, marble is a limestone that has been subjected to the action of heat and pressure to such an extent that it has been changed or metamorphosed. Limestone is an elementary rock formed, usually, from the deposition of shells or other marine elements in the bottom of an ocean. Oyster shells and coral reefs in the ocean today will in time form ledges of limestone. During former geological ages seas covered the area now occupied by continents. In these seas vast deposits of shells and other low forms of life were laid down. Afterward these deposits were covered by mud, sand, silt and other debris, until in most cases many thousands of feet of other material has been deposited on top of the limestone. The weight of these accumulated sediments was very great and the pressure alone was often effective in changing or metamorphosing the limestone. Heat was sometimes generated also and this added to the pressure was often effective in still more rapid change; so that in many cases both heat and pressure acted together in transforming the limestone into marble.

The best quality of marble in the world, for instance, the famous marble of Greece, Italy and Vermont, is found in regions where the rocks were at one time very deeply buried, during which time they were subjected to the action of heat and pressure. Afterward the rocks above were removed by erosion leaving the marble exposed on the surface.

Perhaps no better popular definition for marble can be found than the one used by builders and contractors, namely, "any limestone that takes a good polish is a marble." If this definition is accepted as the true one, it is evident that our ideas must be reconstructed. For many limestones, which have not been subjected to heat and pressure will take a good polish, and on the other hand many limestones that have been deeply buried for long periods of time will only take a poor polish or none at all.

In general, however, the distinction is true, and ledges of limestone which have been deeply buried and have since been uncovered by erosion are the ones which take the best polish. Other

things being equal, then the oldest limestones are more hard and susceptible to polish, while the younger limestones are soft and take a less beautiful polish. This distinction may be fairly well made in regard to the limestones of Oklahoma.

There are six general areas in the State in which limestone occurs in quantity. Some of these rocks are very old, while others were deposited more recently. The limestones in the Arbuckle Mountains, for instance, are among the oldest rocks on the North American continent. In the Arbuckle Mountains there are three heavy ledges of limestone, namely, the Arbuckle limestone, the Viola limestone and the Hunton limestone. All of these rocks were deposited in a former ocean, afterward buried very deeply below superimposed sediments. Then after a long period of time the region was upheaved into a great dome. During this period of upheaval, immense heat must have been generated. The heat and pressure together were effective in metamorphosing the limestone. Since the time of the upheaval erosion has been going on constantly so that these various ledges are now exposed on the surface. Critical examination will reveal the fact that according to the popular definition, limestone from these formations may well be considered a marble, because the greater part of them will take a good polish.

In the eastern part of the State also, there are certain ledges of limestone which were once very deeply buried and have been brought to the surface by faulting or fracturing of the earth's crust. Some of the best deposits of this character are exposed in the valleys of small creeks entering Sallisaw Creek in Sequoyah County. An exposure near Marble City, which will be referred to later, is the only marble in this region that has been worked.

The limestones of later age, particularly the Carboniferous limestone in the northern part of the State, and the Cretaceous limestone between the Arbuckles and Red River, have apparently never been subjected to sufficient heat and pressure to be metamorphosed. While both the Carboniferous and Cretaceous limestones make a good building stone, and a number of quarries have been opened in different localities, the character of the material is by no means equal to the stone at Marble City or in the Arbuckle Mountains.

Uses of Limestone

There is no ordinary stone which may be used for so great a variety of purposes as limestone. On account of its chemical composition, its texture and its varied color, it may be utilized in many ways. These facts, taken into account with the wide distribution of the stone, renders limestone the most valuable of the common sedimentary rocks. The state or the country that contains deposits of good limestone has a great advantage over the state or country not so fortunate.

The chief uses to which limestone has been put are the following:

1. Building stone
2. Lime
3. Cement
4. Road material
5. Ballast
6. Concrete
7. Manufacture of glass
8. Minor uses.

These various subjects will be considered in brief detail, particularly with relation to the limestone deposits of Oklahoma.

Building Stone: Since the time of earliest civilization, limestone has always been popular for building purposes. Many of the temples, palaces, castles, and other buildings of the ancients were constructed of this material, as also are many of the most beautiful cathedrals and palaces of the present time. St. Peters at Rome, for instance, is built of travertine, which is one variety of limestone.

In the United States, limestone has been used for a great variety of building purposes; not only for buildings of all kinds, but also for bridge construction, arches, breakwaters and in fact all sorts of structures in which native stone has been employed.

The desirability of limestone depends largely upon its color and texture. Oolitic limestone, which is composed of small rounded grains, is especially popular, particularly for ornamental work, such as trimmings on fine buildings and for monuments. The best-known deposit of oolitic limestone in America is that from the vicinity of Bedford, in southern Indiana. Stone from quarries in this region is shipped to all parts of the United States. Other deposits of oolite are found in Kentucky and Arkansas. Some of the oolitic stone from Oklahoma is not inferior to the best of that now being quarried in the country.

One variety of limestone is marble, the distinction between the two being simply an arbitrary one. Marble is particularly desirable for monuments, pillars, cap stones and interior decorations, where an expensive stone may be employed.

Lime: One of the chief uses of limestone is for burning into lime. This process is accomplished by the action of heat. Limestone is a compound known as calcium carbonate. When the stone is heated to a certain temperature, this compound breaks down and part of it goes off as a gas, carbon dioxide. The remainder, calcium oxide, is known as quick lime. Water is added and the resulting compound is known as calcium hydrate, or slacked lime. It is used for preparation of mortars, cements and for other purposes.

In order to make a first class quality of lime, the limestone should be very pure, that is, should contain only a small per cent of any foreign matter. Stone of this character will make "fat lime" and "white lime." Inferior limestone will produce a poorer grade of lime.

Lime is used for a great variety of purposes, the most important of which is for the manufacture of mortar. Mortar is usually made by mixing lime with two to four parts of sand and water. During the past few years, lime mortar has been replaced to some extent by gypsum plaster for interior work and by Portland cement for exterior work, but there need be no fear that either of these products will drive lime mortar from the trade. Other uses to which lime is put are for paper manufacture, for bleaching powders, caustic soda, acetic acid, calcium carbonate, for glass purification, for sugar manufacture, leather manufacture, for the manufacture of soap and candles, for use in lead smelting and for sand-lime brick. It is not necessary to discuss in this connection the technology of the various subjects, but it may be remarked that the lime which might be manufactured in Oklahoma could be utilized for any or all of these purposes.

At various times small lime kilns have been opened in various parts of Oklahoma and lime for local use has been made at a number of places, for instance, at Sasakwa, Wewoka, Hartshorne, Garvin, and at various points in the Arbuckle Mountains.

There are three localities in Oklahoma, where lime is now being burned, namely at Grove, Wapanucka and Bromide. It is reported that plans are being made to enlarge the plants at the two latter points. The quality of the lime is excellent.

The greater part of the lime used in Oklahoma comes from Austin and New Braufels, Texas, Rogers, Arkansas, and Ash Grove, Missouri. All the formations from which the Texas, Arkansas and Missouri limes are burned outcrop in Oklahoma and are much nearer fuel in this State than at the points at which the lime is burned. There is no reason why the lime industry in Oklahoma should not be profitable.

Cement: It is not the purpose in this connection to discuss the utilization of limestone in the manufacture of Portland cement, as one chapter in this report is devoted exclusively to this topic. Suffice it here to say that Oklahoma contains inexhaustible deposits of high grade Portland cement material, lying near fuels, that at the present time there are but three mills at work in the State, and that much of the Portland cement now being utilized in Oklahoma is shipped in from adjoining states.

Road Material: Limestone has for centuries been one of the most popular of all stones for road material. Its value lies in the fact that it is hard, and durable, has sufficient cementing material to bind well, does not easily wear down into dust in dry weather and mud in wet weather; and that roads built of it are easily repaired and not difficult to keep in good condition.

In most of the countries in Europe, particularly in England, France and Germany, macadamized or telford roads have been largely built of limestone. In the greater number of the eastern states such as Massachusetts, New York and New Jersey and many states of the middle west, for instance, Ohio and Indiana, limestone has long been used for road construction. In Oklahoma, the wide distribution of limestone in the eastern and southern parts of the State, where the road problem is a vital one, is of great advantage to the people in the matter of securing an abundant supply of good road building material at a reasonably low cost. Limestone occurs in more than 30 of the counties of the State, and not far distant from 20 others, so that two-thirds of the counties of Oklahoma lie within easy distance of good limestone for road building.

It remains to be seen just how much of this material will be used. Fortunately there is an abundance of gravel, granite, and other material in many places where there is no limestone. The matter of oiled roads is now attracting much attention, but it has not yet passed out of the experimental state. It will be many years before the use of limestone as a road building material will be discontinued.

Ballast: There is no more popular material for railroad ballast than limestone. It crushes easily, is not difficult to handle, packs well and is in every way satisfactory and desirable material for that class of work. A number of the railroads in Oklahoma are employing limestone for ballast, for instance, the main lines of the Atchison, Topeka & Santa Fe, the St. Louis and San Francisco and the Missouri, Kansas and Texas railways. A considerable part of the material from the limestone crushers which have been, or are now being operated at or near Uncas, Crusher, Ponca, Apache, Cement, Limestone Gap, Fort Gibson, Lenapah, Ripley, Avant and Tulsa, is utilized for ballast and other railroad work.

Limestone is also often utilized for rip-rap and fills for railroad embankments and for break-waters along streams. A good example of this use of limestone in Oklahoma is the long fill made by the Atchison, Topeka and Santa Fe Railroad near Purcell, where this railroad has been endeavoring to keep the South Canadian River within its banks. The stone for the embankment, which is nearly a mile long and 20 feet high, came from Crusher, in the Arbuckle Mountains. Many single pieces of the stone used on this work are so large that only two of them may be loaded on a car.

Concrete: During the last few years, since Portland cement has been so largely utilized for construction purposes, there is a great and ever-increasing demand for concrete rock. For this purpose nothing is better suited than crushed limestone. Ordinary cement specifications for concrete pillars and foundations require five parts of crushed rock, either limestone or gravel, to two or three parts of sand, and one part of Portland cement. It so happens that in Oklahoma, good clean gravel is not always available, and for that reason, limestone makes up by far the greater part of the con-

crete rock used in the State. A great part of it comes from the plants at Crusher, in Murray County.

There is, at the present time, no reason for believing that the demand for concrete rock will decrease, or that extensive gravel deposits will be found throughout a considerable part of Oklahoma. For these reasons it seems very likely that in the future, crushed limestone for concrete purposes will be used more and more.

Manufacture of Glass: Glass is made of a mixture at high temperatures of silica, usually sand, lime and soda ash. Some of the cheaper kinds of glass, such as window and bottle glass are made of sodium sulphate, (salt cake) instead of soda ash. In some cases barium sulphate or oxide of lead is used, instead of lime, but in the manufacture of by far the greater amount of glass in the United States, lime is used.

Oklahoma possesses inexhaustible deposits of glass sand and plenty of cheap fuel, and the salt on the salt plains in the western part of the State, will, when developed, furnish the salt cake. Limestone is present near the glass sand and fuel, so that all the natural products for the manufacture of glass are present in Oklahoma.

As a usual thing, the lime for making glass is in the form of finely ground lime dust or "carbonate." Either the oxide (burned lime) or hydrate (slacked lime) may be used, however. It is necessary for the lime to be very pure, for any iron in the lime colors the glass and if magnesia is present the mixture is not easy to work.

Dolomite is often used instead of the limestone for the manufacture of high grade lime-flint glass from which fine pressed table ware, and the best quality of bottles are made. This rock is also found in Oklahoma.

Minor Uses: Limestone is used as a flux in iron furnaces, for the manufacture of sodium carbonate or caustic soda and of chloride of lime, also in the Solvay process for the manufacture of sodium carbonate. It is also employed in the manufacture of a compound which is used as a binder in the manufacture of artificial building stones. In the form of marble it is used for the manufacture of carbon dioxide in charging mineral waters. Lime dust or "carbonate," which is powdered limestone, has a variety of uses, chiefly as a filler for asphalt pavement. Magnesia is extracted from dolomite or magnesian limestone.

At the present time there is little demand for limestone to be used in any of the ways above mentioned in Oklahoma, except in asphalt paving, but it is a source of satisfaction to know that the limestone is present in large quantities and that the industries need not be kept out of the State on account of lack of material.

Limestone Areas in Oklahoma

In the discussion of the limestone deposits of Oklahoma, it will perhaps be best to consider the different areas, without particular reference to geologic age. Passing by certain thin and relatively unimportant ledges, the limestone of Oklahoma may be discussed under six separate areas, namely: first, Northern Oklahoma area; second, Ozark Mountain uplift; third, the Wapanucka limestone; fourth, the Cretaceous limestone; fifth, the Arbuckle Mountain uplift, and sixth, the Wichita Mountain uplift. The map, Fig. 5, shows the location of these areas. These separate areas will be treated in something of detail.

Northern Oklahoma Area: The general shape of the limestone area in Northern Oklahoma is that of a triangle, with the angles at Newkirk ,Tulsa and Welch. The southwestern line corresponds roughly to the Arkansas River; the southeastern side parallels the St. Louis & San Francisco Railroad, from Vinita to Tulsa, while the northern side is the Oklahoma-Kansas line. Within this area the rocks are all of Pennsylvanian or Coal Measures age, and consist of alternating layers of limestone, sandstone and shale, with a few beds of coal. All of the rocks dip slightly to the west or northwest, the average dip being 10 to 50 feet to the mile. That is to say, a ledge which outcrops on the surface in a certain region will dip below the surface on passing westward, and at a point 10 miles from the outcrop may be reached by a well several hundred feet deep. Other ledges come in above and these in turn disappear to the west; so that a well drilled in the western part of the area would penetrate successively the various ledges which outcrop on the surface to the east. The Northern Oklahoma area is shown on the map given in Fig. 6.

The limestone ledges which outcrop in this region are southward continuations of formations which have already been studied and described in southern Kansas. Usually they are much thicker and more important in that State than in Oklahoma. On passing southward toward the region of the Arkansas River the various limestone ledges become thinner and many of them disappear. Some of them have ceased to exist before the river is reached, while others continue southward for 20 or even 50 miles. Between the limestone ledges there are various formations consisting of shale and sandstone. The shale is usually thicker than the combined thickness of both the sandstone and limestone.

The easternmost ledge and the lowest in the geologic section is generally known as the Fort Scott limestone. In the reports of the Kansas geologist it was at one time called the Oswego limestone and is still known by that name to the oil drillers in Oklahoma. For approximately the same formation Ohern uses the name Claremore. [1]

1. The Stratigraphy of the Older Pennsylvanian rocks of northeastern Oklahoma, D. W. Ohern, State Univ. of Oklahoma., Research Bull. No. 4, Dec., 1910.

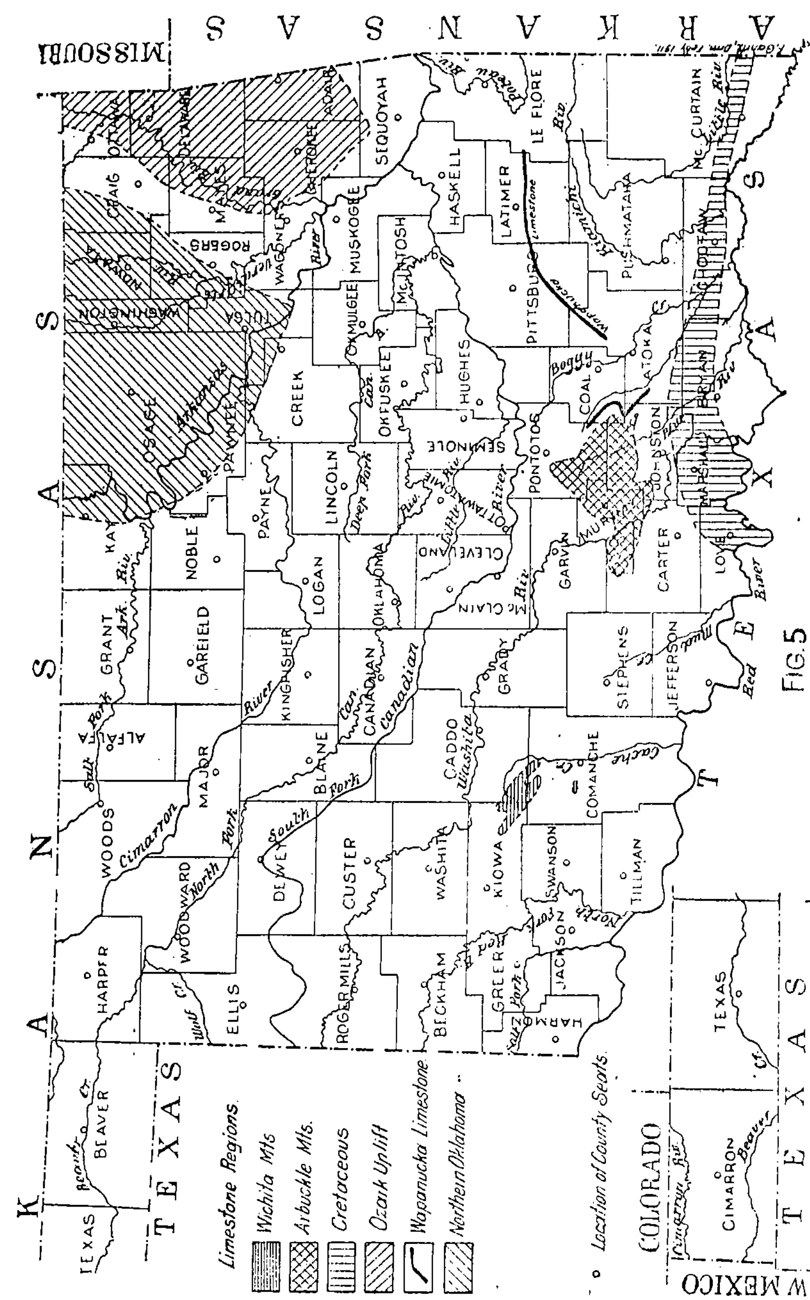


FIG. 5 LOCATION OF LIMESTONE IN OKLAHOMA.

This formation consists of two beds of limestone separated by 6 to 10 feet of shale.

This formation forms a rather conspicuous outcrop. It crosses the Oklahoma line a few miles northwest of Welch and bears off to the southwest, passing near Kennison and Centralia, entering northern Rogers County a few miles north of Chelsea. The ledges outcrop along the top of a bluff which runs parallel with the St. Louis & San Francisco road from Chelsea through Foyil, Claremore and Verdigris, as far as Catoosa. The prominent hill to the northwest of the road is capped with the Fort Scott limestone.

In Kansas the lower ledge of the Claremore has been used in a number of cases for the manufacture of hydraulic cement. In Oklahoma small quarries have been opened at various places to supply local needs; but so far as known, it has never been used extensively for building purposes. This is partly due to the fact that throughout the line of its outcrop into the State it is never far distant from ledges of sandstone which are in better repute for building purposes. For instance, the buildings in Chelsea, Claremore, and Catoosa, are erected of sandstone, although the Claremore limestone is not far distant.

An analysis of the stone shows that in general it would make good Portland cement. Shales both above and below the Claremore are also suitable for the manufacture of cement. The coal near the base of the formation might be used for fuel, or better still, the natural gas which is found in considerable quantities near at hand.

The next limestone above the Claremore is the Pawnee limestone, which is 25 to 50 feet thick and outcrops along a line lying west of, and parallel to, the outcrop of the Claremore. The Pawnee limestone is perhaps best exposed at a prominent escarpment along the west bank of Big Creek and Verdigris River, from the Kansas line nearly to Catoosa. In places it is massive and forms a perpendicular cliff, from which large rectangular blocks, varying in size up to 25 feet, are broken off.

The next limestone of importance is the Altamont formation. It is described as bluish, fine-grained crystalline limestone containing a considerable amount of chert, and having a thickness of 15 to 30 feet. The Pawnee and Altamont combine to the south and form the Oolagah limestone.

Above the Oolagah formation, there is a series of shales known as the Nowata shales, which are succeeded by a ledge of limestone known as the Lenapah. Near the Kansas line this formation is 20 feet or more thick. It extends southeast near the towns of Lenapah, Nowata and Tulsa and through the Glenn Pool oil field. This rock has been utilized for crushed stone and would be useful for the manufacture of Portland cement and in burning into lime.

Shales succeed the Lenapah, and interstratified with these shales, in Washington, Tulsa and eastern Osage counties are sev-

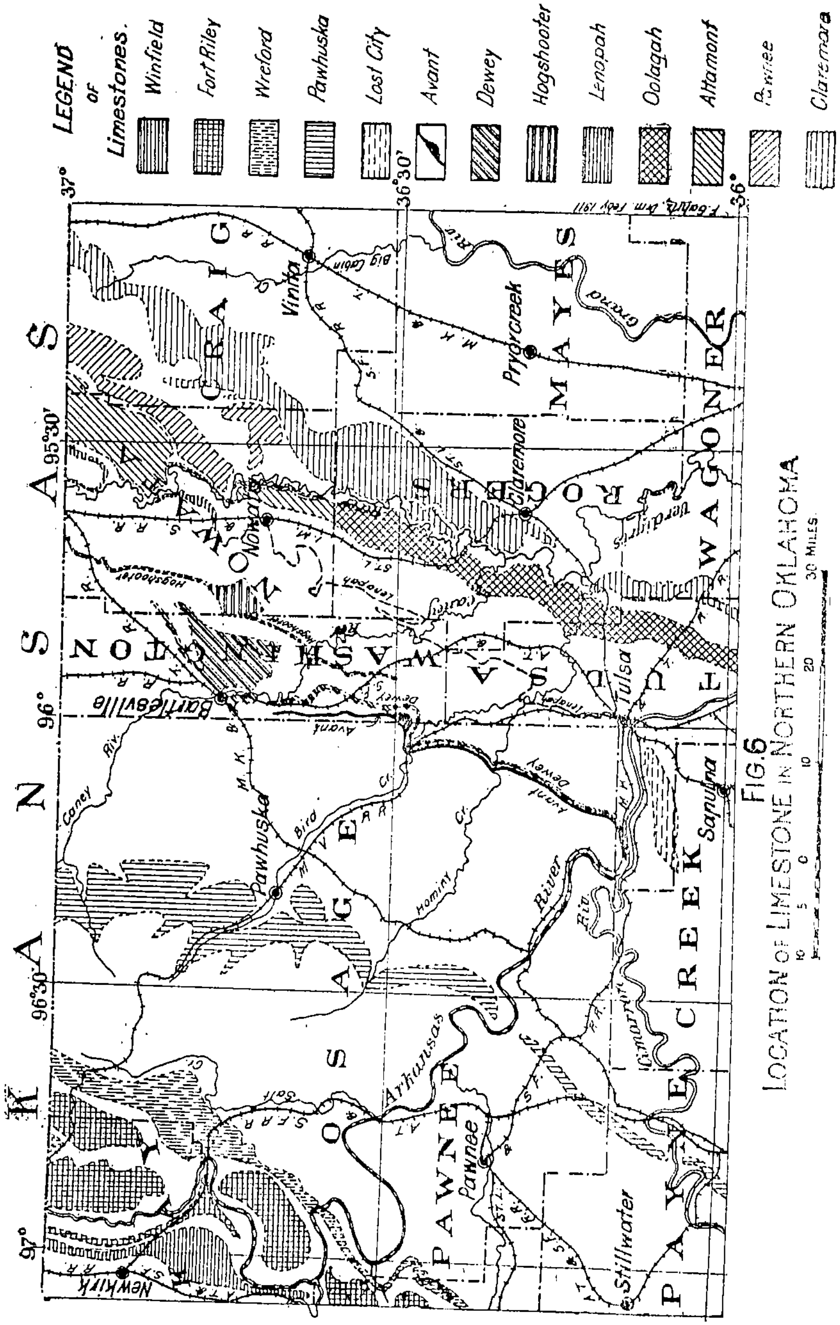


FIG. 6
LOCATION OF LIMESTONE IN NORTHERN OKLAHOMA

eral ledges of limestone, known as the Hogshooter, Dewey and Avant limestones. These are from 10 to 30 feet in thickness and might be utilized for a large variety of purposes. The Dewey limestone is now being utilized for the manufacture of Portland cement at Dewey. A crusher is located in the Avant limestone near the town of Avant.

Shales and sandstones succeed the formation just described, occupying eastern Osage County. A few miles west of the town of Pawhuska is a series of heavy ledges of limestone, which together form the Pawhuska formation. This formation extends from the Kansas line south across the Arkansas River as far as Ripley and Cushing south of the Cimarron River.

Above the Pawhuska there is a series of limestone formations which farther north in Kansas make up the Flint Hills. These rocks consist of limestones and shales, with a number of ledges of heavy flint and chert. To these ledges various names have been given, as the Wreford, Ft. Riley, Winfield and Herrington limestone. These formations outcrop in western Osage and eastern Kay counties, particularly along Beaver Creek and on the bluffs west of the Arkansas River. These limestones have been utilized at various times for building stone, for concrete rock and for ballast, and might be used for burning into lime and for the manufacture of Portland cement.

The Ozark Uplift: The second largest limestone area in Oklahoma occupies the region lying east of Grand River and north of the Arkansas. This is the area occupied by the southwestern extension of the Ozark uplift. The rocks in this region are chiefly of Mississippian age. Three prominent limestone ledges are found here.

The St. Clair marble, the only typical marble so far utilized in Oklahoma, occurs in some deep canyons west of Sallisaw Creek in northern Sequoyah and southern Cherokee county. This limestone is of Silurian age and has been brought to the surface by faulting. It is fine-grained, crystalline, white or gray marble, which takes a fine polish and makes a very handsome building stone. The Pioneer building at Oklahoma City was constructed of this marble The ledge is said to be 200 feet thick and it outcrops over several square miles.

By far the most prominent ledge of limestone in this section is known as the Boone chert. This formation outcrops on the surface in the greater part of Miami, Delaware, Adair, Cherokee and southeastern Mayes counties. It is the rock which forms the extensive upland plateau in this part of the State. Streams which rise on this plateau and flow south and west into the Arkansas and Grand rivers, have cut rather deep valleys making the surface in places quite uneven.

The Boone chert is exposed throughout the region along the sides of these valleys. This limestone varies in thickness from 150

to 300 feet. It is composed of white to gray, hard, brittle limestone. In the upper part of the formation the ledges contain numerous concretions of chert or flint, which weather out on the surface and being less soluble than the limestone, remain behind after the latter has been eroded and carried away. The lower part of the Boone consists of very pure limestone which would make a good building stone. It is the same ledge that has been quarried at Carthage, Missouri, and other points, and utilized in this way.

The Boone is succeeded by shales, and the shales in turn by another ledge of limestone known as the Pitkin limestone. This formation outcrops around the edge of the Ozark uplift, being exposed in southern Adair, Cherokee and Mayes, northern Sequoyah and extreme northeastern Muskogee counties. It usually lies on the hills in regions where the Boone is exposed in the valleys.

The Pitkin limestone is a dense, fossiliferous, fine-grained, gray to dark colored stone, averaging from 50 to 75 feet thick. It can be quarried in large blocks and would make a very handsome, durable building stone.

Succeeding the Pitkin are sandstones and shales and a few ledges of limestone in a formation which is known as the Morrow. This rock is exposed in Sequoyah, Cherokee, Muskogee and Mayes counties.

All of the limestone ledges referred to above contain stone that would be useful for the manufacture of Portland cement, for burning into lime and for building stone. There are, throughout the region described, many localities where Portland cement mills, lime kilns and stone crushers might be erected. So far as known, the only attempt to utilize any of this rock on an extensive scale, is the marble quarry at Marble City. There is a stone crusher at Keough near Ft. Gibson, and a quarry near Stillwell, where ballast has been obtained for the Kansas City Southern railroad.

The Wapanucka Limestone: One of the most valuable ledges of stone in Oklahoma is a formation known as the Wapanucka limestone, which is exposed in the southeast central part of the State. This formation is supposed to be of lower Pennsylvanian age. It lies just beneath the productive Coal Measures rocks. The western extension of the Wapanucka is in western Coal County, some miles west of the town of Coalgate. It is exposed throughout the region east of the Arbuckle Mountains, outcrops near Tupelo, Clarita, Bromide and Wapanucka. It extends as far southeast as old Boggy depot, in western Atoka County, where the formation is covered with Cretaceous deposits. In northern Atoka County the Wapanucka again appears on the surface near Stringtown and parallels the Missouri, Kansas and Texas Railroad from that point to Reynolds. From Reynolds to Hartshorne it extends south of and parallel to the Rock Island Railroad. From Hartshorne it runs east, south of Wilburton, about to the town of LeFlore.

The Wapanucka is about 300 to 500 feet thick and throughout the greater part of its outcrop is tilted at high angles so that the rocks usually stand on edge. In the western part of the exposure, that is, in Coal, Johnston and western Atoka counties, it is largely a high grade limestone. Near the town of Bromide, it is oolitic and would make a very fine building stone, equal if not superior to the Bedford stone of Indiana. In eastern Atoka, Pittsburg and Latimer counties, the rock is more sandy. Several ledges of hard, black, sandy shales are found interstratified with the limestone. The sandstone becomes more prominent farther east and in eastern Latimer and western LaFlore counties, the limestone practically disappears and gives way to sandstone.

For purposes of general utility, there is no more valuable stone in Oklahoma than the Wapanucka. Throughout the greater part of its course, it may be used for building stone. As exposed along Delaware Creek, near Bromide, there is a solid ledge 50 to 70 feet thick, of a very white, medium grained oolite, a very desirable building stone. At the town of Wapanucka, the stone has been utilized for burning into lime. At Limestone Gap the Missouri, Kansas and Texas Railroad has had a crusher for 20 years and large amounts of stone have been taken out, chiefly for ballast and concrete work. At Hartshorne and near Wilburton lime has been burned at various times. The Choctaw Portland Cement Co. has a plant in operation at Hartshorne.

There is enough rock in this ledge to supply Oklahoma with lime, Portland cement, building stone, concrete rock, ballast and other similar products for many generations.

Cretaceous Area: Limestones are found in southern Oklahoma in the region between the Arbuckle and Ouachita mountains on the north and Red River on the south. The rocks in this country are of Cretaceous age, consisting of sandstones, limestones and shales. There are three rather prominent limestone formations in this area, known as the Goodland, Caddo and Bennington limestones.

The Goodland limestone, the lower of the three ledges, is usually a pure white semi-crystalline rock containing large numbers of fossils. The formation is about 25 feet in thickness. It has been quarried at various places for building stone and has been burned into lime.

The Caddo limestone is composed of white, bluish and yellowish limestone, shell beds and several beds of marl and clay. The total thickness of the formation is about 150 feet. The lime contains many fossil shells.

The upper limestone of the Cretaceous area is known as the Bennington limestone. It is a massive dull-blue limestone, rarely exceeding 10 feet in thickness. It is composed largely of fossil shells.

These three limestones all lie nearly level or dip at low angles to the south. They outcrop as a broad band extending from Love

and Carter counties on the west, across Marshall, southern Johnston and Atoka, northern Bryan and Choctaw and southern McCurtain counties to the Arkansas line. Throughout this region all of these ledges have been quarried at various times, and many buildings have been erected of this limestone. Lime has been burned from the various members.

The Arbuckle Mountains

The most extensive limestone deposits in Oklahoma are in the Arbuckle Mountains. The Arbuckle Mountain uplift includes an area of 800 square miles in Oklahoma, located in southern Pontotoc, western Coal, northern Johnston, northeastern Carter and eastern Murray counties. The rocks in the Arbuckle Mountains are granite, limestone, sandstone and shale. There are four heavy limestone ledges known as the Arbuckle, Viola, Hunton and Sycamore. The map in Fig. 7 shows the location of the various ledges of limestone in the Arbuckles. These have been described at various times by different geologists. No better description will be found than that of Joseph A. Taff, which will be given herewith.[1]

"The Arbuckle limestone, which lies above the Reagan, is one of the thickest ledges of limestone in the world. The exact thickness is not known but it is certainly more than a mile.

"The Arbuckle formation is composed chiefly of hard bluish-white and cream-colored limestone and dolomite, with a thickness ranging from thin layers of a few inches to beds of 2 to 3 feet, interstratified with slightly argillaceous layers. Occasional siliceous limestone and shale beds were noted. Chert and cherty oolites and limestone breccia are less common and intraformational conglomerate in thin layers occurs rarely at the base.

"Beginning at the base, there are thin-bedded siliceous limestones 50 feet thick. There is a gradual change upward from these thin beds into the succeeding member, 300 to 400 feet thick, which consists chiefly of heavy-bedded, dull-bluish and cream-colored dolomites. Many of these massive beds are indistinctly bedded and weather into very irregular brown and sometimes nearly black boulders. Others are more crystalline, marble-like and of pinkish or gray colors. Succeeding these come about 250 feet of thin-bedded granular limestones and compact blue limestones which pass gradually into the main body of the formation, consisting of 2500 to 4000 feet of massive, compact magnesian limestone, the lower half of which contains chert in places. These limestones on weathering usually present smooth, white surfaces of practically the same color as the fresh rock. As the top of this thick member is approached, the limestone beds become less magnesian and thinner and are succeeded by the highest member, which is composed of limestones interstratified with occasional sandy beds and strata of red, yellow, and green clays."

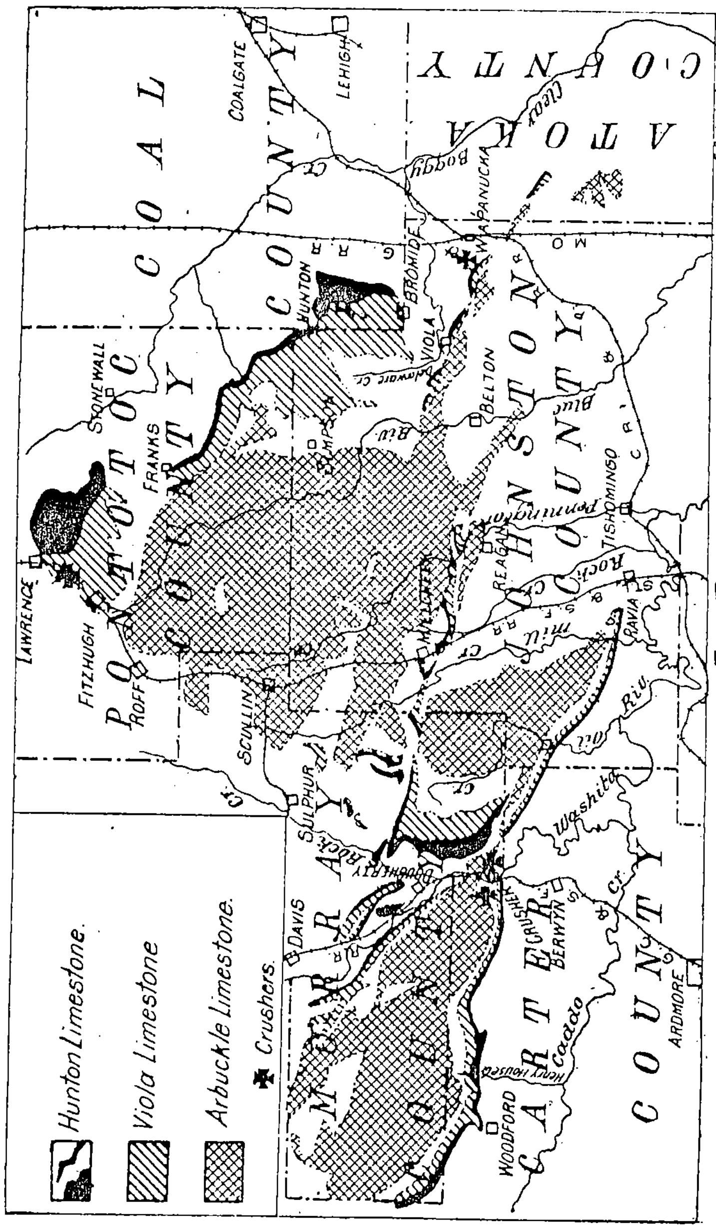


FIG. 7
LOCATION OF LIMESTONE IN ARBUCKLE MOUNTAINS.

0 5 10 20 MILES

The Arbuckle limestone is exposed in the Arbuckle Mountains as a broad, rocky plateau, covered with limestone in southern Murray, northern Johnston and southern Pontotoc counties. In the Wichita Mountains, a range of high rocky hills, extending from near Apache northwest nearly to Rainy Mountain Mission is made up of the Arbuckle. Several small rounded knobs lying southwest of the main granite peaks, several miles northwest of Lawton are also composed of this limestone.

The next limestone in the geologic column, as exposed in the Arbuckle and Wichita Mountains, is the Viola. Mr. Taff describes it thus:

"This formation is approximately 700 feet thick and represents a continuous but slightly variable deposition of limestone. The upper and lower parts, each approximately one-third of the formation in thickness, are composed of thicker and less evenly stratified beds than is the middle part. In fresh exposures, the limestone is massive in appearance. On weathered surfaces the bedding is more pronounced. The layers range in thickness from thin strata to beds rarely more than a foot, and with them are occasional irregular bands and nodular masses of chert. This chert is usually most abundant in the lower and middle parts of the formation. The texture of the middle part of this limestone is generally dense and fine. Some of the beds, especially of the upper part of the formation, are uneven, earthy and coarsely crystalline, while others are composed largely of fossil shell fragments and shells.

"There is a gradual transition from a thin-bedded, platy limestone belonging to the Simpson formation upward into the thicker beds of the Viola limestone, while at the top there is an abrupt change from the limestone to the dark-bluish or greenish clay shales of the succeeding Sylvan formation."

In the Arbuckles, the Viola is easily characterized by the fact that it usually weathers out into high rounded knobs, which are so conspicuous that they are easily recognized. In the Wichitas three rounded hills near Rainy Mountain Mission are composed of Viola rocks. The Viola is of upper Ordovician age, as shown by the fossils.

The Hunton limestone, which lies just above the Sylvan shale, is one of the most interesting formations in Oklahoma. It consists typically of three parts, a lower limestone member, a middle shale member and an upper limestone member. Mr. Taff's description follows:

"This formation is composed of thick- and thin-bedded light-blue to cream-colored limestone, shaly limestone and marl. It is stratigraphically divisible into three fairly well defined members. These members are distinct as a result of the changes in lithologic characters and of the difference of hardness of beds.

"The basal member consists of whitish, massive, crystalline limestone which in places includes a bed of oolite at or near the base. A thin-bedded, compact limestone usually may be found at the top. In the Tishomingo quadrangle this member ranges in thickness from thin beds to strata about 25 feet thick.

"The middle member is composed of white or cream-colored and occasionally pinkish, rather soft limestone beds interstratified with more friable marly lime and rarely calcareous clay, aggregating an average thickness of about 100 feet. This member on account of the softness of the beds, usually outcrops in swales or depressions between the harder members on each side. The variability in hardness of different beds, however, causes them to be exposed in miniature terraces and slopes.

"The middle member grades upward through a few feet of marly white limestone into the top member, which consists of crystalline and in part cherty, bluish to white limestone with accasional thin marly strata. In places this crystalline limestone is overlain by several feet of very cherty limestone. Much of the chert in this limestone is flinty and massive and weathers in angular boulders after the beds that contained it have decomposed.

"The Hunton limestone varies in thickness from 0 to 200 feet; an average is approximately 150 feet. In the vicinity of Sylvan it is absent along the outcrop of contiguous formations for about 10 miles. While certain beds both at the top and bottom of the Hunton limestone seem to be absent in places, the variation in thickness is to be ascribed chiefly to changes in volume of intervening beds."

The Hunton outcrops along the rim of the Arbuckle mountains as a long narrow prairie ridge, sometimes two ridges, lying between the Sylvan shale valley and the rounded, jack oak-covered hills of the Woodford. This narrow grass covered ridge may often be traced for miles along the base of the mountain and is always easily recognized. Fossils show that the Hunton ranges in age from the Silurian to the Devonian.

The Sycamore limestone lies above the Woodford chert. Mr. Taff describes it as follows:

"The Sycamore limestone is separated into rather thin beds, a foot, more or less, in thickness. It is a dense, even textured, bluish limestone, which weathers to yellowish hues and is hard and tough. The beds break down usually into small rudely rhomboidal blocks as a result of jointing running obliquely to the bedding. Wherever present the limestone is always exposed in prominent, narrow and generally level-crested ridges. No fossil remains that could be determined have been found in this limestone."

In many places the Sycamore is not exposed. It is never a conspicuous formation. The age is supposed to be Mississippian.

The limestone in the Arbuckle Mountains is destined to become one of Oklahoma's most valuable resources. At the present time, however, very little of this material has been utilized. The most extensive operations are at Crusher, in Murray County, in

the Washita gorge. Two extensive limestone crushers are in operation at this place and much of the concrete material for building in Oklahoma City, Shawnee and other towns in the State, come from these crushers. A crusher has been in operation intermittently for many years near Fitzhugh. Material for concrete work, railroad ballast and other purposes has been obtained here. A crusher has been operating near Wapanucka also, the material being used for ballast. The Oklahoma Portland Cement plant at Ada secures its limestone from a quarry in the Viola limestone at Lawrence, 6 miles south of Ada. Building stone has been quarried near Sulphur, Dougherty, and Millcreek. There is enough limestone in these mountains to supply the world.

Wichita Mountain Uplift

In the Wichita Mountains, the Arbuckle and Viola limestones occur. Mr. Taff described these formations as follows:

"The Arbuckle limestone is composed of a practically continuous succession of limestone beds, usually less than 5 feet in thickness and aggregating 4,000 to 6,000 feet. The individual beds vary from dense, fine-grained, white limestone to cream-colored dolomitic limestones interstratified with slightly argillaceous and siliceous lime beds, which are usually not so hard. Occasional cherty limestones, and more rarely thin beds of chert, occur. As a result of the variable hardness of the beds, the more resistant ones have a relief which rarely exceeds 5 to 6 feet. A complete section of the formation is not exposed in the region." [1]

The principal exposure of these limestones in the Wichita Mountain region, is in a range of hills about 30 miles long, lying north of the east end of the main range of granite peaks. The hills extend from near Lawton, northwest to Rainy Mountain Mission. Small exposures also occur a mile southeast of Fort Sill and in several rounded hills lying south of Signal Mountain, 5 to 8 miles northwest of Lawton.

There has been no extensive development of the limestone rocks in the Wichita Mountains. A quarry near Fort Sill, located in an exposure of the Viola limestone, furnishes stone for the buildings at that place. A crusher now in operation at Richards Spur, north of Fort Sill supplies ballast and concrete rock. A small amount of limestone has been quarried near Rainy Mountain and Lawton for building purposes. All of this rock is suitable for burning into lime, for Portland cement and for many other uses.

1. The quotations are from Mr. Taff's report entitled Geology of the Arbuckle and Wichita Mountains, etc. Professional Paper No. 31, U. S. G. S. Pages 25-31.

CHAPTER VII.

CLAYS OF OKLAHOMA

By L. C. Snider

Nature and Origin of Clays

Clay is a complex mixture of various minerals, which are derived from the decay of other rocks. It is usually defined as a rock which possesses a sufficient amount of the mineral kaolinite to impart its characteristics to the mass to a noticeable degree, and which does not contain a sufficient quantity of any other substance to serve as a commercial source for that substance.

Clays are originally derived from igneous or crystalline rocks, which constitute the core of mountain ranges and underlie all the other rocks at different distances below the surface. These igneous rocks contain large quantities of minerals known as feldspars, which are silicates of alumina, with soda, potash, and lime in varying quantities. When these feldspars are acted upon by the weathering agencies, they are broken down and the potash, soda, and lime are carried away by the circulating waters, and the silica and alumina is left behind in a compound known as kaolinite, which is a hydrated silicate of alumina.

Many other minerals besides the feldspars are present in the igneous rocks, some of which, on weathering form kaolinite, while others give rise to iron compounds and quartz (sand). Other compounds may be present in the clay in less quantity.

Clay, then, is a mixture of kaolinite and several other minerals, among which are quartz (sand), undecomposed feldspars, mica, iron oxide and carbonate, calcium carbonate and sulphate, magnesium carbonate and sulphate, and organic matter.

Kinds of Clay

If the clay remains where it is formed it is called **residual** or **indigenous** clay. Indigenous clays are usually pure, except for sand which is easily removed by washing, white in color and easily worked . They are called kaolins or china clays, and are used in the manufacture of pottery and high grade ware. Small deposits of kaolin are known in the Arbuckle and Wichita mountains, but no deposits of commercial importance have yet been discovered in this State.

If the deposit is in a position to be acted on by running water, the clay will be carried away by the water. It may be carried to the foot of the hill or slope and deposited as a **colluvial** clay, or may be carried farther down by stream action and deposited in the valley as **alluvial** clay. In former geological ages immense quantities of clay were carried down by the streams to the ocean, and deposited as beds of soft mud. Other beds of mud, sand, or lime were deposited on top of them and, later, the whole was elevated above sea level and became land. The beds of mud were consolidated by the pressure of the beds above them. This consolidated mud is known as **shale.** The glaciers, which covered the northern part of the United States, ground up enormous quantities of rock and, so formed vast deposits of **glacial clay.** None of this material is found in Oklahoma. Colluvial, alluvial and glacial clays, and shale are called **transported clays,** because they have been removed from the place where they were formed from the parent rock. All transported clays are more or less impure, owing to their mixture with various foreign substances in transportation. Another type of clay is that found underneath veins of coal. This clay is the old muck bottom of the swamps in which the coal forming plants grew. The roots of the plants and the stagnant water of the swamps leached the lime and iron compounds out of the clay leaving it very pure. The best fire clays occur under coal veins, although all clays occurring in this way are not fire clays.

Mineralogical Composition

The mineralogical composition of clays has already been noticed very briefly. The essential constituent is **kaolinite,** the hydrous silicate of alumina, which is the cause of the plastic property of the clay and is also largely responsible for the refractory or heat-resisting properties. It is a white soft mineral with a greasy feel. Iron occurs as ferric oxide, ferric sulphide and ferrous carbonate. The ferric oxide produces the red color in so many of the clays in Oklahoma. Ferrous carbonate occurs in many shales. It melts very easily and may give rise to much trouble in burning, if it is present in considerable amounts. All clays containing over 3 or 4 per cent. of iron burn to a red color, unless sufficient lime is present to unite with the iron, upon which a buff color may be produced.

Iron is also present in **mica,** producing a very dark red color in the burned ware. **Lime** may be present as calcium carbonate (limestone) and calcium sulphate (gypsum.) In burning, the carbonate is changed to the oxide which, if finely divided and disseminated throughout the clay, acts as a flux, causing the clay to melt rapidly at a low temperature. The lime, if in large pieces, slakes and swells on becoming wet and may cause the brick to crumble. If lime is in excess of iron in the clay, the two substances combine, forming a yellow compound, thus producing buff colored brick. The calcium sulphate acts as a flux and is liable to produce swelling of the ware, by the action of the sulphur dioxide gas, which it liberates.

It also causes scumming or whitewash on the bricks. **Magnesium** compounds behave similarly to those of calcium but are less active. **Quartz,** in the form of sand, is present in practically all clays. When added to a very pure clay it decreases the melting point, but has the opposite effect on impure clays. It is often added to clays to decrease the shrinkage and to prevent cracking in drying. Very sandy clays, however, show a marked tendency to crack in burning.

Physical Properties of Raw and Burned Clays

The principal physical properties of clays, which may effect its working or burning qualities, are plasticity, bending power, fineness of grain, shrinkage, slaking, feel, and color.

Plasticity is that property of a clay which allows it to be molded into any shape while wet, and enables it to hold that shape when dry, with sufficient strength to allow handling. It is this property which distinguishes clays from practically all other mineral substances, and makes it suitable for the various uses to which it is put. Many theories have been advanced to account for the plasticity of clays. At present it is usually considered, that plasticity is due to the presence of jelly-like substances, or colloids. The latter absorb water and retain any salts which may be present therein.

These salts greatly increase the viscosity of the water film surrounding the clay particles, and so produce plasticity. Fineness of grain and shape of grain are conditioning factors of plasticity. Plasticity is determined, practically, by the feel of a wet lump of clay.

By **bonding power** is meant the power of a clay to be mixed with non-plastic material, thus rendering the whole mass plastic. It is an important property in clays used for the manufacture of fire brick, and also in clays which are mixed with sand or other non-plastic materials in order to render them less plastic. As a rule the more plastic the clay, the greater is the bonding power; but there are many exceptions to this general rule.

Fineness of grain is important in several ways. Other things being equal the finer grained clays will be the more plastic; will have greater shrinkage; are more liable to crack in drying; will vitrify and melt more rapidly; and will produce denser ware, than the coarser grained clays.

Drying shrinkage: When a clay is in the wet, plastic condition the grains are separated from each other by a film of water. In drying, this water is removed allowing the grains to move together. This produces a shrinkage, sometimes as great as 30 per cent of the wet length in plastic, fine grained clays; but which may

be almost zero in sandy clays. Excessive shrinkage may cause the pieces of ware to crack in drying. Sand is often added to clays to decrease the shrinkage.

Slaking: When a lump of dry, surface clay is put in water it rapidly crumbles to a shapeless mass. This is called slaking. Shales slake very slowly and some clays, flint fire clays, for instance, do not slake at all. The rate of slaking often gives some idea as to the amount of grinding and preparation a clay will require for molding.

Feel: The feel of a wet and dry clay will often give approximate ideas of its plasticity and working properties.

Color: The color of the raw clay cannot be depended upon to indicate the color of the burned ware. As a rule clays which are red in the raw state will burn red, but there are a few exceptions to this rule, thus it is impossible to predict with certainty, the burned color from the raw colors except in case of the red known to be due to iron.

The important properties of burned clay, are color, specific gravity, porosity, hardness, toughness, crushing strength, and tensile strength. For some wares an attractive, clean color is necessary, while for others the color is of little importance. The crushing and the tensile strength is important in structural clay products such as brick, fire proofing, etc., although there is comparatively little trouble with clay products from lack of strength. The porosity is an important factor in face brick, paving brick and sewer pipe. When a clay is burned, the change in porosity with increasing heat is a valuable indication of the properties of the clay.

Processes of Winning and Manufacture

Clays may be won in a variety of ways. Surface clays are often worked with hand shovels and wheel barrows, with scrapers, and in some instances with wagons. Soft shales are often worked by means of steam shovels. They may be hauled to the plant in dump cars, drawn usually by a wire rope attached to a winding drum at the plant. At some plants the cars are hauled by an electric motor car, the power being furnished by a trolley or third rail. Fire clays are mined in the same manner as coal.

Clays are molded by three different processes; the soft mud, stiff mud and dry press. In the soft mud process, as the name indicates, the clay is made a soft mud, and is thrown by hand into the molds of the desired shape. Machines using soft mud, force the wet clay into molds by means of a plunger. Brick is the only product that is made by the soft mud process. In the stiff mud process, the clay after grinding, is mixed with enough water to form so stiff a mud that it will not be deformed by handling. It is then pushed through a die, of the desired shape, by a plunger or an auger machine. The clay issues from the die in the form of a bar, and is cut into sections of the desired size by cutters, usually of wire. The great mass of clay ware is made by this process. In the dry press process, the clay is only sufficiently moist to retain its shape after being pressed. The clay is fed into molds and subjected to great pressure. Brick and electrical porcelain are formed in this way.

After being formed, the ware must be dried and burned. Any discussion of the methods of drying and burning would be too long, and not of sufficient general interest, to have a place in this connection.

Clay Products and Their Uses

The number of uses, to which clay in the raw and burned state is put, is so great that only a few of the more important can be mentioned here. These are, common and front brick, paving brick, drain tile, sewer pipe, fire proofing and hollow block, terra cotta, roofing tile, stone ware, and fire brick.

Practically any clay can be used to make common brick, but those are usually selected, which make the cost of manufacture as low as possible. They should be easily accessible to transportation, should work easily and burn hard at a low temperature. Clays suitable for common brick are found in abundance in practically every county in Oklahoma. Front brick and face brick must have a pleasing color and be of uniform size, with smooth surfaces. As a rule the porosity of face brick is less than that of common brick. Both common and face brick may be made by any of the three processes, soft mud, stiff mud or dry press. Face brick, made by either the soft or stiff mud processes, are usually repressed to give smooth faces and straight edges.

Pottery and stoneware are made of high grade clays that usually burn to a dense body, with a white or light buff color. The glaze is formed by dipping the pieces of dried or of soft burned ware into a thin "slip" of easily melted clay or mixture of different mineral substances. After drying the pieces are again burned, causing the thin layer of the glazing material, which adheres to the ware, to melt and form the glaze. Pottery and stone ware are usually molded by machines, although hand molding is often resorted to. There are many variations of the process.

Fire brick are made of clays, that are very difficult to melt. Large amounts of "grog," i. e., broken pottery, old fire brick, etc., are often used to make fire brick, with only sufficient plastic clay to produce a bond capable of holding the mass together. Fire brick are usually hand molded. They are used for setting boilers and for lining kilns and furnaces.

The Clays of Oklahoma

For the consideration of the clay resources, the State may be divided into the following section which are shown in Fig. 8: (1)

Arbuckle and Wichita Mountains; (2) Ouachita Mountains; (3) Ozark Uplift; (4) Pennsylvanian Region; (5) Redbeds or western region. These will be discussed in turn.

The Arbuckle Mountains in south-central Oklahoma consist of a central core of granite surrounded by formations of limestone, sandstone and shale. These are usually steeply tilted. The only formations in the mountains important from a clay-working standpoint, are the Simpson and the Sylvan.

The Simpson formation consists of three heavy ledges of sandstone, separated by limestones and shales. The shales are usually thin, but in some cases are thick enough to be utilized, although none of them are worked at present. They are well exposed along the Santa Fe Railroad just south of Crusher in Murray County. Here they are light brown to gray shales and from appearance would be suitable for either brick or tile. No tests have as yet been made. Near Ravia, along the Frisco Railroad in Johnston County, a ledge of the Simpson shale is exposed. It is about 40 feet thick and stands practically on edge. It is light-brown colored clay shale, of excellent working, drying and burning qualities. It burns to a peculiar dark buff color and is well adapted for common or front brick, fire proofing or drain tile.

The Sylvan shale is 100 to 300 feet thick, the mass of which is a blue clay shale. It is accessible from both the Santa Fe and Frisco railroads. At Lawrence, near Ada, the Oklahoma Portland Cement Company secures its shale from the Sylvan formation. It is similar in appearance to the shale at Ravia. Chemical analysis shows it to be a very pure clay shale, low in iron. It would burn to a buff color, but to the writer's knowledge no burning tests have as yet been made. So far no clay products have been manufactured from the Sylvan.

Extensive deposits of shale are not known to occur in the Wichita Mountains. Some deposits of kaolin have been reported from the region near Roosevelt and Cooperton, but none, of sufficient size to be commercially important, have so far been found.

The Ouachita Mountain Region: The Ouachita Mountains in the southeastern part of the State consist of five formations, the Stringtown shale, Talihina chert, Standley shale, Jackfork sandstone and Caney shale. The Stringtown shale is only exposed in small areas and is not at present known to be available for manufacture . The Talihina chert contains considerable shale near the middle of the formation; but not enough field work has been done to determine whether or not this could be utilized. The Standley shale is reported to be 6,100 feet in thickness. The formation contains considerable sandstone, but there is in it an immense amount of shale suitable for clay products. The lower portion of the formation is well exposed about one mile north of Antlers, at which place the Frisco Railroad crosses a ledge of fissile, black shale over 100 feet in thickness. The shale dips steeply to the southeast, but

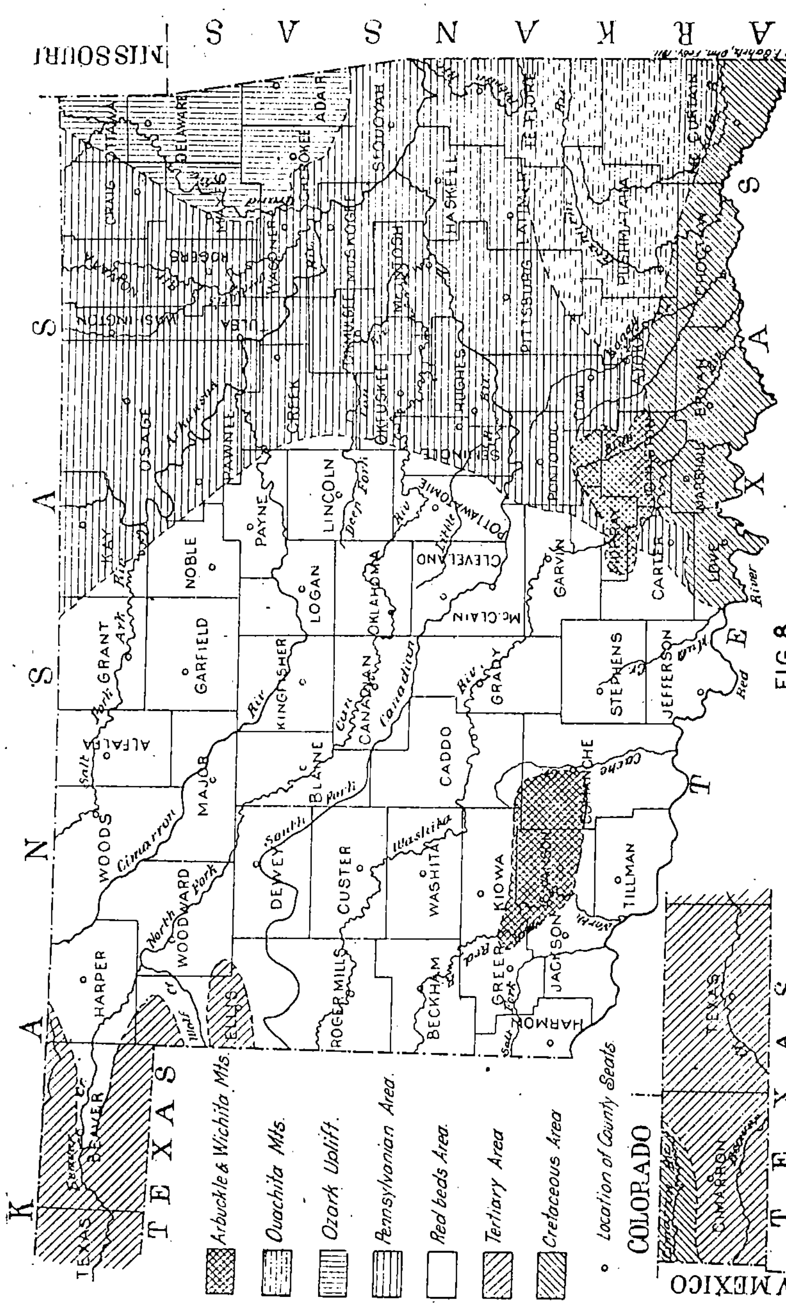


FIG. 8
LOCATION OF CLAYS IN OKLAHOMA.

an unlimited supply is in sight without excessive stripping. The shale works and burns nicely, vitrifies at a low temperature, and has a bright, light red color with a pronounced self glaze. This is the only exposure of the Standley shale observed by the writer, but more extensive field work will doubtless reveal other favorable localities, as the formation is very thick and is exposed over wide areas.

The Jackfork sandstone, 3800 feet thick, contains some thin shale beds, but not sufficient to be considered in this connection.

The Caney shale is a blue to black, fissile clay shale occurring in the level plains south and west of Wapanucka and also a few miles north of the same town. There are also several exposures along the north side of the Ouachita Mountains, farther east. The shale is described by Taff [1] as follows:

"The Caney shale in its lower part consists of black, bituminous, fissile shale with spherical calcareous segregations and irregular dense blue limestone bodies. This bituminous shale is succeeded by clay shales which include small ironstone concretions and occasional calcareous septaria."

No tests have been made on the Caney shale but from the description, owing to the lime concretions, it can be considered suitable only for the lower grade clay products.

The coal fields lie just north of the Ouachita Mountains, also much of the area is heavily wooded, so that the question of fuel is not a serious one in this region. The Frisco Railroad crosses the mountains from north to south, following the valley of the Kiamichi River. Development of clay industries in this section will necessarily be along this railroad.

The Ozark Uplift: The portion of Oklahoma occupied by rocks of the Ozark Uplift is the extreme northeast part of the State, comprising all of Ottawa and Delaware counties and parts of Craig, Mayes, Cherokee and Adair. The surface rocks are of Mississippian age. Locally the streams have cut through the Mississippian rocks into the underlying rocks of Devonian, Silurian and Ordovician age, but the exposures of these older rocks are small in area and, with possibly one exception, are not near enough to transportation to render them available for development.

The Chattanooga shale, of Devonian age, is exposed for several miles along Barren Fork of Illinois River in T. 17 N., R. 24 E. The Muskogee branch of the Frisco Railroad follows the outcrop of this shale. It is probable that a thorough examination would show locations along this road, where this shale might be developed. The shale is a fissile, black shale and should be available for the manufacture of the ordinary clay products.

The principal formation of Mississippian age in this region is the Boone formation. The latter is composed of chert and lime-

1. Geol. Atlas of the U. S., Atoka Folio.

stone, 100 to 375 feet in thickness. This is exposed over large areas comprising the mass of the country rock. It contains no shale.

Many of the higher hills are capped by the Fayetteville shale which contains a sandstone member of considerable thickness. The Fayetteville shale is exposed in several favorable localities. A sample taken near Miami, presumably from this formation, shows properties resembling a No. 3 fire clay. It would make paving brick, sewer pipe, or fire proofing. Its color is unsatisfactory for face brick or roofing tile. There are many other localities where similar shale is exposed, near transportation, that could be developed. The same shale is exposed along the Missouri Pacific Railroad near Fort Gibson.

The greater portion of this area is wooded, while gas, oil and coal, although not occurring in the immediate region, are near at hand. The Kansas City Southern and two lines of the Frisco Railroad provide transportation.

The Pennsylvanian Area: The portion of Oklahoma occupied by rocks of Pennsylvanian age include that part of the State lying north of the Arbuckle and Ouachita mountains, west of Grand River, and east of the Redbeds. The area is separated into two parts by the Arkansas River.

Along the Kansas line, the rocks consist of alternating limestones and shales with occasional sandstones. The sandstones and shales thicken to the south, and new ledges appear while the limestones thin out and disappear, so that south of the Arkansas River there is an immense thickness of sandstone and shale with only an occasional limestone lens. Shales make up three-fourths of the Pennsylvanian rocks, the majority of them being suitable for manufacture. The outcrops of these shales enter the State from Kansas and extend slightly west of south, and gradually broaden, due to the thickening toward the south mentioned above. Some of the principal shale formations are the Vinita formation (Cherokee shales of the Kansas geologists), Labette shales, the Nowata shales, the Curl formation and the Copan member of the Wann formation. These formations extend westward to approximately the line between Washington and Osage counties. In eastern Osage county there is a succession of shales and sandstones, typical exposures being at Avant, Big Heart, Nelagony and Pawhuska. West of Pawhuska, limestones come in again and form a large part of the rocks in western Osage and eastern Kay counties, although they soon pinch out to the south. The shales of this section are sometimes calcareous and are not so important as those farther east.

In the coal fields farther south the following section is given by Taff in the Coalgate folio:

Calvin sandstone	200	Feet.
Senora formation	500	Feet.
Stuart shale	250	Feet.
Thurman sandstone	200	Feet.
Boggy shale	2000	Feet.
Savanna sandstone	1200	Feet.
McAlester shales	2000	Feet.
Hartshorne sandstone	200	Feet.
Atoka formation	3000	Feet.
Total	9550	Feet.

Farther north in the Muskogee quadrangle Taff names the Winslow and the Boggy formations, the Winslow being the equivalent of the Hartshorne, McAlester and Savanna.

From this brief review of the stratigraphy of the region it is evident that there are immense beds of shale in this part of the State and that these beds are available to transportation and fuel, since they lie in the great coal, oil and gas producing region of Oklahoma. Most of the clay industries are now located in this region and no doubt the greater portion of the development of such industries will take place here.

Plants are in operation at several localities north of the Arkansas River. Bartlesville, Nowata, Claremore, Vinita, Tulsa, Pawhuska, Broken Arrow, Collinsville and Pryor Creek have plants that produce common and building brick, and in some cases, sidewalk and paving brick. South of Arkansas River, Cleveland, Sapulpa, Okmulgee, Wainwright, Boynton, McAlester, Poteau and Ada have plants. There is a plant at Ardmore that uses shale from an area of Pennsylvanian rocks southwest of the Arbuckle Mountains. Other places where shales are exposed, but are not now being worked, are Avant, Big Heart, Nelagony, Ramona, Henryetta, Ochelata and Holdenville.

Practically all these shales, and the surface clays derived from them, have good working, and drying properties and also burn to good red colors. Locally some of the shales seem to contain so much soluble salts that the ware whitewashes badly in drying. As a rule, however, any of these shales can be depended upon to make drain tile, and common or building brick, while many of them can be used for more refractory ware, such as sidewalk and paving brick, sewer pipe, roofing tile, etc. The clays underlying the coal veins, so far as tested, do not prove to be high-grade fire clays. Some of them contain so much carbonaceous matter that it would be impossible to oxidize them in commercial kilns. The thicker veins however, prove to be very valuable material for paving brick, sewer pipe, fire proofing, etc. In some cases these clays burn to dark red colors very pleasing for face brick.

The Permian or Redbeds Area: The Permian or Redbeds area includes practically all of the State west of a line passing through or near Blackwell, Ponca, Pawnee, Stroud, Prague, Byars and Davis and west around the Arbuckle Mountains and south to Red River. The Wichita Mountains consist of older rocks surrounded by Redbeds. There are deposits of Cretaceous age on the hills of some of the counties in the western part of the State and there are Tertiary deposits in the extreme western part of the State. With these exceptions practically all the rocks of this area are of Permian age.

The Redbeds consist of a great, but unknown, thickness of red clay shales with lenticular masses of red sandstone and ledges of gypsum. There is little continuity of ledges except in the cases of some of the gypsum beds. A ledge of shale or sandstone many feet in thickness in one locality may thin rapidly in both directions or merge into other ledges, so that it can be traced only a short distance. Three-fourths or more of the Redbeds consist of soft red clay shale, the red color being due to the presence of oxide of iron. The latter may constitute as high as 10 or 12 per cent of the rock. On account of this iron, none of the Redbeds shales are suitable for refractory materials, and their extremely fine grain usually renders them too dense and brittle after burning to make good paving brick. These factors practically limit their range of use to common and front brick, drain tile and irrigation tile and possibly fire proofing or hollow block and roofing tile. Some of these clays give fine dark red colors, for example those burned at Oklahoma City and Comanche, while others especially in the region of the Gypsum Hills whitewash badly and show a tendency to puff and swell in burning, on account of the gypsum in the clay. The question of fuel is a very serious one in this region and several plants have shut down on this account. There is no oil or gas and coal must be shipped in from the McAlester district or from Kansas.

Brick plants are now located at Enid, Guthrie, Oklahoma City, Chickasha, Marlow, Addington, Comanche, Waurika, Alva, Geary, Hobart, Blackwell and Mangum. Most of these plants make dry press brick. Several of them are in operation only part of the time. Other towns in the Redbeds have had plants which have ceased operations from various causes.

The Cretaceous Area: This region lies along Red River south of the Arbuckle and Ouachita Mountains. There are several ledges of shale which extend from west to east. The majority of these shales are very calcareous and could not be used for vitrified products, but would be all right for common brick. Ledges of considerable thickness near Durant and Woodville contain shale which can be vitrified safely. The red sandy clay which forms the surface soil near the Red River is suitable for the manufacture of common brick by the soft mud process. Wood is plentiful over much of the area.

General Summary.

In the development of any center of the clay industry there are at least four essential factors to be noted. These are first, the supply of raw material; second, fuel; third, transportation facilities and, fourth, markets. Oklahoma possesses advantages in all of these essential features, which should make it one of the great centers of the clay working industries.

In the matter of raw material, Oklahoma is certainly as well supplied as any other state. The eastern portion of the State, except the extreme southern part, is underlaid by the sandstones and shales of the Carboniferous system. These shales are of the same age as those of Ohio and Pennsylvania. Some of them are the continuation of the beds that are worked with excellent results at Cherryvale and Coffeyville, Kansas. The beds are often many feet in thickness and easily accessible. The few tests that have been made, show that practically all of these shales are suitable for either building, or front brick, paving brick, drain tile, or hollow ware. These shales are usually gray to black in color and have fine working and burning properties. Practically all of them burn to a good red color.

The rocks of the greater part of western Oklahoma consist of the Redbeds. The latter are made up of a great mass of red clay shales with a few intervening ledges of some other material, usually sandstone, gypsum or dolomite. The red color of this shale is due to the presence of iron.

Chemical analyses show that in certain cases the amount of iron in the shale is as much as 15 to 20 per cent. The clays from the gypsum region often contain sufficient gypsum to cause them to whitewash badly, when made by the stiff mud or soft mud process, and also show a pronounced tendency to puff and swell during burning. The chief difficulty in the way of manufacturing brick in the Redbeds, is the lack of cheap fuel. There is no coal in the region, the nearest mines being at McAlester, 140 miles southeast of Oklahoma City. A little gas has been found at Gotebo and Lawton, but, so far, not in large amounts. There is little to warrant the hope that fuel of any kind will be found in anything like paying quantities in the Redbeds. Freight rates on coal have been high, while a very reasonable rate has been secured on gas-burned brick from Cherryvale and Coffeyville, Kansas, into Oklahoma. For these reasons a number of the plants in western Oklahoma have been abandoned.

In the south portion of the State, along Red River, east from Marietta, the shales occur usually in thinner beds than in the eastern portion, but there are many localities with beds of workable thickness, well situated with regard to fuel and transportation. Many of these ledges are suitable for clay products, but some of them contain so much lime that they are very difficult to work. The shale should be carefully tested before an attempt is made to locate a plant in this region.

In regard to the second essential factor, the fuel, it is only necessary to state that the northeastern portion where the Carboniferous shales occur in greatest abundance, is in the midst of the world's greatest oil and gas field. The gas can be obtained, for manufacturing purposes, at a few cents per thousand feet. The field is being constantly enlarged and shows no signs of failure in supply. There are also smaller fields in the southwest and south central parts of the State. Just south of the oil and gas belt lie the coal fields, which will supply an abundance of cheap fuel for years to come. The western portion is not so fortunate in this respect, but in no part would the cost of fuel be prohibitive.

All parts of Oklahoma are well supplied with railroads, the eastern portion, where the better shales and the fuel are most plentiful, being especially so. The main lines of the M. K. & T. and the Frisco systems traverse this portion of the State from north to south, and each system has many branches or cross lines which connect them at several points. The Iron Mountain has a line from St. Louis to Ft. Smith, and the Midland Valley crosses the oil field from northwest to southeast. The Fort Smith & Western and Rock Island give east and west connections through the coal fields. Through the Redbeds region, the Santa Fe, Rock Island, Frisco and Orient give excellent connections in all directions.

In regard to the markets it should be noted that the rapid growth of such cities as Oklahoma City, Muskogee, Tulsa, McAlester, Enid, Ardmore, Durant and many others, creates a demand which is much larger than the supply. Several plants have been installed in the State, but over one-half the brick and all the other clay products used, are still imported from the older states. No one, who has investigated the conditions, doubts that the area of permanent building in the State is just beginning and that the demand for all sorts of architectural clay products will steadily increase. No farm drainage has been done and few roads built. Drain tile and sewer pipe will be used in constantly increasing amounts, for drainage and culverts on roads, and for draining farm lands. There is also a new field opening in the use of tile for subirrigation.

The combined product of all the plants at present does not supply the local demand for building and paving brick; and hundreds of thousands of brick are imported from Kansas into the region each year. These brick are hauled in some cases two or three hundreds of miles through a country, having just as good shale as that from which the brick was made, and also having inexhaustible quantities of cheap fuel. All of the sewer pipe, drain tile, hollow block, fire proofing or terra cotta used in the State is manufactured outside the State, although it has the clay and the

fuel required to make such products as cheaply as they can be made elsewhere.

With very few exceptions all the clays tested from the State are red or very dark buff burning clays. At present no deposits of high grade fire or pottery clay are known. The tests made have only covered a small portion of the deposits and it is probable that such deposits will be found.

Even if these materials should not be found in the State, the abundance of shales suitable for building and paving brick, drain tile, sewer pipe, etc. combined with the advantages in the way of fuel, transportation and markets should make Oklahoma one of the great centers of the clay industry.

CHAPTER VIII.

GYPSUM

By Chas. N. Gould

Introduction

Gypsum is hydrous calcium sulphate, that is, sulphate of lime, containing a certain amount of water of crystallization. A large amount of this water is given off freely when heat is applied. The manufacture of plaster, which will be discussed later, depends on this quality. Gypsum is a very soft mineral, ranking only 2 in the scale of hardness. Its specific gravity is 2.32 and in the scale of fusibility it ranks from 3 to 3.5.

The gypsum area, of which the Oklahoma beds form a part, is the largest in the United States. The area extends almost uninterruptedly from central Iowa across Kansas, Oklahoma and Texas, nearly to Pecos River. Over a considerable part of the area outcrops are continuous and one may often travel 200 miles or more and at no time be out of sight of heavy gypsum ledges.

The line of outcrop from southern Nebraska to west-central Texas is approximately 600 miles long. The width of the area containing gypsum varies from a few miles to more than 100 miles. Oklahoma is in the center of this region; the most extensive deposits are in this State. The amount of gypsum in Oklahoma is practically inexhaustible. With very few exceptions, every county west of the main line of the Rock Island railroad contains enough gypsum to make plaster to last an indefinite length of time.

Location of the Gypsum

For convenience of discussion all the deposits of the State may be roughly grouped under four general regions as follows:

1. The Kay County region occupies the central part of Kay County.

2. The main line of Gypsum Hills extends from Canadian County northwest through Kingfisher, Blaine, Major, Woods, Harper and Woodward counties to the Kansas line.

3. The second line of Gypsum Hills lies along a line parallel to the main range, and from 50 to 75 miles farther southwest. It extends from the Keechi Hills, in southeastern Caddo County, northwest through Caddo, Washita, Custer and Dewey, and into Woodward and Roger Mills counties.

4. The Greer County region occupies the greater part of western Greer County, practically all of Harmon, as well as the southern part of Beckham and western part of Jackson counties.

The location of these general regions is shown on the map, Fig. 9.

Kay County Region: In the central part of Kay County, in the region between Newkirk and Blackwell, particularly along Duck, Bois d'Arc and Bitter creeks, there are a number of local deposits of gypsite or gypsiferous earth. These deposits are "pockety" and of comparatively small importance. There was formerly a plaster mill in Kay county, but it ceased operations some years ago on account of lack of material. The rocks are soft shales and clays, gray and blue in color, with a few beds of gray, impure limestone. Whether or not there are gypsum deposits of any magnitude along the line of this formation, farther south than Kay County, is not known.

Main Line of Gypsum Hills: The first considerable gypsum deposit encountered in crossing Oklahoma from east to west is along the main line of Gypsum Hills. These hills are formed by two, sometimes three, ledges of massive white rock gypsum, interstratified between beds of red clay-shale; that is to say, the gypsum ledges are members of the Redbeds formation. There are red clays above, below and between the heavy ledges of gypsum. The clays and shales are usually soft, while the gypsums are relatively hard, and, following the universal law of erosion, known as the survival of the hardest, the gypsum beds often remain intact after the softer clays have been eroded away. The various ledges of gypsum with the interbedded clays and ledges of dolomite, that are found below the gypsum ledges, aggregate from 60 to 90 feet in thickness.

Viewed from the east, the hills appear as a wall crowned with a white band. The skyline is not continuous, for numerous breaks occur where the gypsum ledge is absent, having been carried away by water. The general appearance is rather that of an uneven row of flat-topped buttes or mesas.

The line of outcrop of these hills extends from the north line of the State southeastward to El Reno. The ledge crosses the Kansas line near the point where the Salt Fork enters Oklahoma. West of Alva the ledge outcrops near Whitehorse Creek and reaches Cimarron River in northwestern Woods County. Gypsum forms the cap of the bluffs which enclose the canyon of Cimarron from the Kansas line southeast for a distance of thirty miles. These bluffs vary from 50 feet in height near the State line to nearly 150 feet below Big Salt Plain.

The following section was taken at the high bluff at the southeast corner of Big Salt Plain:

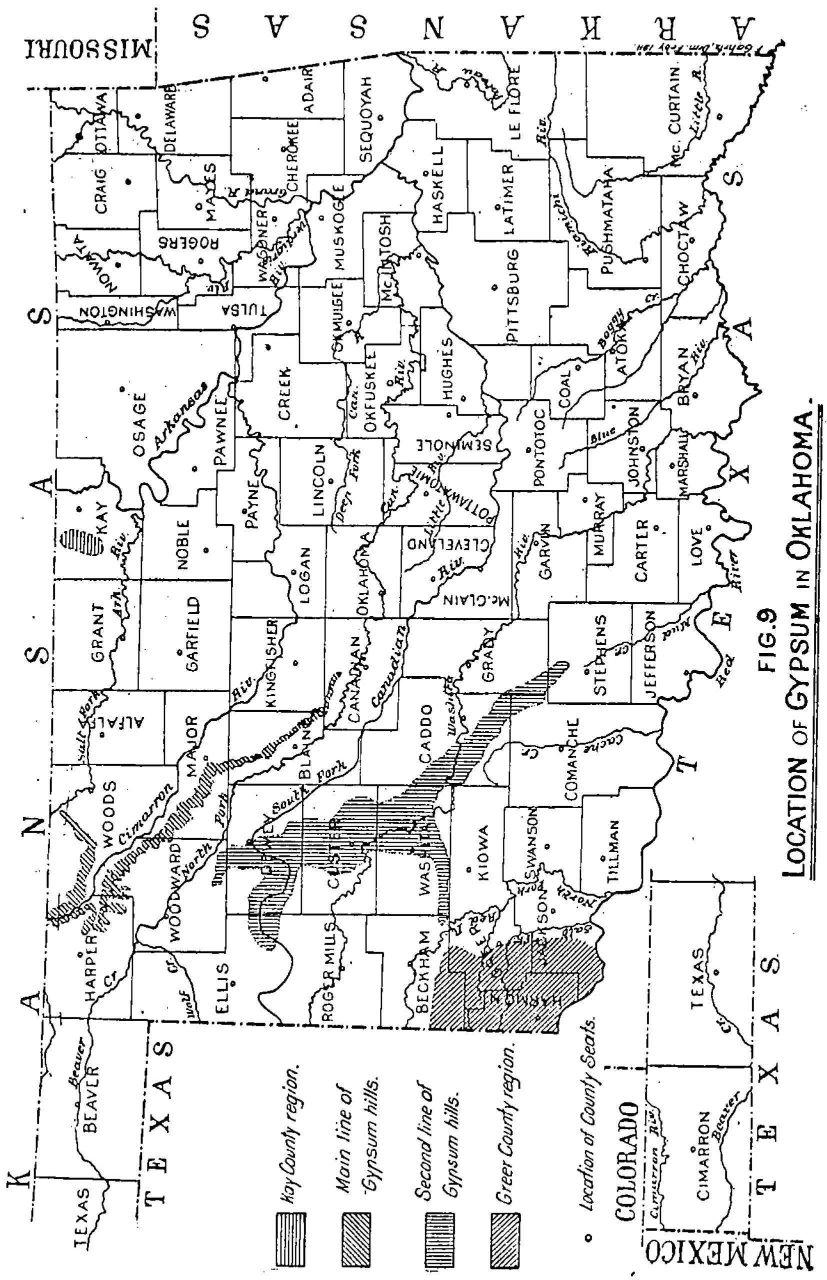


FIG. 9 LOCATION OF GYPSUM IN OKLAHOMA.

No.	Description.	Feet.
1.	Red clay	15
2.	Massive white gypsum, the Shimer	15
3.	Red clay	10
4.	Massive white gypsum, the Medicine Lodge	24
5.	Red clay, bands of selenite	80
	Total	144

The bluffs capped with gypsum are particularly well developed along the south side of Cimarron River as far as Glass Mountains in Major County. This line of hills is the region of bat caves and natural bridges. South of the Glass Mountains the ledge bears off to the south, gradually leaving the Cimarron, and approaches the North Canadian a few miles north of Darlington and El Reno.

The upper ledge of gypsum, which usually caps the hills, is known as the Shimer gypsum. Below the Shimer, and separated from it by a ledge of red clay-shales, is the Medicine Lodge gypsum. A third ledge, known as the Ferguson gypsum, is found in the southern part of this range of gypsum hills.

The following section taken on the south canyon at the head of Salt Creek at the Rubey Stucco-Plaster Company's mill in northern Blaine County, will illustrate the character and thickness of the ledges of this region:

No.	Description.	Feet.
7.	Massive white gypsum, the Shimer	15
6.	Soft gray dolomitic sandstone	1
5.	Red gypsiferous clay	27
4.	Massive white gypsum, the Medicine Lodge	17
3.	Red gypsiferous clay with green bands of selenite	25
2.	Pinkish, mottled gypsum, irregularly stratified, the Ferguson	4
1.	Red gypsiferous clay with thin green and white selenite bands and layers	86
	Total	175

Throughout Blaine County various ledges of gypsum are exposed, usually outcropping along the side of a hill or as the cap rock of a bluff or butte. In many places, however, the entire thickness of one of the ledges may be concealed beneath a load of debris, while in other localities the same ledge is entirely uncovered and may be exposed over an area of several acres.

In the region around the head of Salt Creek and its tributary, Bitter Creek, the Medicine Lodge gypsum, the middle of the three ledges, assumes a peculiar form. The lower half of the ledge, usually consisting of a thickness of 8 to 10 feet, is much harder than the rest, or, in fact of any other gypsum, so far as known, in the State. As seen from below this part of the ledge is pure white and breaks with an even fracture into cubical blocks of such unusual form that the unique structure may often be distinguished a mile away. On close examination the gypsum is found to be very hard and fine-grained, usually pure white, but with an occasional bluish or reddish tint. It takes a good polish and has the general appearance of marble, being known locally as the Salt Creek marble. Chemical analysis reveals the fact that the rock is an anhydrite, containing a very small percentage of water of crystallization. Ordinary gypsum contains from 20 to 25 percent. of water bound up in the crystal. In the rock from this ledge the amount of water is sometimes as low as 2 per cent. An analysis of the rock—No. 2 in the table at the close of the chapter—will give an idea of the composition of the rock.

Second Line of Gypsum Hills: From 50 to 75 miles west of the main line of the Gypsum Hills and at a higher level, geologically, there is a second line of gypsum hills. In general the gypsum in this region differs both in form and structure from that heretofore described. For one thing, it is not usually found in continuous ledges, that is, ledges of constant thickness do not extend for any great distance across the country. On the contrary, the stratification is very erratic. Sometimes practically all the thickness of the formation is composed of gypsum, while in nearby localities only sandstones and clays occur. Another point of difference is that the rocks of this region do not form conspicuous hills as do those farther east. In general these gypsums appear on the surface in the form of rounded knolls, or as mounds on the top of a divide between two streams, or as persistent ledges along the side of a local bluff, or perhaps more frequently still, along the side of one of the rather deep canyons cut out by small streams into the soft rocks that make up the region.

This range of hills extends from the southeastern corner of Caddo County northwest through Washita and Custer counties as far as Dewey, Ellis and Roger Mills counties. The width of the gypsum outcrops of this region, from east to west, varies from a few miles to nearly 30 miles.

A section taken along the Washita River 5 miles southeast of Cloud Chief in eastern Washita County is given herewith:

No.	Description.	Feet.
1.	Massive white gypsum	18
2.	Sandstone and red clay	28
3.	Massive white gypsum	8
4.	Soft, red gypsiferous sandstone	75
	Total	129

Greer County Region: The fourth general region of gypsum deposits in Oklahoma is in the southwestern corner of the State in Greer, Harmon, Jackson and southern Beckham counties. There is reason to believe that the deposits of this region belong to the same general level or geologic horizon as those just discussed under the name of Second Gypsum Hills; in fact, in a geologic classification, the rocks of these two regions would be described together. There is, however, a considerable area in southwestern Washita County, lying between Cloud Chief and the North Fork of the Red River where the gypsum ledges are rarely exposed. This area separates the deposits in the southwestern counties from the main region and so differentiates the former region.

In the Greer County region, both in Beckham County, along the North Fork of Red River, and in northern Greer and southern Beckham counties, near the line of the Panhandle of Texas, the gypsum ledges are well defined and persist for long distances. In this regard they are like the ledges of the main line of Gypsum Hills in Blaine, Major and Woodward counties, rather than like the second line of hills in Caddo, Washita and Dewey counties. In the greater part of the region there are five well defined ledges.

This section, taken along Hay Stack Creek 6 miles south of Delhi, Beckham County, will show the stratigraphy of gypsum in southwestern Oklahoma:

No.	Description.	Feet.
1.	Red Clay	50
2.	Hard sandy rock	4
3.	Red and green clay	20
4.	Massive white gypsum	16
5.	Red and green clay	8
6.	Massive white gypsum	18
7.	Red and green clay	20
8.	Bluish and drab gypsum	4
9.	Red clay	15
10.	Gypsum and hard rock	5
11.	Red clay	100
	Total	260

A different phase of the same series of beds is shown in the section given below. It was taken on the bluff between Salt Fork of Red River and Horse Branch, ten miles south of Mangum:

No.	Description.	Feet.
1.	Dolomite, hard rock	3
2.	Red and blue clay	12
3.	Massive white gypsum	8
4.	Red clay with ledges of gypsum	24
5.	Massive white gypsum	12
6.	Red and blue clay	15
7.	Soft shaly rock and gypsum	5
8.	Red and blue clay	22
9.	Bluish gypsiferous rock	10
10.	Red and blue clay	8
11.	Massive white gypsum	3
12.	Red clay	100
	Total	222

Amount of Gypsum in Oklahoma: Not long since the writer had occasion to prepare an estimate of the amount of gypsum available in Oklahoma. After some consideration as to the best method to be employed, the following plan was adopted: A ledge of gypsum a foot thick and a mile square was used as a basis. The specific gravity of gypsum was estimated at 2.32 and the weight of a cubic foot of water at 62.5 pounds. Hence, a cubic foot of gypsum would weigh 2.32 times 62.5 pounds, or 145 pounds. From this it would be found that a ledge of gypsum of the thickness and area given, would weigh 2,021,148 tons. In the calculation of the amount of gypsum in a region the odd numbers, 21,184 tons, were discarded and the weight of a ledge of a mile square and a foot thick has been considered as 2,000,000 tons.

In estimating the amount of gypsum in any particular region, care has been taken to include only available material. No deposits have been considered in these calculations that are at a greater depth than 100 feet beneath the surface and, in general, the ledges discussed are less than 50 feet under ground.

In arriving at results the plan has been first, to estimate the number of square miles occupied by gypsum; and next, to approximate the combined thickness of the ledges. In both calculations care was constantly taken to make conservative estimates. The number of square miles was multiplied by the thickness in feet and then by 2,000,000. This product is considered the number of tons of gypsum in the area under discussion.

Classified by counties the approximate amount of gypsum in Oklahoma is as follows:

County.	Tons.
Canadian	50,000,000
Blaine	2,500,000,000
Woods	8,000,000,000
Woodward	8,000,000,000
Major	12,000,000,000
Harper	10,000,000,000
Comanche	200,000,000
Caddo	3,000,000,000
Washita	20,000,000,000
Custer	6,000,000,000
Dewey	1,000,000,000
Ellis	500,000,000
Roger Mills	1,000,000,000
Beckham	12,000,000,000
Greer	14,000,000,000
Harmon	15,000,000,000
Jackson	13,000,000,000
Total	126,300,000,000

Occurrence of Gypsum [1]

Gypsum occurs in five forms: (1) rock gypsum, (2) gypsite, (3) concretionary, (4) selenite, (5) satin spar. Each of which occur in Oklahoma in great abundance.

Rock gypsum is by far the most abundant form of gypsum in the State. It occurs in massive ledges varying in thickness up to 100 feet or more. The physical character of rock gypsum varies greatly. In color it ranges from pure white to gray, bluish white, and pink. It sometimes occurs in a selenitic or granular form that is made up of very small closely-packed gypsum crystals. Most of the gypsum of northern Oklahoma is of this kind, while far the greater part of gypsum in the southern counties is compact and massive.

Gypsite occurs in great abundance in Oklahoma. It is not at all practical to attempt to estimate the amount of gypsite in the State. In the first place, it is quite probable that there are many gypsite deposits as yet undiscovered; then, too, in many places this material occurs in such small quantities and under such conditions that it is not practical to utilize it; and still another reason is that on account of the nature of the deposits only approximate estimates can be made as to the amount of gypsite in the known beds. Gypsite, which is sometimes known as earth gypsum or dirt gypsum, varies in color, from white to gray and brown. It has an earthy appearance, being distinguished in the field from soil, clay, shale, etc.,

1. From report of Mr. Frank A. Herald.

mainly by color and characteristic feel when rolled in the hand.

Concretionary Gypsum occurs as more or less rounded lumps, varying in size from very small concretions up to those 12 inches in diameter. These lumps or concretions, usually white or gray in color, are found scattered through the red clay in many places. They often lie close together, making a sort of stratum. In general they are of about the same nature as the ordinary rock gypsum.

Selenite is crystallied gypsum. It belongs to the monoclinic system of crystals, and has very perfect cleavage. Ordinary selenite crystals are diamond shaped. In the pure state it is transparent. Some specimens have been collected in Oklahoma as much as six inches thick, that were so clear that ordinary printed matter could be read through them. Selenite sometimes contains more or less coloring matter, chiefly that which forms a red color. It separates readily along cleavage plans, and can be divided into very thin layers.

It occurs in veins from the thickness of a sheet of paper to two and a half or three feet. Veins of more than two feet in thickness are rare, while those from two to six inches are most common. Selenite usually is found interstratified with clay between ledges of gypsum rock. In most cases the strata are level, but sometimes it is found dipping in all directions, making various angles with the perpendicular. The veins or ledges of selenite are made up of crystals bound together at various angles. Selenite crystals vary in size from infinitely small particles to those as large as sixteen by forty inches. Ordinarily the crystals are from one to three inches in width and from two to seven inches in length.

Satin Spar is the second of the two forms of crystallized gypsum. It is crystallized in long needle-shaped crystals, which have a direction perpendicular to that of the bed. With these exceptions its mineralogical characters are practically the same as those of selenite. Satin spar occurs in beds having thickness all the way from that of a sheet of paper to four or five inches. The veins run in various directions in clay and shale. It is of common occurrence that the beds branch and run in different directions through the clay and then reunite. Satin spar is often found in the Redbeds at considerable distances from the outcrop of the more conspicuous rock gypsum.

The Manufacture of Gypsum Products in Oklahoma [1]

At the present time there are eleven plaster mills operating in the State, and plans are being completed for the erection of others. The mills now in operation are located at the following places: Bickford, Marlow, Okeene, Alva, two at Watonga, Southard, Okarche, Eldorado, Ferguson and McAlester. A considerable amount of gypsum is being shipped to the eastern part of the State and used in the manufacture of Portland cement. The above mentioned mills are manufacturing the following products: Wall plaster, dental plaster, plaster of paris, finish plaster, moulding plaster, stucco, and land plaster.

1. From report of Mr. Frank A. Herald.

For the greater part of these products rock gypsum is used; in fact it is used to some extent in all of them, except in the dark-colored wall plaster because pure material is required for these.

Although gypsite is used in fewer products than is rock gypsum, yet because of the great demand for cheap wall plaster it is being used much more extensively than is the rock for the reason that it can be manufactured much more cheaply. Many practical plaster men contend that gypsite makes a better plaster than does the rock gypsum. Plasterers prefer gypsite plaster because it is said to be easier to apply. It is claimed that a workman can put on a greater number of yards of gypsite plaster, and leave a smoother wall in a certain length of time than of plaster made from gypsum rock. The reason that gypsite can be made into plaster with less cost than can gypsum rock is because the rock has to be quarried and ground before it is ready for cooking, while the gypsite can be taken from the beds with scrapers and transferred in the kettles without the expense of grinding. These two forms, rock gypsum and gypsite, are the only kinds of gypsum that are utilized in Oklahoma.

Process of Manufacture: The process of manufacture of plaster from gypsum is very simple. It consists primarily in removing the water of crystallization from the gypsum. Just enough water is left in the finished compound to start crystallization when the other water is added. If the plaster is overburned so that all the water is removed crystallization will not take place upon addition of water. As a matter of fact plaster is seldom overburned. To completely dehydrate gypsum, it must be heated to 650 degrees Fahrenheit, while if it is heated beyond 430 degrees Fahrenheit, so nearly all of the water is removed that it will take up water of crystallization only very slowly. The most satisfactory results are reached by heating to a temperature of 350 to 370 degrees. Few mills in the State, however, heat their plaster to a temperature as high as 360 degrees. Most of the plaster manufactured in Oklahoma is turned out of the kettle at a temperature between 330 and 350 degrees Fahrenheit.

The gypsum rock is taken from the quarry to the jaw crusher, or nipper as it is commonly called, and crushed into lumps varying in size all the way from the size of a man's hand down to fine powder. These lumps pass down through the nipper into the cracker just below. The cracker is a machine operated on the same principle as a coffee mill. In the cracker the gypsum is crushed into fragments the size of a pea or smaller. It is then elevated to bins. From there is passes into ordinary buhr mills where it is ground into flour. In some of the mills the finer products are passed through buhr mills the second time to secure extreme fineness, but this is rather rare.

After the gypsum is ground as fine as flour, it is ready for the calcining kettles. It is first elevated to a bin, but usually reaches the kettle before it looses the heat imparted to it in the buhr mills. The ground gypsum is cooked from two and a half to three hours in the calcining kettle. As the manufacture of plaster from gypsum takes place, strictly speaking, in the calcining kettle it is worth while to describe this part of the mill in detail. The kettles used in Oklahoma are six to eight feet deep and from six to ten feet in diameter, usually called "ten foot kettles," are by far the most common, in fact smaller ones are used in only two mills in the State. This size seems to be most satisfactory for nearly all new kettles are of this size, not only in our State, but in other states as well. Since the ten foot kettles are the most common I shall limit my description mainly to them. The material in the kettle is constantly stirred by a revolving mixer. This mixer is composed of a vertical shaft, running down through the center of the kettle almost to the bottom, with three cross pieces reaching out almost to the sides of the kettle. The mixer is propelled by a cog wheel, from six to twelve feet above the top of the kettle. All the ten foot kettles have four flues through them, while the smaller kettles have only two. These flues are about a foot in diameter and run parallel through the kettle in pairs, the upper pair being about eight inches above the point midway between the top and bottom and the other pair about eight inches below the middle point. There is about ten inches of space between the members of each pair. The purpose of the flues is to aid in using as much of the heat produced as possible. All of the bottom of the kettle, which is cupped up in the middle, is exposed to the fire pit, as it affords a covering for the same. The bottom of the kettle is from five to six feet above the grates of the fire pit. The kettle is enclosed within a brick wall with fire courses or flues running around on the outside of the kettle, so as to make as much of the heat as possible come in contact with the kettle before it goes out through the smoke stack above. The heat comes up from the fire pit on the front side and passes around and through the kettle through the lower flues and back to the front side again. Then it passes around the kettle again and back through the upper pair of flues and then out the smoke stack which stands on the front side of the kettle. By this method the heat produced is well utilized. The capacity of a kettle eight feet deep and ten feet in diameter is thirteen tons but usually only about ten tons of plaster is calcined in it at a time.

While gypsum is being cooked it boils like water. The steam is carried off through a flue from the top of the kettle. When the gypsum is sufficiently calcined, i. e., has the water of crystallization removed, a gate at the bottom of the kettle is opened and the

plaster runs into the hot pit. From here it is elevated to bins in the upper part of the plant. The kind of product desired determines the further course of the plaster. If it is to be finish plaster it is sacked as it comes from the kettle. Sometimes a little retarder is mixed with finish plaster. This is done in one of two ways: The retarder is either thrown into the kettle with the ground gypsum or it is mixed in the mixer as with other plasters. Most plasters contain both retarder and fiber, either hair or wood. These are put in various proportions according to the nature of the product desired. If a quick setting plaster is desired a small amount of retarder is used, while more retarder is used, if it is desired that the plaster set more slowly.

The constituents of the plaster are put together on the second floor of the plant. A gate to the bin is opened and about twelve hundred pounds of pure plaster as it comes from the kettles is turned into a pyramidal box which has its point downward through the floor. Then weighed amounts of fiber and retarder are added. These go together into the mixer below. The plaster is thoroughly mixed and then sacked directly from the mixer. A sample is taken from every batch and tested, mainly to see just how long it will take it to set. Usually the plaster is sacked before it has time to cool. Quite often it is loaded into cars while it is so hot that it can hardly be handled with the hands.

The process is the same for the manufacture of gypsite, only in this case the material goes directly to the calcining kettles without preliminary grinding. More heat is required to calcine gypsite than rock gypsum as gypsite usually contains a certain per cent of free water. Gypsite has to be cooked from three to four and a half hours. More fuel is required to calcine gypsite than gypsum rock, but the cost of the extra amount of fuel required, does not amount to as much as the expense of quarrying and grinding the rock.

Uses of Gypsum [1]

Plaster of Paris: All gypsum, when calcined, becomes plaster of Paris. Of course only a very small per cent. of it is sold as such. Only the very pure product made from pure rock gypsum is sold as the commercial plaster of Paris.

Dental Plaster: Dental plaster is a very fine grade of plaster of Paris. Very pure material is required for this product. In some mills dental plaster is made largely from selenite. It is usually reground and sifted so as to insure fineness and uniformity.

Wall Plaster: There are a great many kinds of wall plaster. Many mixtures made with plaster of Paris, more or less pure, are used as wall plaster. For finishing white coat on walls the plaster is used as it comes from the calcining kettle. It is just the same

1. From report of Mr. Frank A. Herald.

as, and in fact is, plaster of Paris. Sometimes retarder is mixed with it to give a slower set to the white coat. Retarders are organic compounds which are mixed with the plaster, to delay the set of the material. Various constituents enter into the composition of retarders, different ones containing different ingredients, common among the contents being slaughter house products, glue, hair and slacked lime. Retarder is used in practically all plaster, for pure plaster of Paris sets too quick for ordinary use.

For general use, retarder and fiber are mixed with the calcined gypsum . These are mixed in proportions to suit the demand of the trade. Two kinds of fiber are in common use, hair and wood. Wood fiber is comparatively a new product, but it is rapidly becoming known and is giving good satisfaction. It is made by tearing wood, most commonly cotton wood, into fiber by a machine made especially for the purpose. This machine is operated within a few feet of where the fiber is mixed into the plaster. It is claimed that wood fibered plaster has the quality of deadening sound. Some mills even go so far as to mix sand in certain brands of their product before it leaves the mill. This is rare, however, but where it is done good results are more likely to follow, for, as a rule the manufacturer of the plaster knows better how to prepare it for use than does the ordinary workman.

At the present time the plaster made from gypsite seems to be more satisfactory with the trade than that made from rock gypsum. This material is usually of a dark color so that it is not suitable for a finish coat. Because of the impurities it contains, it requires less retarder than that made from pure rock gypsum. Certain other things are sometimes added to gypsum plaster to develop. certain qualities, but I have enumerated all the more common. constituents. Comparatively speaking, almost all of the gypsum calcined in Oklahoma is used as wall plaster. Other products are made and sold, but the manufacture of them is of little importance as compared with that of wall plaster.

In his report on the gypsum of Michigan, Prof. Grimsley says, in speaking of gypsum plaster:

"Its advantages as set forth in the advertising circulars of the companies and supported by the testimonials of prominent architects and builders are as follows:

"Its superior tensile strength and hardness. It dries out much more rapidly than lime plaster so that the carpenters can soon follows the plasterers; the painters and paper hangers can follow the carpenters in a day or two. The entire building can be delivered and occupied from five to six weeks sooner than with lime mortar. Coloring compounds can be mixed with the material in its preparation for mortar to produce any tint desired. Ceiling and walls, thoroughly soaked by leaking from unprotected roofs, have not been injured. It attains a high polish and may be used for wainscoting as a substitute for marble. It is fire proof and a non-conductor of heat and cold, so that changes of temperature do not effect the walls which, therefore, do not chip or crack. The walls being dense and hard are vermin proof, making the plaster valuable for hospital walls."

Pottery Moulds: Gypsum is used to a great extent in the manufacture of moulds for various pottery designs. It is usually used for this purpose in the form of plaster of Paris.

In Plate Glass Polishing: About 40,000 tons of plaster are used annually in the plate glass factories of the United States. Plaster is used to imbed the glass, in order to hold it firmly while it is being polished. For this purpose very pure plaster is required, so as not to scratch the glass.

Plaster Relief Work: A great amount of gypsum has been used in the last few years in the construction of temporary buildings, especially at the great fairs. An enormous amount was used in the buildings at the World's Fair at St. Louis. The material used, is ordinary gypsum plaster mixed with fiber, making what is known as staff. Staff is well adapted for decorative construction. The main objection to it is that within a few years it will disintegrate and crumble. Some experiments have been made to protect it by an outside coating or wash of Portland cement or some material that the elements will not disintegrate. In some cases these expedients have proven fairly satisfactory. Such experiments are likely to develop a great field for the utilization of gypsum products as an outside material.

Staff is also used for inside decorations. Group figures, mouldings, etc., in our public buildings, theaters, and buildings of all kinds, even private residences, are made almost entirely from staff.

Portland Cement: It is claimed that Portland cement can be made from gypsum, with sulphuric acid as a by-product. Several patents have been granted for this work, but as yet the process has not gone much beyond the experimental stage.

Gypsum Boards: The manufacture of plaster boards from gypsum is a comparatively new industry. Boards of various styles, shapes, and dimensions are made. Some have strips of lumber running through them, some are made with alternate layers of porous paper and many other various ways. Among the advantages claimed for this sort of building material is that it is fire proof and also a sound deadener.

Paint: Gypsum is used some in the manufacture of paint, though not very extensively. Its chief use in paint is as an adulterant; but it is also used as a base of certain kinds of paint.

Alabastine: Alabastine is a sort of paint, in fact it is often called "cold water paint." A good quality of gypsum is carefully ground and reground for this product. In his description of alabastine Grimsley says:

"This superfine gypsum flour is mixed with metallic colors and sold in packages to be used for tinting and frescoing interior walls. Five pounds of the material will cover fifty square yards of plain tinting on a smooth non-porous wall. It can be used over any solid surface, such as plaster, wood ceiling, brick, or canvas, and is applied with an ordinary wall brush. It does not flake or scale off, and hardens like the wall on which it is placed and so can be applied coat over coat."

The word "Alabastine" is a trade name. It represents a class of materials of which it seems to be the most important. Cementico and Muresco are other products of a similar nature.

Adulterant: Pure white, finely ground gypsum is used in many ways for adulteration purposes. For most purposes it is used uncalcined. It is mixed with some white lead paints, making a cheap substitute for the white lead. It has been known to be used in flour, sugar, candy, baking powder, and many other common materials. The pure food laws, recently put into operation, are restricting its use along these lines.

Fertilizer: Land plaster, chiefly uncalcined gypsum, is a commercial product used as fertilizer in many eastern states. In some cases insect poison is added to it so as to destroy certain insects on the fields where it is applied. So far it has not been used to any extent in Oklahoma.

Minor Uses: The principal uses of gypsum have been enumerated above. It has various other uses, such, for instance, as material for blow-pipe tests, as a drug, as salt for brewing water, etc. These minor uses are so numerous and relatively unimportant that it is not worth while to treat of them in this paper.

Unsolved Problems

Gypsite Beds: There are two problems to be solved in connection with the gypsum industry of Oklahoma, namely, the location of available gypsite deposits, and the securing of cheaper fuel. The plaster men believe that the greater part of the gypsite has been located and that the supply will soon be exhausted. There are geological reasons, however, for believing that there are vast undiscovered deposits of gypsite in each of half a dozen of the western counties, and all that is needed is systematic prospecting. It is my conviction, based on ten years of careful study of conditions, that at a conservative estimate, not 10 per cent. of the available gypsite deposits have yet been found.

Fuel: The fuel problem is more difficult. It is useless to look for coal anywhere in the gypsum region, and the geological structure precludes the probability of petroleum or natural gas being found in quantity. The nearest coal is 200 miles or more from the gypsum, and under existing conditions the railroads get the freight on both the coal and the finished plaster. A milling and transit rate to the gas fields of eastern Oklahoma has been suggested as a solution of the difficulty. The fact, however, that gypsum is more than one-fifth water of crystallization, presents

grave difficulties to this plan, even if a suitable rate could be obtained from the railroad. The last resort is to pipe the natural gas to the gypsum. Gas mains are already laid as far as Oklahoma City, and they will probably soon be extended to El Reno, which is not more than 15 miles from the southern end of the gypsum hills. Whether or not a rate can be secured which will enable the plaster men to utilize the gas remains to be seen. To my mind this is the most practical solution of the problem.

Analysis of Oklahoma Gypsums

The following table shows analysis of material taken from various parts of Oklahoma, and will illustrate the general character of the gypsum:

	Lower ledge Ferguson	Marble Gypsum (Anhydrite ledge) Ferguson	Selenite Flakes Mt. Heman Woods Co.	Gypsum from caves near Weatherford
Calcium sulphate	80.09	94.83	76.76	75.57
Calcium carbonate		.....	.....	1.11
Magnesium sulphate		1.93	.....	.....
Magnesium carbonate		.....	.85	.40
Water	19.82	2.74	19.80	20.22
Oxide of iron and aluminum		.....	1.45	.45
Insoluble residue	.65	.....	.95	1.66
Totals	100.56	99.50	99.80	99.41

CHAPTER IX.

PORTLAND CEMENT

By Gaylord Nelson

Introduction

Artificial stone or cement has been used by man from very early times in structural work, but it is only within the past twenty years that the full importance of an artificial building material has been recognized in this country. The rapid destruction of our supposedly inexhaustible forests, the great cost of natural stone, the vast increase of our building operations, and above all the invention of the modern "sky-scraper" have necessitated the use of some building material other than stone or wood. In response to this demand, Portland cement and steel have been brought forward and are rapidly becoming the structural materials. The severest tests of buildings in the Baltimore fire and the San Francisco earthquake prove conclusively that reinforced concrete is one of the most durable of all building materials. In these catastrophes buildings of stone were destroyed, at San Francisco they were shaken down into piles of splintered rocks, at Baltimore granite walls "spalled" and crumbled in the intense heat of the fire, but reinforced concrete structures were but little damaged. They withstood with equal facility the most intense heat of the fire above and the shaking of the earth beneath.

We in Oklahoma are especially interested in an artificial building material, as we have no timber and natural stone is difficult and expensive to quarry. At the present time a vast amount of structural work is under way, and as the State continues to grow in population, economic importance, and development, structural materials will be more and more in demand, both for private buildings and municipal enterprises, such as paving, sidewalks and bridges. For these reasons, if for no other, Oklahoma is interested in the Portland Cement industry. But there are other reasons why this industry is of particular interest to Oklahoma. In this State we have unlimited amounts of raw materials used in the manufacture of cement, as well as great deposits of cheap fuel, coal, oil and gas, so that, from the standpoint of raw materials and fuel, cement can be manufactured as cheaply in Oklahoma as any other place. The west and the southwest are the parts of the country that are destined to show the greatest strides in economic development in the immediate future, and the value of making our structural material within our gates can not be estimated. There is no reason why we should continue to pay tribute to Pennsylvania, Kansas and other states for our building materials, when we can produce a material right here at home, that is the equal of any that is imported. It is for the purpose of showing—in brief, the cement resources of Oklahoma that this paper is written.

Historical Sketch

Hydraulic cements have been in use for so long that the history of their first discovery is lost. It is known, however, that the Egyptians were extensive users of cement fully 4,000 years ago. Also a natural cement was in use by the Carthaginians, who constructed of this material an aqueduct 70 miles long, crossing a valley on arches 100 feet high. One of these arches has fallen down on the rocks beneath and yet remains intact and unbroken, illustrating the tenacity and durability of natural cement. The Romans, the greatest builders of the ancient world, were well acquainted with the use of hydraulic cements 2,000 years ago. Many of their greatest structural works were built of cement and crushed stone. Their aqueducts, still the marvel of the world, testify to their mastery of cement, while the Pantheon, probably the most famous building of ancient Rome, had an arched roof of 140 feet span, built of brick embedded in cement. The ancient Mexicans and Peruvians were also extensive users of hydraulic cements. It has been reported that walls which they built of cement and stone, have been exposed to the weather so long that the face of the stone has been worn away, leaving the cement standing out in prominent ridges. This shows the remarkable enduring qualities of cement as a building material.

The modern cement industry received its first impetus from the investigations of James Smeaton, the builder of the famous Eddystone lighthouse. In 1756 he discovered that by burning an argillaceous limestone, a cement was produced which had the power of hardening under water. He utilized this discovery in the building of the lighthouse, and so durable was his cement, that although the lighthouse was rebuilt in 1882, it was not due to any failure of the cement but to the wearing away of the solid rock beneath the tower.

A true artificial cement was first invented by Joseph Aspdin, in 1824, and a description of his process will be found later, but it was not till about 1850 that cement came into extensive use in England.

In the United States the first cement was manufactured by Canvass White in 1818, from the natural rock near Fayetteville, New York. This cement was largely used in the masonry work of the Erie Canal. The first true Portland cement was manufactured by David O. Saylor, at Coplay, Pennsylvania, in 1872. In 1880, there were six plants in the United States, producing 42,000 barrels per year. From this modest beginning the industry has developed until in 1906, there were 84 active works in the country, with a total annual production of 48,463,424 barrels, valued at $52,466,186. These figures show the magnitude and importance of the industry at the present time.

Classification of Cements

The term cement, in its broadest sense, is applied to any material which, on the addition of water, has the power of hardening or setting. Under this heading there is an innumerable variety of substances. We are, however, only concerned with those cements which are of use in structural work. Such cements have been variously classified by different authors. E. C. Eckel divides them into two great classes, simple cements and complex cements.

Simple Cements

There are two divisions of this class, hydrate cements, and carbonate cements.

Hydrate Cements: Hydrate cements include those cements from which the combined water has been driven off at a temperature not exceeding 400 degrees Fahrenheit, and which, upon reabsorbing water, produce an artificial rock similar to the natural. This class includes plaster of Paris, cement plaster and in fact all forms of cement and plaster in which gypsum is the essential constituent.

Carbonate Cements: Carbonate cements are derived from limestone, or chalk, by driving off carbon dioxide at a heat of from 1300 degrees to 1600 degrees Fahrenheit, producing quicklime or calcium oxide. On the addition of water, calcium hydrate or slaked lime is formed, which reabsorbs carbon dioxide from the atmosphere and reforms calcium carbonate, or limestone.

Complex Cements

In complex cements heat brings about the formation ot new chemical compounds which impart the setting property to the cement. Under this class come (1) Natural cements. (2) Puzzolan cements, (3) Hydraulic limes, (4) Portland cements. These are all compounds, which owe their hydraulic properties to a combination of calcium oxide, silica and alumina.

Natural Cements: Natural cements are produced by burning an impure limestone, containing from 15 to 40 per cent of silica, alumina, and iron oxide. Other ingredients, notably sodium and potassium oxides, magnesia, and sulphur are generally present in small quantities, but are inconsequential except when present in

large amounts. They are then detrimental to the quality of the cement.

The temperature at which natural cements are burned varies from 900 degrees to 1300 degrees Fahrenheit, or about the same as the temperature used in burning lime. The lime and magnesia combine with the silica, alumina and iron so that the burned product shows very little free lime. The burned mass, or clinker on being ground to a fine powder has the power of setting under water. To this class of natural cements belong all calcium-silica cements which are produced by burning, to a point below vitrification, an indefinite mixture of calcareous and argillaceous material. They are made from natural lime-clay mixtures and no attempt is made to keep the chemical composition constant.

Puzzolan, or Pozzuolane Cements: Puzzolan cements consist of an uncalcined mixture of slaked lime and volcanic ash or other silica-aluminous materials such as blast-furnace slag. The ingredients are simply thoroughly mixed and ground to a fine powder, which sets under water. This is the cement that was used by the ancient Romans for building purposes. It derives its name from the town of Puzzolano, in Italy.

Portland Cements: By the term Portland cement, is to be understood the product obtained by finely pulverizing clinker produced by burning to semi-fusion an intimate artificial mixture of finely ground calcareous and argillaceous materials, the mixture consisting approximately of three parts of lime carbonate (or an equivalent amount of lime oxide) to one part of silica, alumina and iron oxide. The ratio of the lime in the cement to the silica, alumina and iron oxide, together, shall not be less than 1.6 to 1 or more than 2.3 to 1.

The chemical composition of all Portland cements is therefore fairly constant, varying only within very narrow limits. The heat required to burn the mixture to a semi-fused mass is far above that necessary for natural cements, approaching 3000 degrees Fahrenheit or about 1300 degrees Centigrade. This semi-fused mass, or clinker, when finely pulverized will set under water. Natural cements are not only burned at a much lower temperature, but have a quicker set and a much lower ultimate strength than the true Portlands.

Another authority groups under the term cement all mortars which will harden under water as well as in the air, in distinction from the common lime mortars, gypsum plasters, and the so-called sorel cements. There are four kinds of hydraulic cements, and in addition Pozzuolane cements, and Portland cements. These owe their hardening properties to a process of hydration, requiring water for their initial set. The Pozzuolane and Portland cements are the same as described above. Hydraulic limes and Roman cements differ merely in the amount of impurities or clayey matter present in the limestone, the clay content of Roman cements being greater than that of hydraulic limes. Both are essentially the same as the natural cements, described above and can be included under that heading.

Portland cements are more expensive than the others, owing to the greater fuel consumption which their higher burning temperature requires. Additional cost also enters in, because they require finer grinding and more intimate mixture of raw materials. The greater cost of production is, however, more than offset by their greater tensile strength. No two natural cements have the same hardening properties or the same strength, while all standard Portlands are uniform in these properties. Their greater tensile strength permit the additon of more sand or crushed stone in mixing. They are by far the most satisfactory cement material yet brought forward, and are more used than all the other cements, Roman, Puzzolan or natural.

It is solely with Portland cements, as the term is now understood, that the present work will deal, the other hydraulic cements being of such subordinate importance from an economic standpoint.

The name Portland cement was first given to an artificial compound of lime and clay prepared by Mr. Joseph Aspdin, a Leeds bricklayer. He chose the name in consequence of the fancied resemblance in color and texture, of his hardened cement, to the oolitic limestone of the Island of Portland which was much esteemed in England as a building stone.

Aspdin's specifications, dated Otcober 21, 1824, are as follows: [1]

"I take a specific quantity of limestone, such as that generally used for making or repairing roads, after it is reduced to a puddle or powder; but if I can not procure a sufficient quantity of the above from the roads, I obtain the limestone itself and I cause the puddle or powder, or the limestone as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay and mix them with water to a state approaching impalability, either by manual labour, or machinery. After this proceeding I put the above mixture into a slip pan for evaporation, either by the heat of the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan, until the water is entirely evaporated. Then I break the said mixture into suitable lumps, and calcine them in a furnace similar to lime kiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat or rolled to a fine powder, and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it into consistency of mortar and thus applied to the purposes wanted."

From Aspdin's specifications it is seen that he applied the name Portland cement to one that is essentially a Roman cement

1. Calcareous Cements, their nature, manufacture and uses. Redgrave & Sprachman, Page 31.

inasmuch as he did not calcine his mixture to the point of incipient fusion demanded by the present definition; thus the present name is a misnomer.

Since Aspdin's time the cement industry has been rapidly growing. Improvements of mixture and processes of manufacture have been made till the present product has been evolved.

Chemical Composition of Portland Cements

Portland cement is an artificial silicate, produced by burning an intimate mixture of calcareous and clay material, the firing being carried to the point of incipient vitrification. The dark slag-like mass resulting from this burning is ground to an impalpable powder which, when mixed with sand or other inert material, has the power of hardening under water. The essential chemical constituents of good cement are, silica, lime, and alumina; but other ingredients are present in small quantities, notably iron oxide, magnesia, sulphuric anhydride, carbon dioxide, alkalies and water. These are present only in small quantities and when thus present have no appreciable effect on the quality of the cement. According to LeChatelier the composition of good commercial cement may vary within the following limits:

Silica	21-24 per cent
Alumina	6- 8 per cent
Ferric oxide	2- 4 per cent
Lime	60-65 per cent
Magnesia	0.5- 2 per cent
Sulphuric anhydride	0.5-1.5 per cent
Carbon dioxide and water	1- 3 per cent

Bleininger makes the following limits: [1]

Silica	18-26 per cent
Alumina	4-11 per cent
Ferric oxide	2- 5 per cent
Lime	58-67 per cent
Magnesia	0- 5 per cent
Sulphuric acid	0-2.5 per cent
Alkalies	0- 3 per cent

Professor E. D. Campbell places the permissible limits as follows:

Silica	20-24 per cent
Alumina	6-10 per cent
Ferric oxide	3- 5 per cent
Lime	60-64 per cent
Magnesia	1-3.5 per cent
Sulphuric anhydride	0.5-0.7 per cent

1. Manufacture of Portland Cements. A. V. Bleininger, Bul. 3, 4th Series, Ohio State Geological Survey, Page, 197.

From the above permissible limits, as placed by different authorities, it is seen that there is a slight discrepancy in their figures, though in the main they agree very well. LeChatelier's limits are too narrow and are more nearly averages than limiting values as many excellent cements have percentages far outside of his limits.

Functions of the Constituents

Silica constitutes from 19 per cent to 26 per cent of Portland cement and is the essential ingredient, which, combined with lime, gives to cement its hydraulic properties. The silica should, however, be present in the combined state, as feldspar, and not as free silica, or quartz. Grains of this mineral are difficult to fuse completely with the lime and alumina and also make the fine grinding of the mixture difficult. If large they wear the machinery at a rapid rate, especially that used in the grinding. On burning, the silica, whether free or combined, is broken up and unites with the lime to form a complex silicate of calcium, to which the hardening power of cement is largely due.

Lime: Lime is present in cement in a larger proportion than any other constituent, since it makes up from 58 per cent. to 67 per cent of the whole. Enough must be present to combine with all the silica, alumina, and iron oxide, but no more, as any free lime in the finished product tends to weaken the cement. Free lime will, on the addition of water, slack and expand, thus causing the cement to crack and disintegrate.

"Too low a proportion of lime on the other hand produces a fusible clinker liable to over-burning. This is especially the case with materials of a high aluminous content. If hard burned, such mixtures give a fused clinker liable to fall to dust on cooling, hard to grind, and yielding slow setting cements of poor hardening qualities. If light burned, a mixture containing an excess of clay material, yields a soft brownish clinker, grinding to a brownish, quick setting cement of inferior strength.

The source of the lime in the cement mixture is usually limestone or chalk, the latter being a mixture of calcium carbonate, siliceous and clay matter

Alumina: Alumina is present in Portland cements in amounts varying from 4 per cent to 11 per cent, the amount varying with the percentage of ferric oxide present. The alumina of cement is usually combined as calcium aluminate. To this compound the setting property of cement is attributed.' Prof. Zulkowski found that a mixture of calcium oxide and alumina, corresponding to the formula $Ca\ O\ Al_2O_3$, burnt for eight hours, when mixed with water, set in two minutes and hardened to a very hard mass over night; in three months it became so hard that it could scarcely be scratched with a knife. Other white cements were prepared by Zulkowski from pure kaolin and calcium oxide. These cements set very

quickly and become very hard in a few days. Other investigators, notably S. B. and W. B. Newberry obtained practically the same results.

These experiments prove that much of the setting property, especially the initial set, is due to the calcium aluminate ($Ca\ O\ Al_2O_3$) present in the cement. Therefore alumina is an essential constituent of Portland cement. However the proportion of alumina must not be too high, though the higher the alumina content the more rapid the set, but the ultimate tensile strength of cement with a high alumina content is apt to be inferior. Furthermore the volume of such a cement may not remain constant.

Alumina also tends to aid in the burning of the cement mixture, as its compounds are more readily fusible than those of silica.

Ferric Oxide: Iron is present in cement in only small quantities, from 2 per cent to 5 per cent, and has no marked effect on the quality of the product. In its chemical behavior it is analogous to alumina and in cement it seems to take the place of alumina, so that it is usually estimated with the alumina.

Zulkowski, experimenting along this line, burned the mixture $Ca\ O\ Fe_2O_3$ till party fused, when it assumed a graphite-like appearance. This graphite-like clinker ground to a powder and mixed with water set in four hours, in five hours more it was hard enough to be placed in water. In several months this calcium-iron cement became so hard that it could be scratched with a knife only with difficulty, though it did not show the strength of the corresponding alumina compound.

From these experiments, it is seen that the iron compounds act in much the same manner as the alumina compounds, though much feebler in their action. The iron present in the cement, however, serves to reduce the burning temperature, as the iron compounds are powerful fluxes. The cost of firing cement mixtures containing iron is less than that of mixtures made up solely of alumina. On the other hand, the presence of an excess of iron reduces the tensile strength and setting power of cement, as well as making the cement dark colored. The color of cement is entirely due to iron, so that the cements which contain no iron are pure white, for example the lime-kaolin cements mentioned above.

Magnesia: The function of magnesia in cement is still uncertain, though some investigators, including LeChatelier, claim that it can replace lime and form silicates and aluminates of magnesia whose character is similar to that of calcium. Fuchs produced a very hard cement by burning talc, which is a hydrous magnesian silicate ($Na_2\ Mg_3\ (SiO_3)_4$). Other authorities claim to have produced good cements by burning magnesia-silica mixtures. "S. B. and W. B. Newberry came to the conclusion that magnesia shows no hydraulic properties when heated with silica, alumina or clay and say that it probably plays no part in the cement reaction. Hence these investigators claim that magnesia can not replace lime in cement mixtures."[1]

Professor E. D. Campbell, of the University of Michigan, says that the influence of magnesia on the strength and soundness of Portland cement, although not well understood, seems, from recent experiments, to be under certain conditions much less injurious than is commonly supposed.

A committee of the Association of German Cement Manufacturers, in 1895 presented a report stating that their investigations had shown that a content of magnesia up to 8 per cent was harmless. A minority report of the same committee stated that more than 4 per cent of magnesia, whether added to a normal mixture or substituted for an equivalent portion of lime, caused a steady decrease in the strength of the cement.

From this conflicting testimony it is seen that the effect of magnesia on cement is uncertain, although it is probable that the injurious effect is over estimated. However, cement users are accustomed to look with suspicion on a cement in which the magnesia runs above 5 per cent. The British specifications do not allow more than 3 per cent.

Sulphuric Anhydride: Portland cement contains from 1 per cent to 2 per cent of sulphuric anhydride, the greater part of which is introduced in the form of gypsum added to the ground clinker to retard the set of the cement. Not over two or three per cent of gypsum should be added, as a larger amount is injurious both to the strength and the soundness of the product, especially when placed in sea water. The standard French specifications place 1 per cent as the limit of the sulphuric anhydride, while in America it is allowed to go higher, up to 2 per cent. The British specifications allow as high as 2.5 per cent. In addition to the sulphuric anhydride introduced through the gypsum added, there may also be small quantities added from the sulphur contained in the coal used in burning the mixture.

Alkalies: The alkalies are usually present in cement in small quantities; but not in sufficient amounts to affect the product in any manner, though they are strong fluxes and may facilitate the vitrification of the mixture to a slight extent. As they never run above 2 per cent or 3 per cent their presence is negligable in so far as they affect the quality of the cement.

Raw Materials

Since Portland cement is composed chiefly of silica, alumina and lime, any natural product containing these ingredients in the proper proportion will be suitable for its manufacture. These are found widespread and in great abundance in nature, the greater

1. The Constitution of Hydraulic Cements. Journal of the Society of Chemical Industries, November, 1897.

part of the sedimentary rocks being made up of them. It is usual to obtain the calcium oxide from limestone, chalk, marl, blast furnace slag, or industrial waste. The silica-alumina content may be introduced as clay, shale or a mixture of clay and sand.

Limestone: Pure limestone is calcium carbonate but the pure mineral is seldom found in nature in large quantities, being on the other hand, mixed with various impurities, such as clay, sand and magnesium carbonate. Calcium carbonate and magnesium carbonate are found intimately associated in nature, forming a series of rocks from pure limestone ($Ca\ CO_3$) at one and to pure magnesite ($Mg\ CO_3$) at the other. No sharp distinctions can be drawn anywhere in the series, except between the end members. A rock containing equal proportions of calcium carbonate and magnesium carbonate is called dolomite. However, it is very seldom that these minerals are found, in a rock, in equal proportions, hence the term dolomite is rather loosely applied to any rock composed of a mixture of calcium and magnesium carbonates, in which the magnesium carbonate makes up any considerable proportion of the rock.

The color of limestone is as variable as its chemical composition, from pure white, to gray, blue or brown. The color is dependent on the percentage of impurities. Pure limestones and marbles are white.

A great majority of American cement plants derive their calcium oxide from limestones.

Argillaceous Limestone: The term argillaceous limestone is applied to a limestone that has a high percentage of clay matter. It is usually softer and easier to work than pure limestone. When the clay matter is present in nearly the proper amount the rock is especially favorable as a cement material. It is this class of limestone that is usually called cement rock, owing to the fact that it forms the raw material for the cement manufactured in eastern Pennsylvania and southeastern New York. In the Lehigh Valley, probably the most famous cement region in this country, if not in the world, producing over thirty per cent of the total cement output of this country, the raw material is cement rock or argillaceous limestone. As here found, it is necessary to add a pure limestone to the cement rock before burning because the natural rock has too high a clay content.

Chalk: Chalk when pure is calcium carbonate; but like limestone it varies from the pure state to a chalk containing a large percentage of silica, alumina and other impurities. It is essentially an incoherent limestone so soft that it can easily be scratched with the finger nail. It is formed from the shells of small animals known as foraminifera deposited in clear water. It is a very good source of lime for cement, as it is soft and easily worked. At present, however, with the exception of Texas, it is not extensively employed in cement manufacture.

Marl: Marl is the name applied to any incoherent, calcareous earth. Marl may be of chemical origin, or derived from the finely disintegrated shells of animals. It is found in great abundance in the glaciated region of the northern United States and Canada, and in the Cretaceous and Tertiary formations of the Atlantic and Gulf coast regions, also as a brackish or marine deposit. The calcareous matter is usually mixed with much sand or clay. Marl forms a good source for the lime necessary in cement but at present it is not so used except by the plants in Michigan and Ohio.

Travertine: Travertine is a soft porous rock consisting principally of calcium carbonate deposited around springs or from running water, either by chemical precipitation or by super-saturation due to evaporation. It is soft, easily worked and eminently fitted for use in cement; however, it is not used at present to any considerable extent owing largely to its small amount and limited distribution. A plant in Ohio has used it with excellent results.

Slag: Blast-furnace slag is a prolific source of lime. It is a basic mixture which results as a waste product in the smelting of ores. The latter are generally smelted by fluxing with limestone, consequently the resulting slag contains much lime in combination with the silica, alumina and other impurities of the ore. Sometimes the slag runs as high as 36 per cent to 40 per cent in calcium oxide.

Alkalies: In manufacturing caustic soda, by the ammonia process, precipitated calcium carbonate is obtained as a by-product. When the LeBlanc process is used the by-product contains a great deal of calcium sulphate, owing to the use of pyrite in the process. The calcium carbonate, obtained in the ammonia process, is used successfully in the manufacture of Portland cement. In this country there is but one plant which derives its lime from this source, and that is the plant of the Michigan Alkali Co. at Wyandotte, Michigan.

Oyster Shells: Along the Atlantic seaboard where oyster canning is a prominent industry, oyster shells form an important waste product, which is largely employed in the making of shell roads. The shells are nearly pure calcium carbonate and might form an important source of lime for the manufacture of cement. The material could be easily ground and in every way would be suitable for the purpose of cement manufacture. At present the only economic use made of the shells, except as a road material, is in the lime industry, where they have been utilized to a very limited extent.

Clay and Shale: Clay is a mixture of various kinds of residual materials resulting from the decay and disintegration of different kinds of rocks. The material is transported by the streams, and other agents, and is deposited in a very fine state of division. The constitution of the clay depends on the source from which it was derived. Clays contain the mineral kaolinite, hydrous aluminum silicate, together with feldspars, mica, etc. The higher the percentage of kaolinite the greater the plasticity of the clay, and the fatter the clay.

Chemically clays consist principally of silica, alumina, ferric oxide, magnesia, lime, alkalies and sometimes a little sulphur. The magnesia, lime and alkalies are usually present in only small quantities.

The value of a clay for the cement industry rests upon its percentage of silica, alumina and iron, and upon its regularity of composition throughout the bed.

Shales are of the same origin and composition as clays being simply indurated clays. They are generally harder and show bedding, while clays are heterogeneous.

The glacial clays of the northern states are in many cases undesirable for cement owing to the presence of stones and gravel, which render grinding necessary and difficult.

Slate: Slate is merely shale hardened by heat, pressure and other means to a point where it is very brittle and cleaves readily along the bedding planes. It has the same chemical composition as clay and shale but is not as satisfactory for cement purposes owing to greater hardness, which necessitates the expenditure of considerable power for grinding. It is seldom used in the manufacture of cement, but no doubt the waste from slate quarries could be utilized.

Processes of Manufacture

The processes of manufacture of cement may be roughly grouped into two classes, commonly called the wet and the dry processes. The latter is the one in general use in this country, the plants using the wet process consisting only of those located in the northern states and who obtain their lime content from the fresh water marls. As the dry process is the most economical and the one in general use, it will be described first.

The process of manufacture naturally divides itself into four steps which may be designated as follows: winning of the raw materials, grinding and mixing of the raw materials, calcination and grinding of the clinker.

Winning of the Raw Materials

Lime Material: If the calcareous material is limestone or cement rock the usual quarry methods will suffice to work the material. Power drills are usually employed. The rock after blasting may be loaded by various means, although steam shovels are the most efficient and, in plants of large capacity, are the only economical way of loading the cars. From the quarry the stone may be transported to the plant by various methods. If the quarry be located close at hand, cable tramways are suitable, but when used, they should be operated by endless cables so that cars can be kept going steadily in both directions. For longer hauls electric or steam locomotives are best adapted for the work. If the quarry be located on the side of a hill above the plant a tramway operated by gravity, the loaded cars hauling up the empty ones, will be found very efficient. This is the ideal location for a quarry as the haulage charges then consist merely in the depreciation of the equipment.

In working fresh-water marls for the calcareous material, dredging is practiced. Where the marl contains a great deal of water, it is frequently transported from the dredge to the plant by means of pumping through pipes.

Clay Materials: Where the output of the plant is small, hand digging may be resorted to, especially if the clay is soft. Where the output is larger the material, if soft, can be worked by plowing and scraping. This method is adopted only for comparatively level areas. The steam shovel can be used to advantage both with soft and hard clay though the initial cost is too great for plants with a small output. When obtaining clays from river beds or lake bottoms dredging may be resorted to.

If the clay content is derived from hard, compact shale the usual quarry methods of drilling and blasting will be found most useful. If care be taken, and the bank sufficiently undercut, a vast amount of material can be loosened at one shot.

Cost of Raw Materials: Bleininger estimates the cost of winning the raw materials as follows: hand digging of clay, 35 cents per cubic yard; quarrying shale, 25 cents per cubic yard; plow scraper method of obtaining clay, 20 cents per cubic yard; steam shovel method for clay, 5 to 12 cents per cubic yard; dredging clay, 4 cents per cubic yard containing 58 per cent moisture; quarrying limestone, 20 cents per ton; steam shovel in connection with blasting, 5 cents per cubic yard.

Mining may be resorted to in order to obtain both the lime and the clay materials, but is inadvisable, owing to the increased cost of the raw materials and should be avoided if possible.

Grinding and Mixing of the Raw Material

The raw material, as it comes from the quarry, is delivered to powerful crushers for the coarse crushing. These are of various types, of which the jaw and spindle crushers are examples. The jaw crushers, as the name suggests, operate by the opening and closing of steel faces, iron jaws. The spindle type of crusher differs from that of the jaw crushers in that their crushing is continuous and not intermittent as in the jaw type. In this type the crushing is done by a conical steel spindle, to which a gyratory motion is imparted by bevel gears. This spindle rotates within a conical space in the form of an inverted cone. The size of the crushed product is regulated by the width of the throat at the bottom.

For the coarse grinding of the raw materials the spindle type seems to have the advantage, in that, the crushing being continuous, it has a greater capacity than a jaw crusher of the same size.

The coarse crushers reduce the material to pieces from two to three inches in size. From the crushers the raw material is elevated to bins where it is stored till a chemical analysis has been made. From these bins it is customary to run the material through driers. These are revolving tubes 4 to 5 feet in diameter and 40 to 50 feet long, heated by a small furnace. It is necessary to dry the stone, as all rock contains a small amount of hydroscopic moisture which renders fine grinding difficult. The tube driers rotate slowly and have the receiving end only slightly higher than the discharge end so that the passage of the material is slow. From the driers the material is delivered to the intermediate grinders. These may be of the ball type, or the Kent mill, or even of the hammer type. The ball mill is a short cylinder half filled with iron balls from three to five inches in diameter. The material is ground by these rotating balls. In the Kent mill there are three rolls on the interior pressing against a revolving ring. The grinding is done between the inner surface of the ring and the rolls. In the hammer type the grinding is done by the impact of hinged hammers. The ball or the Kent mill is the most efficient. It is claimed that in the latter there is less wear on the grinding parts and no rubbing of the rock.

In the Edison plant both the coarse crushing and the intermediate grinding are done by means of rolls of large size. A very high efficiency has been claimed for these machines but at present they have not been used to any extent.

From the intermediate grinders the material is elevated to storage bins,then run into hopper scales in which the limestone and clay are carefully mixed in the proper proportions before the final grinding. The latter process is usually performed by tube mills or mills of the Griffin type, though mills of the Kent type have been successfully employed for this purpose. The tube mills are rotating cylinders, 16 feet to 24 feet long and 4 feet to 5 feet in diameter, about half full of flint pebbles which do the work of grinding. The tubes are rotated from twenty to thirty revolutions per minute. The finely ground material leaves the mill at the end through a screen. In the Griffin mill the grinding is done by means of a steel roll hung from a universal joint, and a steel ring or shor. On rapid rotation of the shaft carrying the steel crushing roll, the centrifugal force causes the roll to follow closely around the steel ring. It is between these two surfaces that the grinding is done.

On leaving the fine grinders the raw material has been reduced to fine powder, so that 90 per cent to 92 per cent will pass a hundred mesh seive. From this final grinding the material is elevated to storage bins from which the kilns are charged.

Burning of Cement

The burning of cement, in American practice, is usually carried on in continuous rotary kilns, while in Europe stationary kilns seem to be favored. The rotary kilns are long tubes from sixty to one hundred and fifty feet in diameter. They are slightly inclined, the charging end being higher than the end from which the clinker is discharged. This inclination is about three feet in sixty. The kilns are rotated by means of cogs on a collar which is driven by a gear wheel, the speed being about one revolution per minute. The interior is lined with fire bricks to a depth of six to twelve inches. There are parallel flanges running the whole inside length of the kiln. The fuel is forced in at the lower end by means of a blast, and ignited. The blast is strong enough so that the flame fills the lower twenty-five feet of the kiln. The raw material is introduced at the upper end as dust and becomes gradually heated as it progresses through the kiln. It leaves the lower end as dark greenish-black, fused pieces about an inch in diameter.

The fuel for firing these kilns may be either powdered coal, oil or gas. The temperature of the lower part of the kiln is not much below 2700 degrees Fahrenheit. At this temperature the charge is partially fused. It takes a charge about thirty minutes to pass through the kiln.

The rotary kiln has a greater fuel consumption than the stationary type. [1]

The following table gives the fuel consumption, per barrel of the cement, from a number of plants.

Process	Raw materials	Length of kiln	Output per kiln per day bbls. Range	Output per kiln per day bbls. Average	Coal consump. per kiln per bbl. Range pounds	Coal consump. per kiln per bbl. Average pounds
Dry	Limestone and clay	60	150-250	160	90-170	130
Wet	Marl and Clay	60	60-140	85	150-250	200
Wet	Marl and Clay	80-90	80-150	100	140-220	160
Wet	Marl and Clay	110	135	135	150	150
Dry	Limestone and Clay	60	150-250	160	90-170	130
Dry	Limestone and Clay	80	180-250	220	85-160	115
Dry	Limestone and Clay	80	225-300	260	85-120	110
Dry	Limestone and Clay	150	375	375	65	65

From the table just given it is seen that the coal consumption ranges from 200 pounds of coal per barrel to 65

1. Lime and Cement, Vol. VI, 2nd Series, Missouri Bureau of Geology and Mines, by H. A. Buehler.

pounds, the greatest consumption being in the wet process. But even where the dry process is used, the consumption varies from 130 pounds to 65 pounds, the fuel, necessary to burn the cement, decreasing with the length of the kiln. Eckel gives 28 pounds as the amount of coal necessary theoretically to burn a barrel of cement, so that it is plain that there is a great loss of heat in the rotary type of kiln. However they more than make up for this fuel loss in the ease and small labor with which they can be fired.

The clinker as it leaves the kiln is in the form of white-hot lumps. These are sprayed with water to partly cool them, then run through the coolers. One type of cooler is a revolving tube, on the inside of which is a number of flanges running longitudinally. On the rotation of this tube the clinker falls from one flange to another and goes slowly down the tube against a current of air. From the coolers the clinker is stored in bins and allowed to season for a considerable length of time before the final grinding.

The grinding of the clinker is done by the same type of machinery used in the grinding of the raw material, tube mills or Griffin mills. Either before the final grinding or just after, a little gypsum is added to the cement to retard its set. After leaving the grinders the cement is placed in the stock room and is ready for packing.

Wet Process

In the wet process the raw materials are usually marls obtained by dredging, and contain a large percentage of water and clay. They are pumped into storage tanks, then ground and mixed while wet. This wet mixture has about the consistency of cream and is called the slurry. The grinding is done by the same general type of machinery as in the dry process. The slurry is introduced into the kiln in a thin stream. After leaving the kiln the treatment of the clinker is the same as in the dry process in every respect. As shown by the table above, the burning of cement by the wet process requires a greater consumption of coal per barrel of cement, as a considerable amount of heat is necessary to drive off the large percentage of water in the slurry. The extra fuel cost, however, is offset by the cheaper handling of the raw material in the wet state, so that the ultimate cost of cement per barrel is approximately the same.

In America, cement is manufactured by the wet process only by those plants using fresh water marl, such as the Michigan plants and several in northern Ohio. The plant that utilizes the alkali waste also uses the wet process.

Location of Portland Cement Rock in Oklahoma.

As has been stated the greater part of the Portland cement manufactured in the United States is made of limestone and clay or shale. No other materials are used in any of the western states. It naturally follows therefore, that where good deposits of limestone and clay occur near fuel and transportation, Portland cement mills may be established.

The location of the principal limestone deposits of Oklahoma has already been discussed in Chapter VI of this report. Clay is usually found near these limestones. Maps showing the general location of the limestone in different parts of the State are given in Fig. 5, page 73 and Fig. 6, page 75. To these maps and accompanying description the reader is referred.

Suffice it to say that there is enough limestone and clay in Oklahoma to make Portland cement to supply the United States for ten thousand years. With the cement we have very large deposits of fuel, including coal, oil and gas. No state in the Union has more raw material or fuel for the manufacture of Portland cement than has Oklahoma.

Portland Cement Plants in Oklahoma

Oklahoma at present has three cement plants, though several others have been projected. These plants are located at Ada, in Pontotoc County; at Dewey, in Washington County; and at Hartshorne, in Pittsburg County; the plant at Ada being the pioneer in the development of Oklahoma's cement resources. Brief descriptions of these plants follow. [1]

The Plant of the Oklahoma Portland Cement Company at Ada: The plant of the Oklahoma Portland Cement Company is located one mile southwest of the town of Ada, in Pontotoc County, on three lines of railroad; the Oklahoma City and Atoka branch of the Missouri, Kansas and Texas; the St. Louis and San Francisco, and the Oklahoma Central, which runs from Chickasha to Lehigh.

The mill has a capacity of 3,000 barrels per day. The buildings are of reinforced concrete, and cover about ten acres of ground.

The shale and limestone are quarried six miles south of the plant and hauled to the plant, over a standard track by a switch engine furnished by the Frisco Railroad. The limestone and shale are found together and in position to be quarried with economy. Owing to the lack of time at the writer's disposal he did not visit the quarry, but from information of the officers of the company the usual quarry methods are employed in mining the raw material, namely, drilling and shooting off the stone in benches, and loading on cars by means of hand labor.

From the quarry the stone is delivered to the plant, unloaded and fed direct into two gyratory crushers of large capacity. From the gyratories the crushed stone is run through hammer mills, then elevated to bins from which it passes through two cylindrical dryers from which it is delivered to dry storage and carefully mixed on Fairbanks Hopper scales. After mixing it is ground to the requisite fineness of 97 per cent through 100 mesh sieve by Fuller Mills. The burning is carried on by two rotary kilns 125 feet long by 8 feet in diameter, and two rotary kilns 125 feet long by 9 feet in diameter. The fuel used is powdered coal which is forced into the lower part of the kiln by means of a blast. The clinker is passed through rotary coolers into which a stream of water is constantly playing. After adding three per cent of gypsum as a retarder, the clinker is ground in Fuller mills so that 95 per cent. will pass a hundred mesh screen, and 85 per cent. a two hundred mesh screen. The finished product is placed in large storage bins from which it is sacked by automatic sackers.

1. The descriptions are largely from the thesis of Mr. Nelson, but have been brought up to date.

The power is furnished by four Corliss steam engines, of 200, 400, 960 and 1260 horse power respectively; the 400 H. P. engine drives a generator, supplying electrical power to the outlying parts of the mill. Belt conveyors of 18 and 24 inches in width are used wherever possible.

Powdered coal is the fuel being used at the present time, but it is the intention of the management to use oil in the future, and to that end a complete oil burning equipment is installed.

The plant is favorably located as regards transportation facilities. The cement manufactured, known as the O. K. brand, is of high quality, uniform and light in color, caused principally by fine grinding; chemically a well balanced cement, which ranks physically with the best foreign and domestic brands, making a product suitable for any class of work in which Portland cement may be used.

The analyses of the limestone, shale, and finished cement as furnished by the company chemist are as follows:

	Limestone	Shale	Cement
Silica SiO_2	.42	42.30	22.04
Iron oxide Fe_2O_3	.10	5.92	3.12
Alumina Al_2O_3	.71	12.36	7.10
Lime CaO	55.08	12.86	62.00
Magnesia MgO	.28	5.50	2.40
Sulphur trioxide SO_3		Not determined	1.39
Loss	43.11	18.11	2.02

The cement takes its initial set in 2 hours, 45 minutes; and its final set in 5 hours, 30 minutes. The neat cement shows a tensile strength in 24 hours of 285 pounds; in 7 days of 600 pounds; in 3 months of 682 pounds; and in one year of 912 pounds.

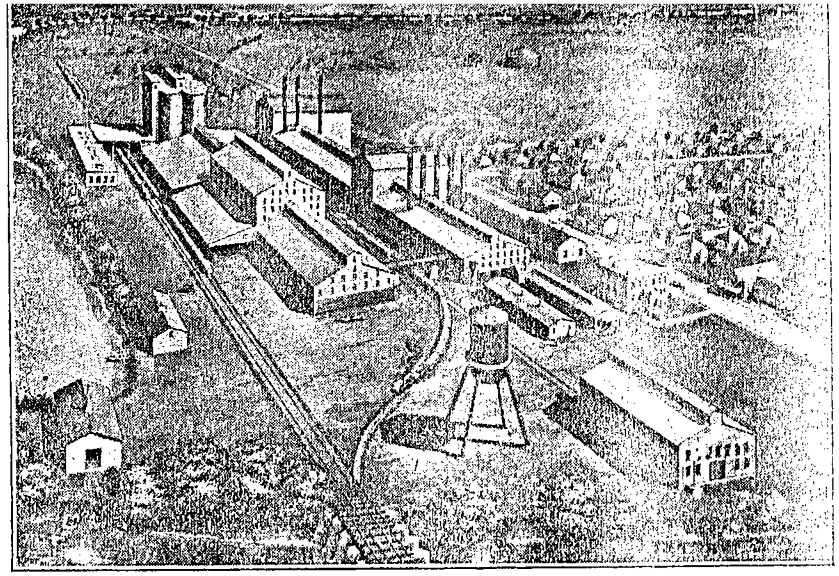
The Plant of the Dewey Portland Cement Co. at Dewey: The plant of the Dewey Portland Cement Company is located at the town of Dewey, in Washington County, four miles north of Bartlesville, on spurs running from the Independence-Tulsa Branch of the Atchison, Topeka & Santa Fe and the Parsons-Oklahoma City Branch of the Missouri, Kansas & Texas railroads. The main office is at Kansas City, Missouri.

The quarry is located one and a half miles east of the plant with which it is connected by a standard guage track. The limestone at the quarry is 22 feet thick and consists of shaly limestone. The rock is drilled by churn drills and shot down in one bench, after which it is loaded on dump cars by a steam shovel of 3 yards capacity. The rock is hauled to the plant by two 15 ton Davenport oil burning locomotives. The management is very proud of their quarry methods and claim their raw material is costing only ten cents per ton delivered at the plant. A small clay pit is located just north of the plant but only a small amount of clay is used owing to the shaly character of the limestone. It is taken from the surface by scrapers and loaded on cars.

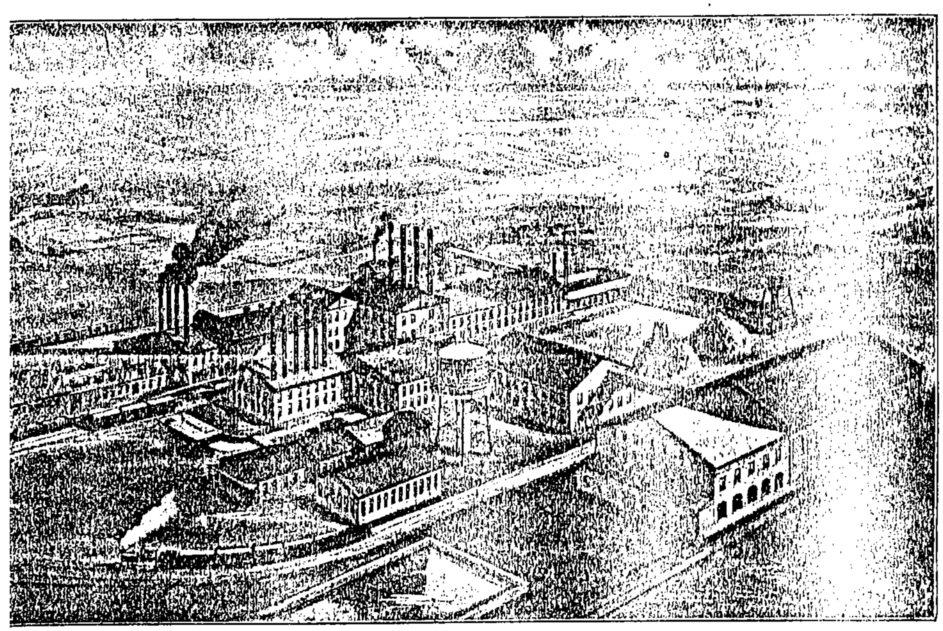
At the plant the loaded cars from the quarry are hauled up an incline by cable, and dumped into a large gyratory crusher. From the crusher it is elevated into storage bins from which it is passed through two rotary dryers fired with gas. After being dried thoroughly the limestone is fed to four Kominuter mills which grind it to about twelve mesh. The ground material is then elevated into 5 steel storage bins of 30 tons capacity from which it is drawn to the mixer. The shale comes in at the ground floor, is passed through a dryer and then through a roller mill, from which it is elevated into a storage bin of steel. The mixing is done very carefully in a Fairbanks hopper scale. From the mixers, the raw material is delivered to tube mills, 22 feet long and six feet in diameter. These mills grind to the requisite fineness, 97 per cent. through a hundred mesh and 85 per cent. through a two hundred mesh screen, after which the material goes to kilns, five in number, 100 feet long and eight feet in diameter. The firing is done with gas, piped from the company's own wells. The clinker is run through two rotary coolers, 65 feet long and six feet in diameter, from which it is distributed on the storage piles and allowed to season for some time. Before grinding three per cent. of gypsum is added as retarder. An underground conveyor draws the clinker from the storage piles and delivers it to four Kominuter mills. These mills reduce it to about twelve mesh. The clinker is now elevated to storage bins to await the final grinding. The final grinding is done by four tube mills. The final grinding reduces it to such a fineness, that 97 per cent. will pass a hundred mesh and 85 per cent. a two hundred mesh screen.

The plant is operated by electrical power, which is generated by six double acting gas engines of 550 horse power each, directly connected with generators. Each unit of the plant is driven separately and run in parallel.

The plant is new, having been run three years and is of excellent arrangement and construction throughout. It is well located both as to shipping facilities, raw material, and fuel, but the site is level and a great deal of elevation of material is necessary. The cement, which is known as the "Dewey" brand, is light in color and very high grade.



PLANT OF DEWEY PORTLAND CEMENT CO., DEWEY, OKLA.



PLANT OF OKLAHOMA PORTLAND CEMENT CO., ADA, OKLA.

The analyses of the raw material and finished product of the Dewey plant, are given below and are on the authority of Mr. P. R. Chamberlain, the company's chemist.

	Clayey limestone	Pure limestone	Clay	Raw Mix
SiO_2	11.92	1.40	83.04	14.96
Al_2O_3	6.46	.92	7.29	3.60
Fe_2O_3			2.79	1.80
CaO	55.24	54.65	1.90	42.58
MgO	1.23	Tr	Tr	.98
Loss	36.29	43.29	4.76	36.16
			Alkalies not determined	

	Cement
SiO_2	22.98
Al_2O_3	5.88
Fe_2O_3	2.79
CaO	15.33
MgO	1.70
SO_3	1.33

The cement takes its initial set in three hours and final set in five hours. The neat tensile strength is 375 pounds at the age of 24 hours and of approximately 1000 pounds in 28 days.

Choctaw Portland Cement Works at Hartshorne: The plant of the Choctaw Portland Cement Company is located one and one-half miles south of Hartshorne, Oklahoma, on a spur from the Ardmore Branch of the Chicago, Rock Island and Pacific Railroad which has been built to the plant.

The rock is obtained from an exposure of the Wapanucka limestone which stands as a bare ledge 100 feet high near the plant. Shale is secured underneath the limestone. The rock crushing plant consists of a No. 5 1-2 and a No. 8 crusher, the rock being brought to the crusher in quarry cars.

The rock passes from the bins under the screen into tramway cars, which are operated by a continuous cable along a tipple 400 feet in length, to the raw grinding building.

The material, after passing through the dryers, is emptied in steel and concrete tanks, from which it passes into two 7 by 9 ball mills, and from these into an 8 by 26 tube mill.

The kilns are 8 feet in diameter and 110 feet in length. The waste heat is utilized by passing it over vertical boilers. The steam from these boilers is passed through turbines developing 1500 k. w. of electricity to operate the plant. The plant is thoroughly modern in every respect, line shafts having been dispensed with, and every unit is driven by an individual motor.

From the storage bin the clinker passes into a finishing mill

where it is ground by five 40 inch Giant Griffin Mills. From here it is carried by a conveyor to the stock house, which is of concrete and stone construction, 140 feet in length and 75 feet in width.

The sacking is done by automatic machines.

The water supply comes from the artificial lake covering 242 acres, 300 feet from the mill. The dam is 240 feet in length, and 30 feet high. Water is carried from the lake to the plant by a tunnel through limestone and shale.

Coal, which is used for fuel, is obtained half a mile from the plant. The coal is ground by three 30 inch Griffin mills. The coal bin is 117 feet in length and 34 feet in width.

The following are the analyses of the limestone and shale by the Kansas City Testing Laboratory:

	Limestone	Shale
Silica SiO_2	1.10	55.50
Iron oxide Fe_2O_3	0.10	7.65
Alumina Al_2O_3	0.60	19.25
Lime CaO	54.70	5.60
Magnesia MgO	1.10	.60
Loss, CO_2 and organic matter	42.10	10.80
Alkalies K_2O & MaO_2		0.96
Sulphur trioxide SO_3	Trace	Trace

The finished cement analyzed and tested by the Engineering Department of Cornell University gave the following results:

Analysis

Silica SiO_2	22.85
Iron oxide Fe_2O_3 and Alumina Al_2O_3	10.31
Lime CaO	63.28
Magnesia MgO	1.57
Sulphur trioxide SO_3	1.47

The cement is slow setting, taking its initial set in 2 hours, 45 minutes, and final set in 9 hours, 15 minutes. 98.3 per cent. passes 100 mesh sieve and 83.0 per cent. passes 200 mesh sieve. The neat cement with 24.7 per cent. of water when aged one day in air, developes a tensile strength of 294 pounds; when aged one day in air and six days in water 662 pounds; and when aged one day in air and 28 days in water, 697 pounds.

CHAPTER X.

STRUCTURAL MATERIAL IN DIFFERENT COUNTIES

By Chas. N. Gould

Introduction

On the following pages I have attempted to outline in a very brief form, our present knowledge of the structural material in each county in Oklahoma. It is not the intention in this place to enter into a detailed discussion of all the materials of any county nor to discuss thoroughly any particular class of material, but rather to give a birds-eye view of the entire subject. The details are to be worked out in later bulletins.

In the treatment of the various counties the plan has been, first, to outline in a very few words the location, drainage, topography and timber of each county. Next follows a brief statement of the general geology, and of the various mineral products, including stone of various kinds, clays and shales, Portland cement rock, gypsum, gravel and building sand. Mention is made of many of the mines, quarries, plants or other similar enterprises found in the various counties.

The arrangement of counties is alphabetical. Fig. 10 shows the location of the counties of Oklahoma.

Adair County

Adair County lies in the extreme eastern part of the State. The principal drainage is into Illinois River, which flows west across the northern part of the county, and into its tributary, Barren Fork. The southern part of the county is drained by Sallisaw and Lee creeks, tributaries of the Arkansas. The surface is in general, a level plateau dissected in places by stream valleys. The greater part of the county is heavily forested, although there are certain upland regions in the northern townships which are barren of timber.

The greater part of the surface rock of Adair County is a formation known as Boone chert, of Mississippian age. This rock varies from 150 to 300 feet in thickness and lies nearly level. Streams have cut rather narrow valleys in the rock, exposing, in many places, older formations which lie below the Boone. In the southern part of the county, however, higher rocks than the Boone

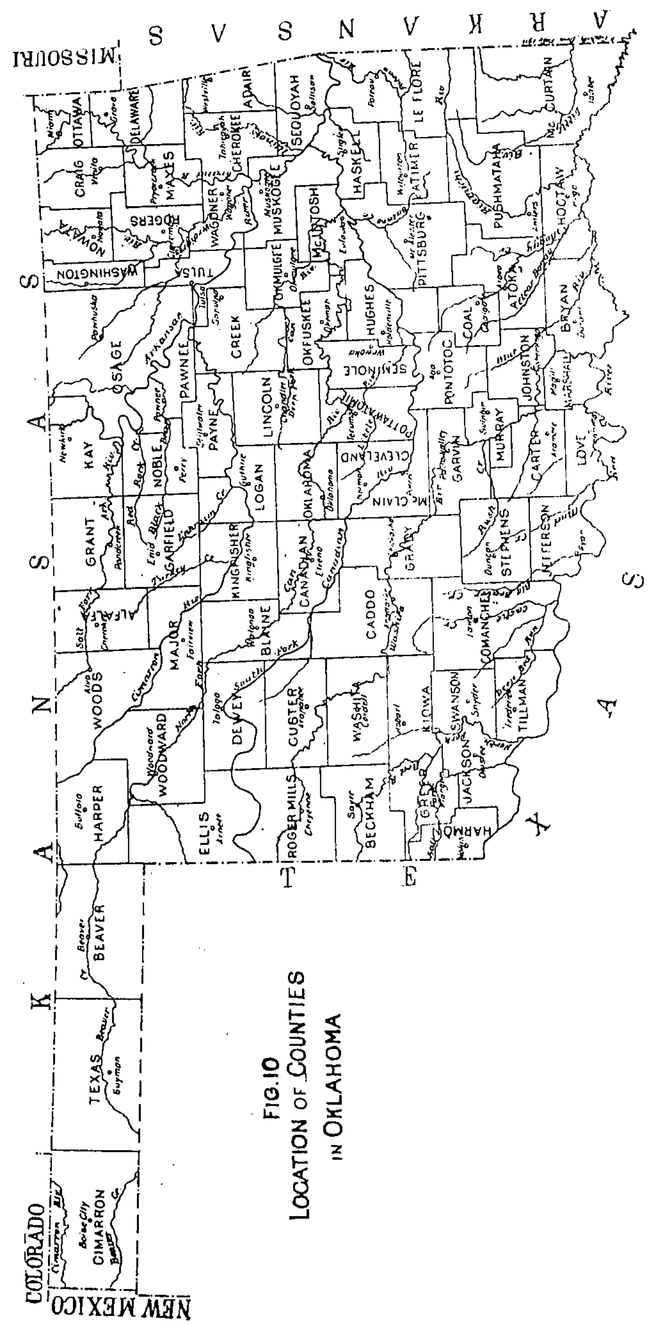


FIG. 10
LOCATION OF COUNTIES
IN OKLAHOMA

occur. They consist of a heavy ledge of limestone, known as the Pitkin limestone, several shale members, and some heavy ledges of sandstone, making up the Muskat and Brushy Mountains in the southeast corner of the county.

Alfalfa County

This county is located in the northern part of the State, bordering on Kansas. It consists of what was formerly the northeastern part of old Woods County. Salt Fork River flows across the county from west to east. Parallel to and north of this river, lies a strip of sand hills averaging 15 miles in width, but, aside from this variation, the surface in general is a level plain sloping slightly to the east. There is little timber in the county, except a few cottonwoods along the streams.

The largest salt plain in Oklahoma lies in the eastern part of the county. It is oval in shape, 12 miles long, north and south, and 6 miles wide, east and west; as flat as a floor, and usually as white as snow, the white color being due to a thin incrustation of salt that covers the surface of the plain.

Alfalfa County lies entirely in the area occupied by the Redbeds and contains very little hard rock of any kind. A soft sandstone has been quarried and used locally for foundations, outbuildings, etc., but practically all the building stone used in this section of the state must be shipped in. The red clay shales of the Redbeds usually make a good quality of brick, but, except for local use, very little brick has been manufactured. There is plenty of building sand, particularly in the region north of the Salt Fork.

Atoka County

Atoka County lies in the southeastern part of Oklahoma, just north of Bryan County. The eastern part of the county lies in the region of the Ouachita uplift, the northwestern portion in the Carboniferous area, while the southern part is occupied by rocks of Cretaceous age. The greater area of the region is hilly or even mountainous, and in general, is covered with timber. There are, however, certain sections, particularly in the southern part of the county, that are prairie land.

The rocks of the Ouachita uplift, in the eastern half of Atoka County, consist of steeply tilted sandstones and shales. The sandstone would make valuable building stone while the shales might be utilized for a number of different purposes, particularly for making brick and tile. The Wapanucka limestone, which is about 500 feet thick, parallels the Missouri, Kansas & Texas Railroad from near Stringtown to Reynolds. For a number of years it has been quarried at Limestone Gap, by the above railway company for use as ballast material and concrete rock. This rock was used in construction of the concrete wall of the State Penitentiary at Mc-

Alester. The same formation outcrops in western Atoka County near Wapanucka and is used for burning into lime. It is also suitable for the manufacture of Portland cement.

In the extreme western townships there are exposures of granite and hard massive limestone belonging to the Arbuckle Mountain system, this region being the southeastern extension of that range. The granite is a hard, massive, and rather coarse-grained crystalline rock; excellent for building stone, concrete rock and other similar uses. The limestone is also suitable for rip-rap, concrete, for burning into lime or for the manufacture of Portland cement. It is usually too badly fractured for large blocks of building stone to be obtained.

The northwestern part of Atoka County contains extensive deposits of heavy sandstone, an excellent building material, as well as of shale and clay. Coal is also abundant in the region. There is a ledge of limestone of Cretaceous age in the southern part of the county, suitable for structural purposes, for the manufacture of Portland cement or for burning into lime.

Taking everything into consideration, very few regions in Oklahoma have more varied or more abundant structural material than Atoka County.

Beaver County

Beaver County occupies the east third of what was formerly "No Man's Land" or "The Neutral Strip," in the so-called Panhandle of Oklahoma. Beaver Creek flows across the county and Cimarron River cuts through the extreme northeastern corner. The entire county, except the valley of Beaver Creek and other small streams, is a high, level prairie upland. The greater part of the surface rocks are deposits several hundred feet thick of Tertiary age, consisting largely of loose sand and clay and containing but few hard rocks of any kind. Along the south side of Beaver Creek and some of the tributaries entering it, there are a few exposures of Redbeds shales with occasional thin ledges of gypsum.

There is little building stone of any kind in Beaver County. A few ledges of red sandstone occur in the Redbeds, and the Tertiary deposits are sometimes sufficiently hardened to form a poor quality of building stone; these have occasionally been used for foundations. However, there is plenty of building sand. The clay might be used for the manufacture of brick.

Beckham County

Beckham County is situated in the southwestern part of the State. North Fork of Red River flows east across the county. The surface is generally level, except where is has been broken by stream valleys.

Beckham County lies entirely in the Redbeds region of Oklahoma. Throughout the greater part of the county, the rocks consist largely of soft, red sandstones and red clay shales. In the southeastern corner, several massive ledges of gypsum are exposed as high cliffs, some of which are more than 10 miles long on the north side of Red River. One of the seven salt plains of the State lies among the Gypsum Hills in this region. Gypsum is also exposed at the head of Fish and Valley creeks in the southwestern corner of the county. South of Red River there is a strip of sand hills from 3 to 6 miles wide.

Red sandstone has been utilized for building at such towns as Elk City, Sayre, Erick and Texola. In the southern townships there is a ledge of rather hard dolomite, which makes a good building stone. The red clay shales, that are abundant in all parts of the county, are suitable for the manufacture of pressed brick and tile. Building sand is abundant.

Blaine County

Blaine County lies northwest of the center of Oklahoma. Its northern corner touches Cimarron River. Both Canadian and South Canadian rivers take a southeasterly course across the county.

The northeastern part of Blaine County is level, while the southwestern portion is more or less broken. There is little native timber, except cedar in the canyons of the Gypsum Hills and oak among the Sand Hills. The county lies entirely in the Redbeds region of Oklahoma, and, with the exception of strips of sandhills north of North Canadian and South Candian rivers, all the rocks belong to the Redbeds series. The Gypsum Hills, which cross the northern part of the county, are made up of three ledges of massive white gypsum, separated by red clay shales. The gypsum is too soft for building purposes, but it has been extensively manufactured into wall plaster and stucco. Six gypsum plaster mills or half of those in the State are located in Blaine County, two at Watonga, and one each at Bickford, Ferguson, Southard and Okeene.

South of the North Canadian the hills are capped with a ledge of massive white or pink dolomite, which is in this instance a hard, brittle rock suitable for building. It has been burned into lime. Similar rock is also found in small quantities in the Gypsum Hills southeast of Watonga, and has been used for foundations and small buildings. Soft red sandstone common in most parts of the Redbeds also occurs in Blaine County. It has been sparingly utilized for building purposes in such towns as Watonga, Geary and Okeene.

Building sand is found abundantly in all parts of the county. The red clay shales are suitable for the manufacture of brick. A small plant is now in operation at Geary.

Bryan County

Bryan County is situated in southern Oklahoma; Red River separates it from Texas. Washita River forms its western boundary. Blue River flows southeast across the county and Boggy Creek touches the northeastern corner. About half the county is covered with timber, the remainder being prairie.

The rocks throughout the greater part of this region are of Cretaceous age, consisting of limestones, sandstones and shales. Along Red River there are deposits of still later age, made up chiefly of soft clay and loose sand.

Prominent ledges of limestone, which extend from west to east across northern part of the county, are of considerable commercial importance. These limestones are suitable for the manufacture of Portland cement, for burning into lime and for building stone. The soil formed from the disintegration of this rock is very fertile. The country occupied by the outcrop of these formations is known as the Black Prairie.

In certain regions, for instance in the country north of Bokchito and Bennington, there are deposits of dark brown or black irony sandstone. In places this is a fairly good iron ore.

The shales of Bryan County, which are widely distributed, are suitable for the manufacture of brick, tile and a large variety of clay products. Particularly fine clay known to occur near Durant and Bokchito. The former city would be a splendid location for the establishment of a clay products plant.

Caddo County

Caddo County is located in southwest-central Oklahoma. South Canadian River touches its northern boundary and the Washita flows east across the county. The greater portion of the drainage is into one or the other of these rivers. A little timber occurs along the streams, but as a whole the greater part of the county is prairie.

With the exception of the extreme southwest corner, Caddo County is located entirely in the Redbeds area, and rocks belonging to this formation outcrop practically all over its surface. The higher hills are made up largely of soft red sandstone. In the northern and western townships, there are a number of isolated buttes, the tops of which are capped with ledges of white or pink dolomite. These ledges are all members of the Redbeds.

Gypsum is abundant in certain parts of Caddo County. This rock consists of massive ledges of white gypsum or deposits of gypsite . Red clay shale, suitable for making brick, is found in all parts of the county, and the local stone, sandstone, dolomite and limestone, has been utilized for buildings in a number of towns. A stone crusher and a gypsum mill are being operated near Cement, in the Keechi Hills. There are several hills, outliers of the Wichita

Mountains, in the extreme southwest corner of the county. The rock of these hills would make Portland cement or might be burned into lime. Building sand is abundant in all parts of the county.

Canadian County

Canadian County is located in central Oklahoma. North Canadian and South Canadian rivers flow east across it. The greater part of the drainage is into one or the other of these streams. There is little native timber in the county.

All of Canadian County lies in the Redbeds region of Oklahoma, with perhaps the exception of the sand hill deposits north of the North Canadian. Red clay shales are abundant in all parts of the county, and occasional ledges of soft red sandstone occur. The latter have been utilized locally for farm houses and business blocks.

In the extreme northwestern part occur the south-eastern extension of the Gypsum hills. A gypsum plaster mill has been in operation for a number of years near Okarche. The red clay shale was formerly utilized for the making of brick at El Reno. Building sand is abundant everywhere.

Carter County

Carter County is located in southern Oklahoma. The region is drained directly or indirectly by Washita and Red rivers. The general surface of the county is a plain, somewhat cut up by valleys of streams flowing east or southeast. The eastern half is timbered; much of the western section is prairie. The Arbuckle Mountains are located in the northern part; the Redbeds occur in the western area. The rocks in the eastern section consist largely of sandstone and shales of either Carboniferous or Cretaceous age.

The most important building stone in Carter County is limestone, which occurs in vast quantities in the Arbuckle Mountains, and in the Criner Hills, 6 miles southwest of Ardmore. This limestone, which belongs to the Arbuckle, Viola, and Hunton formations, is of a very superior quality. It may be used not only for building stone, but for concrete rock, for burning into lime and for the manufacture of Portland cement. Certain ledges of sandstone in the Simpson formation, in the Arbuckles, are a good grade of glass sand. In the central and eastern parts of the county there are a number of ledges of light gray or brown sandstone of Carboniferous age, suitable for building material. Business blocks at Ardmore, and Berwyn have been built of this stone.

Clays and shales, which occur in all parts of the county, may be used for the manufacture of brick, tile, pottery and other clay products. A plant at Ardmore manufactures a good quality of brick. Buiding sand is very abundant.

There are in Carter County a number of deposits of both sand

and clay asphalt. This material is suitable for street paving and road material. The city of Ardmore which used Oklahoma asphalt for paving, has exceptionally fine streets.

Coal occurs near Ardmore, and both oil and gas have been found at Wheeler, 15 miles west of that place. There is a great probability that all these fuels will be found in still larger quantities. There are very few counties in Oklahoma that contain such a large variety of structural material, with fuel for its manufacture, as does Carter County.

Cherokee County

Cherokee County is located in eastern Oklahoma, Adair County separating it from Arkansas. Grand River forms the western boundary and together with Illinois River drains most of the adjacent regions. The surface is much broken, consisting of a level upland, occupying the greater part of the county, cut by rather deep valleys of streams flowing into Grand or Illinois river. The greater area is heavily timbered, although part of the upland is prairie.

This county lies in the southwest extension of the Ozark uplift, and the rocks are largely those which make up the mountains of that name. A heavy ledge of limestone, known as the Boone chert, outcrop through the greater part of the area. This formation is 150 to 300 feet thick, consisting of heavy massive limestone in the lower part, while the upper part contains considerable chert and flint.

Along the Illinois and in certain deep valleys in the southwestern part of the county, rocks belonging to formations older than the Boone chert are exposed. These rocks consist largely of shales and sandstones. In the western part of Cherokee County formations higher than the Boone come in. The principal rocks of these formations are shales, limestones and sandstones. The Pitkin limestone, some 50 to 75 feet in thickness, is the most important limestone member in this section. The sandstones and shales are similar to those usually found in the regions of Carboniferous rocks.

Both the limestone and sandstone have been used locally for many years. A number of the older buildings of the Cherokee Nation were constructed entirely or in part of this sandstone or limestone. The same material has been used for several business blocks in Tahlequah.

There is a vast amount of building stone in Cherokee County, only needing development to be of extreme value. The lower part of the Boone formation contains limestone similar to that now being quarried at Carthage, Missouri. This limestone might also be used for the manufacture of Portland cement and for burning into lime. Clays and shales, which are abundant in all parts of the county, would make excellent brick, tile and other similar products.

In a deep valley of Illinois River 5 miles northeast of Tahlequah, there is a valuable deposit of glass sand. Sandstone, suitable for building, occurs in the western part of the county.

Choctaw County

Choctaw County lies in the southeastern part of Oklahoma, its southern boundary being Red River. It is separated from Arkansas by McCurtain County. Kiamichi River flows south across the eastern part of the county and Boggy Creek crosses the western townships. The greater part of the region is forested.

The surface rocks of Choctaw County, except some recent deposits of sand and clay along Red River, are of Cretaceous age. The Trinity formation in the northern part consists largely of loose sand, gravel, and shale. This formation contains but little building stone of any importance; the sand and gravel deposits are, however, of considerable value. Extending from east to west across the central part of the county are outcrops of limestone and shale. This limestone is in many places suitable for building stone and for burning into lime. In connection with the shale, it would be suitable for the manufacture of Portland cement. Many of the shales and clays, so common in all parts of the county, could be used for the manufacture of brick, tile and other clay products, although some of them contain too much lime to be used in this way. Building sand is abundant. There is considerable hard sandstone in Choctaw County, much of which is dark colored due to the presence of iron. In fact much of the sandstone is a fair quality of iron ore.

Cimarron County

Cimarron County occupies the west end of the old "No Man's Land," or "Neutral Strip," the Pan-Handle of Oklahoma. The surface is in general a flat, level plain, sloping to the east, across which Cimarron River has cut a deep valley in the northern part of the county, and Beaver Creek a shallow one in the southern portion. This level upland plain is underlaid by deposits of Tertiary age, several hundred feet thick, consisting chiefly of soft sand and clay. Sandstones and shales of Cretaceous age and Redbeds deposits are exposed in the Cimarron valley in the northern part. In the extreme northwest corner, "The Black Mesa," a high table-land covered with a deposit of black lava rock, 150 feet thick, extends into the county for a distance of four miles. Cretaceous sandstones also outcrop in the valley of Beaver Creek.

Cimarron County has a larger amount of building material than any other county in northwestern Oklahoma. The sandstone and black lava in the vicinity of Kenton make an excellent building stone. The sandstone has been utilized in the construction of business blocks and farm houses. The clays and shales of the Redbeds

and the Cretaceous rocks in the Cimarron valley might be used for the manufacture of brick and tile. Building sand is found in abundance.

Cleveland County

Cleveland County lies in the central part of the State, having as its southern boundary South Canadian River. Little River drains the eastern part of the county. The surface is gently rolling, being more broken in the eastern townships, by low timber covered hills. The western part is prairie.

All the rocks in Cleveland County belong to the Redbeds formation. Red clay shales predominate although occasional ledges of soft red sandstone are found, particularly in the breaks of Little River in the central and eastern portions. This stone has been used quite extensively for the construction of business blocks and residences in Norman, Noble, Lexington, as well as for the building of many farm houses. Red clay shales, suitable for the manufacture of brick, are common in all parts of the county. Building sand is abundant, especially along the courses of the rivers.

Coal County

Coal County lies southeast of the center of the State. It is drained entirely by tributaries of Boggy Creek. The timber is confined to the ridges, the valleys being broad and fertile.

The greater part of Coal County is occupied by rocks of Carboniferous age, chiefly sandstones and shales. The sandstones are massive and form excellent building stone. Many of the business buildings at Lehigh and Coalgate have been erected of this material. Shales and clays, which are common in all parts of the county, are suitable for the manufacture of brick, tile and other clay products. Fire clay should occur beneath the coal veins, but the deposits that have been tested do not prove to be No. 1 fire clay. Much of it, however, would be suitable for the manufacture of paving brick and sewer pipe.

In the extreme western part there are a number of ledges of limestone belonging to the Arbuckle Mountain uplift. These ledges outcrop near the towns of Hunton and Bromide. The rocks in this region are suitable for the manufacture of Portland cement, for burning into lime, and for building stone.

Comanche County

Comanche County is situated in southwestern Oklahoma, its southern boundary being formed by Red River. The greater part of this county slopes to the south and is drained by Cache Creek, one of the tributaries of the Red. There is a little timber in the mountains and along a few of the streams, but prairie occupies the greater part of the region.

The northwestern part of the county contains the eastern end of the Wichita Mountains, in which are to be found several varieties of fine building stone, namely, granite, porphyry, gabbro and limestone. The granite, which is by far the most abundant rock, outcrops in the form of extensive ranges with rough and jagged peaks. These ranges extend westward from a point a few miles north of Lawton to the limits of the county. In the region west of Fort Sill there are extensive deposits of porphyry outcropping as a number of rounded hills. Carlton Knobs and Signal Mountain are made up of this rock. Gabbro, or black granite, is found in large quantities near the north base of Mount Scott and in the vicinity of Meers, as well as in the valley between the two main ranges of the Wichita Mountains.

Limestone occurs in large quantities in the hills lying north of the main part of the Wichita Mountains. These hills extend from near the Rock Island railroad at Richards Spur 10 miles north of Lawton, north and west as far as southeastern Kiowa County. Other deposits of limestone are found east of Fort Sill and on the south side of the main Wichita range, a few miles west of Lawton.

Surrounding the Wichitas on all sides are the Redbeds, consisting largely of red clay shales with occasional thin beds of sandstone. Practically all the hard rocks in Comanche County, except those already mentioned, are red sandstones and thin dolomites of the Redbeds series. There is a small amount of gypsum in the northeastern part. A ledge of limestone, which outcrops on the Fort Sill reservation, furnishes the building stone for the Fort. Local quarries have been opened near Lawton and Cache. The stone obtained has been used for buildings in these towns.

A crushing plant, using the limestone from the eastern end of the limestone hills, has been for some time in successful operation at Richards Spur.

Comanche County contains an inexhaustible supply of very high grade building stone including granite, gabbro and limestone. This in additon to gypsum, clay and immense deposits of valuable building sand. This latter material, consisting of broken granite particles, is found in great quantities in the beds of Cache, Post Oak, Blue, Beaver, Medicine Bluff and other creeks flowing from the Wichita Mountains.

Craig County

Craig County is located in the northeastern part of the State, its northern boundary being the Kansas line. Grand River flows through the northeastern corner; the principal drainage is through Big Cabin Creek and its tributaries. The surface is generally level or slightly rolling. Timber is found along the stream valleys, but the greater part of the county is prairie land.

Craig County is located in the region of Carboniferous rocks,

excepting the southeastern corner which is in the Mississippian area. The greater part of the rocks consist of ledges of limestone, sandstone, and shale striking northeast and southwest. In the southeastern corner, there are outcrops of Boone chert, and a heavy ledge of limestone. The latter occurs more abundantly in Delaware and Ottawa counties. Sandstone and shales predominate in the flat prairie region around Vinita. North and northwest of Vinita there are a number of prominent ledges of sandstone formed by continuous buttes and ridges.

In the northwestern part of the county there are several prominent ledges of limestone with intervening shales, members of the Claremore formation. The limestones form a prominent escarpment that enters Craig County, from Kansas just west of Chetopa and passes southwest from Centralia to Chelsea.

Various ledges of sandstone have been quarried and the stone used locally for building purposes in such towns as Vinita, Blue Jacket, Welch and Big Cabin. This sandstone is light gray to brown in color and makes a handsome and durable stone for building purposes. The limestone of the Claremore formation has not been used in Craig County except for foundations and small buildings. It would make a good Portland cement. Shale, which is abundant in all parts of the region, has been used in the manufacture of brick at Vinita and Welch. Several clay products plants might well be established in this county. The fact that large amounts of coal are known to exist, and that the greater part of the area lies in the probable oil and gas fields, leads to the belief that when these dormant resources are fully developed, this county will become one of the most wealthy manufacturing regions in the State.

Creek County

Creek County lies northeast of the center of the State. Cimarron River flows across the northern part and Deep Fork of Canadian River crosses the southern portion. The surface is generally hilly, caused by a number of rather prominent sandstone ridges which are covered with timber. The intervening shale valleys take the form of prairies, crossing the county from north to south.

The rocks of Creek County consist of massive ledges of sandstone and intervening shales of Carboniferous age. These sandstones are exposed on the tops of hills or along stream-formed cliffs. In the northeastern part of the county there are several ledges of limestone, which might be utilized for building stone and for the manufacture of Portland cement. By far the greater part of the available building stone is, however, a fine-grained, gray to brown sandstone. This material has been extensively utilized for building purposes in such towns as Sapulpa, Mounds, and Bristow. The amount of good building stone in sight is inexhaustible.

Clays and shales occur in great quantities throughout the entire county. In the extreme western townships the clay is usually that of the Redbeds. The clay in the eastern part is gray or yellowish in color, all of which should be suitable for the manufacture of brick, tile and other clay products. It is now being utilized for brick by two plants at Sapulpa.

Creek County lies in the gas belt and, hence, contains extensive supplies of fuel, which, together with the limestone, shale and other structural material will tend to render this one of the wealthiest counties in the State.

Custer County

Custer County lies in the western part of the State. The South Canadian flows across the northeastern corner and Washita River across the southeastern corner. A number of minor streams, tributaries to these rivers, have dissected the otherwise level plain so that a considerable part of the area is somewhat broken. There is no timber, except along the straems.

Custer County lies in the Redbeds region. Practically all the rocks that outcrop on the surface, consist of either red clay shales or gypsum. This latter occurs in practically all parts of the county, usually in the form of massive ledges forming escarpments along the streams. Earth gypsum of "gypsite" is found in a number of localities. There are occasional deposits of rather hard dolomite. In the western part there is considerable amount of limestone of Cretaceous age, known locally as "shell rock." The greater part of the hard rock, however, consists of red sandstone occurring as ledges in the Redbeds. This material has been utilized at Arapaho, Clinton, Weatherford and Custer City for business blocks, and in various parts of the county, for residences, barns and outbuildings. The red clay shale might be manufactured into brick. Building sand is abundant.

Delaware County

Delaware County lies in northeastern Oklahoma, the eastern boundary being Missouri and Arkansas. Only one county, Ottawa, separates it from Kansas. Grand River flows southwest across the northwestern corner of the county; the drainage is through such streams as Spavinaw, Saline and Sharp creeks, its tributaries. A considerable portion of northern Delaware County is a flat prairie, but long the streams there are heavy growths of timber. The southern part is hilly.

Practically all of this county lies in the region of the Ozark uplift, consequently the rocks are largely the limestones and shales common to that formation. The most prominent limestone is the Boone formation and varies from 150 to 300 feet in thickness. Above this lie shales and occasional ledges of sandstone.

The limestone of the Boone formation would make excellent building stone. The famous Carthage limestone of Missouri comes from this formation. It outcrops in nearly all parts of Delaware County, hence the amount of building stone is practically inexhaustible. The only lime kiln in the State that was in operation for several years prior to 1910 is located near Grove in the northern part of the county. Shales, that are found in connection with the limestone would be suitable for the manufacture of a large variety of clay products; and if mixed with the limestone would make a good Portland cement.

Delaware County lies in the region in which we may expect to find lead and zinc and there need be no surprise if further search reveals workable deposits of these minerals.

Dewey County

Dewey County lies in northwestern Oklahoma. South Canadian River flows across the county through the level plain in a rather deep valley. North Canadian River crosses the northeastern corner. Except for a little timber along the streams and in the sand hills all the county is prairie.

All of Dewey County is in the region of the Redbeds. Red clay shales outcrop on the surface in nearly every township. Along the northern side of the larger streams there are strips of sand hills averaging 10 miles in width. The southern and western parts contain a considerable amount of gypsum, outcropping in the form of massive ledges. Gypsite is also present in small quantities. In the northeastern corner on the top of some of the higher hills there are deposits of white or pinkish dolomite. Occasional deposits of Cretaceous limestone, usually known as "shell rock," occur in the county. Very little of this building stone has been utilized, however, except locally for foundations and small buildings. A few business blocks and residences in several of the towns have been constructed of the sandstone of the Redbeds. There is an abundance of red clay shales that might be utilized for the manufacture of brick. Building sand is very abundant.

Ellis County

This county lies in western Oklahoma and joins the northeastern part of the Pan-Handle of Texas. Wolf Creek, one of the tributaries of North Canadian River, flows across the northern part of the county. The South Canadian forms its southern boundary line.

The county is a high upland into which the streams have cut rather shallow valleys. The greater part of the region consists of flat prairie land. The surface rocks are Tertiary deposits consisting of soft sandstone and clay. There are extensive exposures of Redbeds in the southeastern townships along the South Canadian. In this region there are a number of ledges of gypsum and occasional beds of dolomite and red sandstone. The greater part of the country, however, contains no building stone. On the other hand there are very extensive deposits of building sand. Brick might be manufactured from the red shales. Gypsum plaster could be made from the gypsum which outcrops along South Canadian River.

Garfield County

This county is located in the north-central part of Oklahoma. It contains no large rivers. The drainage is through the small streams that flow north into the Salt Fork or south and east into the Cimarron and the Arkansas. The surface is a gently sloping plain with few irregularities. There is no native timber except among the sand hills and along the streams. The entire country is occupied by the Redbeds. In the southwestern part there are considerable areas of sandhills lying to the north of the rivers.

Garfield County contains few hard rocks of any kind. Along some of the streams in the southern part there are several ledges of soft red sandstone belonging to the Redbeds, that have been used locally for foundations and even for small buildings. The western and northern part of the county contain practically no stone. The red clay shales of the Redbeds would make good brick. For several years a brick plant has been in operation at Enid, where the red shales are over 100 feet in thickness, the output of which has been very satisfactory. There is unlimited quantity of building sand particularly in the southwestern area.

Garvin County

Garvin County lies south of the center of Oklahoma. Washita River flows across the county toward the southeast, all the drainage being into this stream. The surface in general is rolling. The eastern part is timbered, while the western area is largely a prairie.

The western half of Garvin County lies in the Redbeds region. The eastern and southern sections lie near the Arbuckle Mountains and the limestone members of these mountains outcrop near the extreme southern boundary. In the eastern townships gray sandstones and conglomerates are found. The western part of the county contains only shales of the Redbeds and occasional ledges of soft-red or gray sandstone. The latter has been used locally for building purposes.

Much of the gravel and coarse sand, that is found in many of the streams, might be utilized for concrete rock and other forms of building material. The limestone and conglomerate in the extreme southern part of the area could be utilized for building stone and concrete. The red clay shale, in the western townships would

make god brick. Building sand is common in most parts of the county.

Grady County

Grady County is situated southwest of the center of Oklahoma. Its northern boundary is formed by South Canadian River. The Washita flows southeast across the county. The drainage is into these two streams. The surface is usually level or slightly rolling. There is little timber except along the streams.

The county lies in the Redbeds region of Oklahoma. The rocks consist largely of red clay shales with an occasional ledge of thin-red sandstone. The later is usually soft and in many cases not suitable for anything but foundations and small buildings. However, business blocks at Chickasha, Minco and Rush Springs have been constructed of red sandstone. A rather prominent ledge of coarse sandstone, sometimes reaching a thickness of 20 feet, outcrops near Ninnekah. This has been used by the Rock Island Railroad for abuttments and rip-rap. The red clay shales have been utilized at Chickasha for the manufacture of brick. Building sand is abundant in all parts of the county.

Grant County

Grant County borders on the Kansas line in the north-central part of the State. The surface is a rolling plain, sloping to the east. Salt Fork of Arkansas River flows across the southern part of the county. There is little timber except in the sand hills and along some of the streams.

Grant County is located entirely in the Redbeds area. All the hard rock of the region consists of occasional thin ledges of red sandstone. There is neither limestone, granite or any other rock of like degree of hardness in the county. North of the Salt Fork there is a strip of country averaging 10 miles in width, covered with sand hills. The latter lie on top of the Redbeds shale. The sand in these hills would be good for building purposes. The red clays and shales, that are abundant in all parts of the county, are suitable for the making of brick or tile.

Greer County

Greer County is located in the southwest corner of Oklahoma. The surface in general is rolling. North Fork of Red River forms its northeastern boundry. Elm Fork and Salt Fork flow across it in a southeasterly direction. There is very little native timber in Greer County.

The rocks are of two general kinds, granite and Redbeds. The granite constitutes the western end of the Wichita Mountains and occurs as a number of knobs and peaks located in the northeastern area. Headquarters, Quartz, Navajo, Sutters and Wildcat mountains, varying from 100 to 200 feet in height, are the most conspicuous peaks.

Some of the best granite quarries in the State are in Greer County, nearly a dozen of which are located near the town of Granite at the foot of Headquarters Mountain. This granite varies considerably in texture in the different quarries, but is usually a fine-grained, dark-red stone that takes a good polish and makes a handsome and durable ornamental stone. The State reformatory was located at Granite because of the large amount of good stone in the immediate vicinity.

Surrounding these granite peaks are the Redbeds. There are a few ledges of rather soft sandstone in this formation, that have been used locally for foundations and for small buildings. In the western part of the county occur the Gypsum Hils, consisting of 5 or more heavy ledges of gypsum. This material is too soft to be used as building stone, but it is an excellent material for the manufacture of wall plaster, stucco and other gypsum products.

Just above the upper ledge of gypsum is a ledge of rather hard, gray dolomite that makes excellent building stone. It outcrops usually along the top of cliffs and stream valleys. Several business blocks at Mangum have been constructed of this stone.

At Mangum, the shales of the Redbeds, have been utilized, for brick. Building sand is abundant.

Harmon County

Harmon County lies in the extreme southwestern corner of the State. Elm Fork and Salt Fork of Red River flow east across the county. South Fork forms its southwest boundary. The greater part of the surface is level, although the streams have cut rather deep valleys across the plains. There is practically no timber in the county.

Redbeds occupy the entire area. Gypsum in the form of massive-white ledges, outcrops along Elm Fork and Salt Fork and along several small tributaries of South Fork. Below and between the ledges of gypsum are beds of red clay shales. A ledges of dolomite, varying in thickness from 1 to 5 feet, is found throughout a considerable part of the county. It makes a durable building stone. However, very little stone of any kind has been utilized for construction purposes, although a few foundations and small buildings have been built of this material.

The amount of gypsum in Harmon County is practically inexhastible. The red clay shales may be utilized for brick. Building sand is abundant in many places.

Harper County

This county borders on Kansas; its western boundary being

the county of Beaver; Cimarron River which forms its northeastern boundary separates it from Woods County. The southwest corner is cut by Beaver Creek, one of the head tributaries of North Canadian River. The northern part of the region is much cut by streams; the largest of which is Buffalo Creek, rising on the level plains and flowing east into the Cimarron. The southwestern part is also dissected by tributaries of Beaver Creek. The central and northwestern parts of the county consists of high level uplands. There is no native timber in the county.

Harper County lies in the Redbeds region of Oklahoma. Red shales and clays outcrop along the Cimarron and along its tributaries, as well as in the country south of Beaver Creek. Gypsum Hills occur in northeastern part of the area. They are made up of two heavy masses of gypsum separated by red shales. On some of the high hills between the streams that flow north into the Cimarron there is a ledge of white or pinkish dolomite, which would make excellent building stone. There is also a considerable amount of red sandstone in the same area. The high upland is formed of Tertiary rocks, containing little hard rock of any kind. Building sand occurs in quantity among the sand hills. The red clay of the Redbeds might be used for making brick.

Haskell County

Haskell County lies in the eastern part of the State. Its northern boundary is formed by Arkansas and Canadian rivers. The chief drainage is through San Bois Creek, into the Arkansas. The greater part of the region is heavily timbered.

The rocks of Haskell County consist largely of sandstones and shales. The former is most conspicuous, forming a number of prominent hills or mountains, of which San Bois Mountain is the highest. The sandstone lies in definite massive ledges, from 10 to 50 feet inthickness. It has been used as building stone in such towns as Stigler, Tamaha, Chant, Kinta, Enterprise and Iron Bridge. It is also suitable for a variety of other purposes.

The clays and shales of this county, are the same as those which occur in similar formations of the other parts of the State. They are suitable for the manufacture of brick and other clay products. Coal is found in practically all parts of the county. It is very probable that oil and gas will be encountered here.

Hughes County

Hughes County lies southeast of the center of Oklahoma, South Canadian River crosses it from west to east and North Canadian flows across the northern part. The surface is hilly. Several ranges of prominent sandstone hills cross the county from north to south. These hills are usually timbered, while the shale country is, in general. prairie land.

Sandstone is by far the most abundant building stone in Hughes County. The most prominent ledge, named the Calvin sandstone by Mr. Taff, enters the county from the north near Dustin, just west of the line of the Missouri, Oklahoma & Gulf Railroad, crosses South Canadian River near Calvin, and occupies the divide between the Canadian and head waters of Boggy Creek in the southwestern area. The Calvin sandstone is a gray to brown stone, occurring in ledges 100 feet thick. It makes a good building stone. Other conspicuous ledges are found near Stuart in the eastern part of the county and some are found near Wetumka and Holdenville farther west.

Clays and shales, both blue and yellow in color, occur in practically all parts of the region. This material might be utilized for the manufacture of brick, tile, pottery and other clay products.

Hughes County lies within the region in which we may expect to find oil and gas and if these fuels are ever found in abundance they will aid greatly in the development of the resources of the region.

Jackson County

Jackson County is in southwestern Oklahoma, between North and South Fork of Red River. It lies in the southeast corner of what was originally Greer County. The surface is generally level, but several streams, tributaries of one or other of the forks of the Red River, have cut rather deep channels in this plain. There is little or no native timber in the county. The greater part of the rocks of the region are Redbeds, consisting chiefly of red shales and clays and red sandstone. In some places there are considerable amounts of gypsum and dolomite, both of which usually occur in the form of massive ledges. At Creta the dolomite is 15 feet thick and when developed will make a valuable building stone. Near Creta and Eldorado gypsite beds are found and have been utilized to a certain extent.

Near Navajoe and Headrick in the eastern part of the county there are several mountains of granite, protruding through the Redbeds plain. The granite is of great value and in time will be utilized. Red shale, useful for the manufacture of brick, and building sand, are abundant in all parts of the county. They have been utilized at Altus.

Jefferson County

This county lies along Red River, in the south-central part of the State. The chief drainage is through Beaver and Mud creeks into Red River. The surface is usually level or gently rolling. There is a little timber along the streams. Redbeds outcrop on the surface throughout the greater part of the area, though strips of sand hills occur at various places north of Red River. Very little

building material, except occasional thin ledges of red sandstone, occurs inthis region. The sandstone has been utilized for buildings at Waurika and Ryan and locally for farm houses and barns. The red clay shale is suitable for the manufacture of brick, to which purpose it is put at Waurika and Addington. Building sand is abundant.

Johnston County

Johnston County is located in the southern part of the State. Washita River crosses the southwestern corner and Blue River, and a number of small streams, tributaries to the Washita, flow southeast. The southern part of the county is largely timbered; the northern part contains much prairie land.

The greater part of Johnston County is located in the region occupied by the Arbuckle Mountains, and practically all of the area contains a very large amount, as well as a great variety, of structural material, including granite, limestone, clays, shales, sandstone, asphalt, glass sand and building sand.

The granite occurs chiefly in the central and southern parts of the county, occupying a triangular area bounded roughly by a line connecting the towns of Mill Creek, Ravia, and Wapanucka. More than 100 square miles are occupied by this rock, usually known as the Tishomingo granite, the name coming from Tishomingo, the county seat.

The granite varies much in texture, that quarried near Tishomingo being very coarse-grained. In other parts of the region, however, the granite is fine-grained, and reddish in color. Gray granite is found in several localities. In a number of places dikes of hard, black diabase and diorite occur.

Limestone is very abundant, the largest area being that of the Arbuckle limestone, which occupies nearly 100 square miles in the northern and western parts of the county. This limestone is heavy, and massive, but it has been much faulted and folded so that it is difficult to obtain symmetrical blocks, and for this reason it is usually not suitable for building stone. It may be used for concrete, ballast, rip-rap and other structural products, also for burning into lime and for the manufacture of Portland cement.

In addition to the Arbuckle, there are several other limestone formations in Johnston County, the most prominent being the Viola, Hunton and Sycamore. These ledges outcrop near the edge of the mountain uplift. The most prominent exposures are found among the hills west of Ravia and between that place and the Washita River. Other exposures occur near Mill Creek and Bromide. All of these ledges contain rock suitable for building stone, for the manufacture of Portland cement and other structural material.

Sandstone occurs in a number of localities in Johnston County, particularly along Blue River and Delaware Creek in the northeastern part and near Mill Creek in the northwestern part. At these places the Simpson formation outcrops on the surface. Near Mill Creek there are deposits of coarse conglomerate made up largely of limestone pebbles. The streams have in many places washed the conglomerate away so that it now occurs as gravel beds along the stream channels.

Clays and shales occur widely distributed in the area, particularly in the valleys of many of the streams. In the country along the Washita west of Ravia, extensive outcrops of Sylvan shale occur. Good kaolin and pottery clay have been reported from this locality.

There are a number of localities in Johnston County where asphalt occurs, the most prolific deposits being near Tishomingo and Ravia. It is also found in small quantities near Bromide. This material being suitable for street paving, will become a valuable comodity when developed.

Glass sand is found in large quantities near Bromide and along Delaware and Blue rivers in the northeastern part of the county, also near Mill Creek and Reagan in the western townships. This material occurs as a member of the Simpson formation and is found in inexhaustible quantities.

Building sand and gravel are found widely distributed. All of the creeks such as Rock, Pennington, Mill, and others, flowing from the mountains, carry large deposits of broken granite and limestone. This material is excellent for concrete rock and is now being shipped from several localities to Ardmore, Oklahoma Ctiy, and other towns in the State for that purpose.

Johnston County contains a vast amount of Portland cement rock, the limestones and shales found in various parts of the region being suitable for the manufacture of this material. Neither coal, oil nor gas has been found in the county, however, and any fuel used for manufacturing would have to be shipped in.

There is no county in Oklahoma which contains a larger amount or variety of building materials than does Johnston County.

Kay County

This county lies in the extreme north-central part of the State. Arkansas River flows southeast across the eastern townships in a deep and winding valley through the limestone hills. Beaver Creek crosses the eastern section and Salt Fork of the Arkansas flows east across the southern areas. Chickasha River is the largest stream in the northwestern portion. Eastern Kay County is quite broken, caused by the streams cutting into the hard rocks. The western section is more nearly level. There is timber along the valleys, but the level uplands are grass covered.

The eastern area contains a large amount of limestone in the form of massive ledges, a southern continuation of the Flint Hills

of Kansas. The principal formations that outcrop in Oklahoma are known as the Wreford, Florence, Fort Riley, Winfield and Herrington limestones. The rocks usually outcrop on the tops of high escarpments along the Arkansas and its tributaries. On passing westward these ledges dip beneath the surface and disappear.

At various times a considerable amount of building stone has been quarried in Kay County. Several quarries have been operated east of Newkirk, of which the two most important are the Armstrong quarry and the Fagens quarry. The Armstrong quarry, located four miles east of Newkirk, furnished the stone for the old administration building of the State University at Norman. A quarry on the Chilocco Indian reservation in the northern part of the county has supplied stone for a number of fine buildings at the Chilocco Indian school. This quarry is still in operation. Stone crushers have been operated at Ponca City and Uncas. The material is being used for ballast on the Santa Fe Railroad and for concrete rock.

There is a vast amount of limestone in Kay County, enough to supply the State of Oklahoma with building and concrete material for hundreds of years. Many buildings in Newkirk and Ponca have been built of the limestone from eastern townships. The stone is also used for the foundations of small buildings and for fence posts. The shale and clay, which occur between the limestone ledges, is valuable for the manufacture of ordinary clay products, such as brick, tile, and fire proofing. The limestone and shale would make Portland cement.

In southwestern Kay County there is no limestone and only a small amount of sandstone. One of the earliest sandstone quarries opened in the region was on the McCann farm near the town of Eddy. From this quarry building stone for local use was hauled for miles. Western and central Kay County contain considerable gypsum, which has been utilized at various times. Some years ago there was a gypsum plaster mill in operation near Peckham.

The fact that natural gas has been found at Blackwell and Ponca City render it probable that sufficient fuel may be developed for the manufacture of the stone and clay resources of the county.

Kingfisher County

Kingfisher County is located in central Oklahoma. Cimarron River flows in a southeasterly direction across its townships. The surface is generally level. Few deep stream valleys are found and high hills are uncommon. There is a little timber along the streams and in the low sand hills.

There is very little building stone in Kingfisher County as it is located in the Redbeds region of the State. North of the Cimarron lies a strip of country averaging 10 miles in width, containing low sand hills. The extreme southwestern corner of the county extends into the Gypsum Hills. Other parts of Kingfisher County contain only red clay shales with occasional thin beds of red sandstone. There are a few buildings at Kingfisher and Hennessey built of this stone, but, in general, very little of it has been utilized. The red clays and shales are suitable for the manufacture of brick. Building sand is abundant.

Kiowa County

Kiowa County is located in southwestern Oklahoma. Washita River touches its northeast corner. North Fork of Red River forms its western boundary. Elk and Rainy Mountain creeks are the chief streams. With the exception of a few elms and cottonwoods in the valleys, there is little native timber in the county.

There are four principal kinds of rocks in Kiowa County, namely, granite, limestone, sandstone and shale. The granite, which is the oldest and underlies everything else, belongs to the Wichita Mountain range. These mountains occur, in the southern part of the area, as a number of hills outcropping on the otherwise level surface. Some of these have received such names as Tepee, Dome, Elk, Devil's Canyon, Longhorn, and Raggedy mountains. The greater part of the granite is red or mottled in color. Its hardness and durability make it an excellent building stone.

Limestone outcrops in the southeastern and the northern parts of the county. In this region there are a number of conspicuous hills, composed of massive ledges of Arbuckle limestone, which have been faulted and folded to such a degree that the rocks are standing on edge. Near Rainy Mountains there are three conspicuous outlying hills composed of limestone. All of this stone is hard and durable and can be used for the manufacture of Portland cement, for concrete, ballast, road material and for burning into lime. In the northern part of the county there are several rather extensive deposits of magnesian limestone that has proven to be locally valuable. This when developed, should become a source of revenue.

Lying around and between the peaks of granite and limestone are the Redbeds, consisting chiefly of red clay shales with occasional ledges of soft red sandstone. The sandstone has been utilized locally for the erection of buildings.

There are clays and shales of considerable importance in the region of the Wichita Mountains. It is also probable that kaolin of a good quality will eventually be discovered there in marketable quantities. Red clay shales outcrop in practically all parts of the county. The granite gravel, which is found in a number of streams flowing from the Wichita Mountains, might be utilized for concrete and road material.

Taking everything into consideration, the building materials of Kiowa County are among the most varied of any county in the western part of the State, and only await further development in

order to become valuable. Gas has been found at Gotebo, and it is altogether possible that it may be found in other localities near the Wichita Mountains.

Latimer County

Latimer County lies in the eastern part of the State; LeFlore County separating it from Arkansas. No large rivers flow through this region. The southern portion is drained by the Kiamichi, a tributary of Red River. The eastern part is drained through Fourche Maline Creek into the Poteau, and the western and northwestern part through Gaines and San Bois creeks into the Canadian and the Arkansas.

The northern part of Latimer County lies in the coal fields of the upper end (northern) of the Ouachita Mountains. The greater part of the rocks are sandstone and shales. The sandstone, being hard and resisting erosion, forms high hills such as Winding Stair, San Bois and Panther mountains. These sandstones have been used in buildings at Wilburton, Red Oak and other towns. The shales, being softer, have been worn away forming valleys and flat uplands.

The Wapanucka limestone crosses the county from west to east a few miles south of the Rock Island Railroad. It might be burned into lime, or manufactured into Portland cement. There is plenty of coal and the chances are good for finding oil and gas in the northern section. There is no reason why, with the abundant fuel, and the varied products, that Latimer County should not develop a number of manufacturing industries. The chert that occurs in the Potato Mountains in the southern part of the county, would make good road material.

LaFlore County

LeFlore County lies in eastern Oklahoma. Its northern boundary is formed by Arkansas River. The chief drainage is through Poteau River which enters the county from the state of Arkansas and flows north in a torturous channel, winding in and out among high sandstone hills until finally it joins the Arkansas near Fort Smith, in the extreme northeastern corner of LeFlore County. The greater part of the county is heavily timbered.

The northern part of LeFlore County, where Cavanal, Sugar Loaf, Poteau, and Backbone mountains are the most conspicuous elevations, lies in the coal belt of Oklahoma. The southern townships are occupied by certain ranges of the Ouachitas, of which Winding Stair, Kiamichi and Black Fork are most prominent. All these mountains are from 1500 to 2000 feet above sea level.

The rocks of the county are practically all sandstone and shale. The sandstone ledges are heavy and massive, and because of their resistance to erosion, form the higher hills. The shales, being softer, wear out into the intervening valleys.

So far as known there have been no extensive quarries opened in LeFlore County. Sandstone has been used locally for building in practically all the towns, such as Poteau, Heavener, Bokoshe, Wister, Howe, Spiro, Panama and Cameron. At Poteau the shales have been used for the manufacture of brick. There is little limestone in the region.

The facts that this county contains vast deposits of coal, and that gas has already been found near Poteau, and that oil may eventually be found, warrant the belief that this area will eventually become an important manufacturing region.

Lincoln County

Lincoln County lies in central Oklahoma. Deep Fork of Canadian River flows east across it. The surface is usually rolling or hilly; the eastern part being timbered; the western part mostly prairie.

Lincoln County is located in the eastern part of the great Redbeds region of Oklahoma, hence the greater part of the building stone consists of a soft red sandstone. In the northern area, however, particularly near Agra, there is a thin ledge of limestone, and in the eastern townships there is gray and brown sandstone. The red sandstone of the Redbeds has been utilized for building purposes at Chandler, Warwick, Fallis, Sparks, Wellston, Davenport, Prague, Carney and in several other towns. Red clay shales outcrop in all parts of the county. They were formerly utilized for the manufacture of building brick at Chandler. Building sand is abundant.

Logan County

Logan County is located in the central part of the State. Cimarron River flows across it from the west, forming part of the north boundary. Skeleton Creek, which flows southeast and the Cottonwood, flowing north, are among the principal tributaries. Deep Fork of the Canadian rises in the southeastern part of the county.

Eastern Logan County is quite hilly, the western part more level. Numerous small stream valleys, tributaries of the Cimarron, have dissected the level plain, giving the surface a broken effect. There is considerable timber along the streams and among the hills.

Logan County lies entirely within that part of the State occupied by the Redbeds. Red clays and shales outcrop in all parts and there are a number of heavy ledges of red sandstone interspersed with the shales. The streams have exposed these ledges of stone along the escarpments. One of the most prominent ledges in central Oklahoma is exposed along the eastern bank of the Cimarron, a few miles northeast of Guthrie, where the sandstone makes a conspicuous bluff several miles in length.

Sandstone has been utilized locally for building purposes. At such towns as Guthrie, Marshall, Mulhall, Coyle and Orlando, there are buildings of this stone. Building sand is abundant in all parts of the county. A sand dredge at Guthrie supplies building sand for Oklahoma City and other large towns in the State. The red clays and shales have been utilized for the manufacture of brick.

Love County

Love County is located in the extreme south-central part of the State. The greater part of the region is rolling. Streams have cut rather deep valleys into the upland plain. Timber is found in most parts of the county.

The most important building stone in Love County is a ledge of limestone of Cretaceous age, known as the Goodland limestone, which outcrops in the northeast and central townships. This stone is suitable for building stone, for the manufacture of Portland cement, for concrete and ballast, and for burning into lime. There are also several ledges of limestone in the southern part of the county, which might be used for a variety of purposes.

Abundant deposits of sandstone occur in a number of localities. This stone has been utilized locally for building purposes. The western part of Love County is in the Redbeds region and here only soft red sandstone occurs in quantity. Clay and shale, occur in many localities, and might be utilized for brick and other clay products. Building sand is widely distributed.

McClain County

McClain County lies south of the center of the State, its northern boundary being South Canadian River. The greater part of the county lies on the divide between the South Canadian and Washita rivers. Small tributaries rising on this divide enter both streams. The surface is gently rolling. Timber is found in the eastern townships, the western partis largely prairie.

All of McClain County, except the extreme eastern area, lies in the Redbeds region of Oklahoma. Red clay shales are abundant in all parts of the county. Soft red sandstone is found in the western region. In the eastern part there are several ledges of coarse gray sandstone and conglomerate. Sandstone has been utilized for the construction of buildings in Purcell, Byars, and Blanchard. Building sand is abundant, particularly along the South Canadian. At Purcell the red clay shale was formerly utilized for the manufacture of brick.

McCurtain County

McCurtain County lies in the extreme southeastern corner of Oklahoma. Red River forms its southern boundary. Little River flows southeastward across the lower half of the county. This stream is fed by several tributaries from the north, the largest of which are Mountain Fork and Clover Creek.

The northern part of McCurtain County is situated in the Ouachita Mountain region of Oklahoma and consequently the surface is very rough and broken. The southern area is occupied by rocks of Cretaceous age, forming a plain now dissected by stream valleys. Considerable areas between Little River and Red River are covered by sands and clays of Pleistocene age. With the exception of a few acres of prairie all of McCurtain County is covered with heavy groves of timber, chiefly pine and oak.

The rocks in the northern part of the region are largely sandstones and shales, standing on edge. The former are usually hard and durable, brown to yellowish in color, and make excellent building stone. The shales and clays are commonly black to yellow in color. Throughout a considerable area, in the eastern townships the sandstone and shale have been metamorphosed, that is, changed by the action of heat and pressure. The metamorphosed sandstone, which is known as quartzite, is usually fine-grained and hard. The shale has in many cases been sonsolidated, forming a fairly good quality of slate. It is altogether probable that systematic investigation in this region, would show the presence of considerable quantities of slate suitable for building purposes.

Throughout much of eastern McCurtain County the sandstones and shales, have been cut by dikes of quartz. This quartz is, usually white or light gray in color, very hard and brittle and in many cases has been broken up and now lies spread out on the surface of the other rocks. So far as known, it is not found in sufficient quantities to be of commercial value.

In the vicinity of Idabel, Garvin and Valliant, there are considerable deposits of Cretaceous limestone, of a nature to make a fair quality of lime. This stone is also suitable for building purposes and for the manufacture of Portland cement.

There is a considerable amount of sand and gravel in the streams of McCurtain County. The shales are suitable for the manufacture of brick and other clay products.

McIntosh County

McIntosh County lies in east-central Oklahoma. South Canadian River forms its southern boundary, and the North Canadian flows across the county from the west. The greater part of the surface is rolling and there are many high sandstone hills. A considerable part of the area is timbered, but prairie lands occur on the divides between many of the streams.

McIntosh County lies within the region of the Carboniferous rocks of Oklahoma, consequently the formations exposed on the surface consist almost entirely of sandstones and shales. Sandstone occurs as massive ledges capping high hills. It is light brown to gray in color, durable and of good quality. It has been used in the construction of business blocks in Checotah, Eufaula and other towns. Shales and clays, which occur in practically all localities, are suitable for the manufacture of a variety of clay products such as brick, tile and fire proofing.

Coal has been mined at a number of points and gas has been found in the western part of the county. It is altogether probable that more extensive development will reveal oil and gas fields of considerable size. The abundance of available fuel and the large amount of obtainable structural material leads to the belief that this county will develop into a wealthy manufacturing community.

Major County

Major County, which occupies what was formerly the southern part of old Woods County, is situated in northwestern Oklahoma. The Cimarron forms part of the northern boundary and flows across the eastern part of the county; the North Canadian crosses the extreme southwestern corner. North and east of the Cimarron there is an area of sand hills country covered with jack-oak timber. South of Cimarron River is a flat Redbeds plain and still farther southwest are the Gypsum Hills, formed by two heavy ledges of massive white gypsum. Outliers of these hills often form buttes, the most important of which are known as the Glass Mountains. Farther southwest and at a higher altitude than the Gypsum Hills are sand hills extending as far as South Canadian River.

The most important structural material in Major County is gypsum, which occurs in inexhaustible quantities in the Gypsum Hills. There are sites in the region south and west of the Glass Mountains for hundreds of gypsum plaster mills. The Redbeds shale and clay, which is widely distributed, would make an excellent quality of brick. There are several ledges of dolomite in this county available for building stone. In the regions north of both Cimarron and North Canadian rivers there are inexhaustible deposits of fine building sand. Red sandstone is found among the Redbeds. It has been used locally for farm houses and other buildings.

Marshall County

Marshall County lies in the extreme southern part of Oklahoma. Red and Washita rivers form its southern and eastern boundaries. The greater part of the region is slightly rolling. In the northern areas are extensive prairies while the southern and eastern halves are timbered.

There is much valuable structural material in Marshall County. The Goodland limestone, which extends east and west across the area is a heavy-bedded, brownish to gray limestone. It is suitable for building stone, for the manufacture of Portland cement, for concrete rock, for ballast and for all sorts of structural purposes. Buildings at Madill and other towns have been erected of this limestone. There are also several thin-bedded limestones that may be used for a variety of purposes.

Sandstone occurs in many parts of Marshall County and has been used locally for various kinds of structural purposes. Business blocks at Woodville have been erected of a dark brown sandstone quarried in the vicinity. Clays and shales, which would make a variety of clay products, are abundant, particularly along Glass Creek, near Madill, and near Washita River. Building sand is abundant in various localities.

Oil of superior quality has been found at Madill and there is no reason why it may not be found in other localities. The presence of fuel and so large a variety of structural material leads to the belief that Marshall will in time become a wealthy manufacturing county.

Mayes County.

Mayes County lies in northeastern Oklahoma. Grand River flows south across the county, draining all of the area in question. The eastern townships are rough and broken and covered with timber; the central part is largely a flat prairie, while rather high sandstone hills covered with scattered growths of timber extend across the western region.

The rocks of Mayes County consist of granite, limestone, sandstone and shales. The granite is confined to a single locality along Spavinaw Creek about one and one-half miles west of the Spavinaw postoffice. At this place a granite dike is exposed in several outcrops along a line more than a quarter of a mile in length. The granite is red in color and of a rather fine texture. It would make a very desirable building stone, and might be used for concrete and crushed rock.

Most of the area lying east of Grand River, is in the region occupied by the rocks of the Ozark Uplift. These rocks are largely limestones and shales. The limestone belongs to either the Boone or Pitkin formations. The Boone formation consists of a heavy ledge of limestone from 150 to 300 feet thick, containing a considerable amount of flint and chert. The Pitkin limestone is dark gray or bluish in color, and from 50 to 75 feet in thickness. The latter outcrops in Mayes County along Grand River. Both the Boone and the Pitkin would make good Portland cement. Building stone might be quarried from either ledge; both are suitable to be burned into lime.

In the western part of the county the rocks are of Pennsylvan-

ian age and consist largely of shale and sandstone. In this area there are high sandstone hills, formed by light brown to gray, fine-textured sandstone, such as are found throughout this section of the State. It is an excellent building stone and has been used at Adair, Pryor Creek and Choteau for the construction of business blocks.

The shales, which are abundant in most parts of Mayes County, might be used for the manufacture of brick, tile and other clay products. A brick and tile plant is located at Pryor Creek. Coal is found in considerable quantities in the western half of the county and gas has been encountered in several localities. There is no reason why Mayes should not eventually develop into a wealthy manufacturing county.

Murray County

This county, which lies south of the center of the State, is crossed from north to south by Washita River. The Arbuckle Mountains outcrop in practically all parts of Murray County, hence the surface in general is hilly.

There is a great variety and a very large amount of building material in this region. The chief varieties of stone are porphyry, limestone, sandstone, conglomerate, shale, clay, asphalt and sand, all of which occur in very large quantities.

In two areas in the western townships, known as the East Timbered Hills and West Timbered Hills, there are extensive deposits of porphyry. This is a hard, igneous rock reddish to brown in color, outcropping over areas several square miles in extent. At the present time, this stone is inaccessible to railroads and consequently has never been utilized. It is suitable for concrete rock, ballast, and building stone.

A considerable part of Murray County is occupied by surface outcrops of Arbuckle limestone. This is a massive, thick-bedded, gray to white stone, that makes up the greater mass of the Arbuckle Mountains. This rock is exposed west of Washita River in the heart of the main range of the mountains and east of that stream, particularly in the region south and east of Sulphur and near Scullin. This limestone is usually much faulted and folded; thus the stone is badly fractured. On this account it is not often suitable for building stone, but is an excellent material for concrete, and for all purposes for which crushed stone may be used.

Other ledges of limestone are the Viola limestone about 800 feet thick; the Hunton 300 feet thick; and the Sycamore, 150 feet thick. All of these formations outcrop in various parts of Murray County, particularly along the edges of the mountains. They are suitable for the manufacture of Portland cement, for building stone, concrete, rip-rap, ballast, for burning into lime, and other structural material.

Sandstone and conglomerate are found in many localities. The formation known as the Simpson sandstone, which is widely exposed, contains three massive ledges of white or yellowish sand, that is suitable for the manufacture of glass. A formation known as the Franks conglomerate, the pebbles of which are composed largely of fragments of Arbuckle limestone and porphyry, covers a number of square miles in the northern part of the county. This material, when eroded by streams, forms the coarse gravel found in the creeks flowing from the mountains.

Clays and shales are abundant in Murray County. The Sylvan shale and a considerable part of the clay of the Simpson formation might be utilized for a great variety of clay products, such as pressed brick, pottery, tile and terra cotta.

This county also contains large deposits of asphalt, occuring in the form of clay, sand and lime asphalt. This material has been mined near Dougherty and Sulphur for a number of years, and only awaits extensive development in order to become an important industry.

At the present time the most important stone quarries of this region are located at Crusher at the point where Washita River cuts through the Arbuckle Mountains. There are two quarries at this place from which material is being obtained for concrete rock and building purposes. The first quarry was opened a number of years ago; and is now owned by the Dolese Brothers. It has a face 90 feet high and 700 feet long. The other quarry, operated by Carter Brothers, has been in operation only during the past two years. The material quarried in both instances is the Arbuckle limestone.

Gravel and building sand, suitable for structural material, is found in a number of creeks flowing from the mountains, particularly Rock and Sand creeks. These materials, as well as the crushed rock from the quarries, are being shipped to Oklahoma City and other towns in the State.

Muskogee County

Muskogee County lies in the eastern part of Oklahoma. Arkansas River flows across it and the Canadian forms the southern boundary. The Grand and the Verdigris unite with the Arkansas in this county. The greater part of the area in question is a rolling or level prairie, although timber is found along the Arkansas River and on many of the hills in the southern and western sections.

Muskogee County lies in the region of Coal Measures rocks. However, in the extreme northern part, east of the Arkansas, other formations below the Coal Measures occur, namely the Boone chert, the Pitkin limestone. These limestones are valuable for building stone, for burning into lime, for the manufacture of Portland cement, and for a large variety of structural purposes.

Only sandstone and shales are found in the area lying south and west of Arkansas River. The sandstone occurs usually as massive ledges capping the high hills, while shales occupy the valleys or the slopes between the ridges. The sandstone has been used locally for building purposes, particularly in such towns as Muskogee, Oktaha, Webbers Falls, Porum, Haskell, Boynton and Chekota. This stone is grown to light gray or yellowish in color, easily worked, durable and handsome, making a valuable building stone.

The clay shale, which is abundant in all parts of the country, is suitable for the manufacture of brick, tile and a large variety of clay products. Plants at Muskogee, Boynton and Wainwright turn out good qualities of brick.

Coal is found in practically all parts of the region. One of the best oil fields in the State is located at Muskogee, likewise oil has been found near Haskell in the extreme western area. A large amount of gas has been found west of the latter town, near Muskogee and in the country lying about Wainwright. Smaller amounts of oil and gas occur in several other townships.

Taking into consideration the vast amount of fuel, including coal, oil and gas in connection with the abundant structural material, such as sandstone, limestone and shale, it will be seen that Muskogee County contains material for a large variety of manufactured products. It should in time become a wealthy manufacturing center.

Noble County

Noble County lies in the north-central part of Oklahoma. Its northeastern boundary is formed by Arkansas River. Black, Bear and Redrock creeks, which flow east across the county, receive the greater part of the drianage. The surface is quite broken in the eastern townships but becomes more level toward the west. Timber is found along the streams and on many of the sandstone hills.

The northern portion of Noble County contains several ledges of limestone, which enter from Kay and Osage counties to the north. This limestone, a southern extension of the Flint Hills of Kansas, thins out to the south and does not extend beyond the central part of the county. Between the various ledges of limestones are beds of shales. From the vicinity of Redrock and Morrison to the southwest, the surface rocks of Noble County are Redbeds. They occur more conspicuously still farther west. This formation consists of red clay shales interstratified with beds of sandstone.

Very little limestone has been quarried in this county except for local use. Sandstone has been utilized for the construction of buildings. A number of quarries near Perry, Morrison and Redrock supply stone for building purposes. The shales are suitable for the manufacture of brick and other clay products. It is altogether possible that oil and gas may eventually be found in the eastern part of Noble County, and, if so, chances are good for the full development of the mineral products of the region.

Nowata County

This county is located in the northeastern part of Oklahoma, bordering on Kansas. Verdigris River flows south across the central part of the county. The greater part of the surface consists of level and gently rolling uplands traversed by stream valleys. The bottom lands are timbered.

Nowata County lies in the region occupied by Carboniferous formations, hence the rocks are limestone, sandstone and shale. Several ledges of limestone cross the region from north to south, while beds of sandstone are found in all setcions.

The most important limestone ledge in this county, known as the Oolagah limestone, outcrops along the west bank of Verdigris River. South of the town of Nowata it is a single ledge, while farther to the north it is split into two distinct divisions by an intervening shale. Other limestones are found in the northwestern area, as well as in the region east of Alluwe in the southeastern corner. Practically all this limestone would be suitable for building stone, for burning into lime, for the manufacture of Portland cement, concrete and ballast. The only extensive limestone quarry in the county is situated on Hickory Creek 3 miles north of Lenapah. At this place there is a rock crusher. Limestone has also been quarried at Nowata.

Sandstone, which outcrops on many hills in Nowata County, has been used locally for foundation work and stone buildings. Such towns as Nowata, Lenapah, Watova and Wann contain buildings constructed of this local stone. It is handsome and durable, light brown in color and should eventually become a valuable resource to the county.

Nowata County contains large amounts and considerable varieties of clay and shale. These materials are suitable for the manufacture of a large variety of clay products, including brick, tile and pottery. A plant is operated at Nowata. At Coffeyville, Kansas, just across the line, these products are being extensively manufactured of similar clay belonging to the same ledge. Kansas brick are being shipped to Oklahoma by the million and in return Oklahoma money is sent out of the State to purchase material that could be manufactured at home.

Okfuskee County

Okfuskee County is in the east-central part of Oklahoma. North Canadian River flows east across the county. The surface is more or less hilly and usually covered with timber.

Sandstone is the principal building stone in Okfuskee County. It outcrops in all parts of the region, chiefly as escarpments of hills or as cliffs along streams. This stone has been used for building purposes in such towns as Okemah, Weleetka and Paden, and makes a handsome and durable building material. One or two thin ledges of limestone have been reported, but at present knowledge they are of little commercial importance. Clays and shales, which are found in all localities, might be utilized for the manufacture of brick and other clay products.

Eastern Okfuskee County lies within the probable extension of the oil and gas region. When these products are developed, they will aid materially in promoting the resources of the county.

Oklahoma County

Oklahoma County is located in the center of the State. Deep Fork and North Canadian rivers drain the northeastern and southern areas. The surface is gently rolling. The eastern townships are timbered while the western part is a prairie. The rocks all belong to the Redbeds series, consisting largely of red clay shales.

There is little building stone of any kind in Oklahoma County except occasional thin ledges of red sandstone, outcropping along many of the streams, particularly in the valley of Deep Fork and certain tributaries of the North Canadian. This stone has been utilized at such towns as Oklahoma City, Jones, Edmond, Luther and Harrah. The western part of the county contains little stone of any kind. There is an abundance of building sand in all sections. The red clay shales, which are everywhere abundant, have been utilized at Oklahoma City for the manufacture of a good grade of pressed brick, now being used in the construction of a number of buildings in that city.

Okmulgee County

Okmulgee County lies in the east-central part of Oklahoma. Deep Fork of Canadian River flows east across the county. The greater part of the drainage is north into the Arkansas or into Deep Fork. The eastern area is chiefly a rolling prairie, while the southern and western parts are rather rugged and covered with timber.

Okmulgee County lies within the region of Carboniferous rocks. Sandstones and shales are exposed on the surface, the sandstone occuring usually as prominent ledges forming caps on the hills, extending north and south across the county. Much of this stone has been utilized for building purposes. The old Creek Council House at Okmulgee is built of this material; and likewise many modern business blocks at Okmulgee, Henryetta, Beggs and Morris have been constructed of this native stone. The sandstone is gray to brownish in color, easily worked and durable, hence in time should become a valuable asset for construction purposes.

There are a few ledges of thin limestone in the eastern part of Okmulgee County. Clays and shales are abundant and might be used for a large variety of products. Two plants east of Okmulgee produce a good quality of brick.

Coal is found in many locations. Some of the best mines in the State are located at Henryetta and Schulter. Oil and gas have been found in practically all sections, particularly at Morris, Bald Hill and Hamilton Switch, where producing wells are now located. It is very probable that further drilling will reveal the presence of even still larger pools.

Taking everything into consideration, there is little doubt but that Okmulgee County will eventually develop into a valuable manufacturing region.

Osage County

Osage County, situated in the northern part of the State, is the largest county in Oklahoma. Arkansas River which bounds it on the south and Humming Bird and Bird creeks, tributaries of the Verdigris, drain the region. Eastern Osage County is heavily timbered; the western part is largely a prairie land.

The rocks of the county are limestones, sandstones and shales of Coal Measures and Permian age. In the eastern townships sandstones prevail, forming conspicuous hills and ridges. This stone has been extensively utilized for building purposes at Pawhuska. In this region there are also several prominent ledges of limestone, particularly the massive ledge known as the Avant limestone, which outcrops on the hills along Bird creek near the town of Avant.

In the western section, limestones are more common; 6 or 8 massive ledges strike north and south across this area. This rock is suitable for burning into lime, for ballast and concrete rock, for the manufacture of Portland cement and for building stone. In Kansas the same ledges have been quarried and used for building stone for many years.

The greater part of this region contains large deposits of clays and shales, lying in massive beds. This clay is suitable for making brick, for tile and other similar purposes. A brick plant is in operation at Pawhuska. Osage County lies within the oil and gas fields. The eastern half of the county produces large amounts of both oil and gas. When these dormant natural resources have been developed there is no doubt but that Osage County will be a wealthy manufacturing center.

Ottawa County

Ottawa is the extreme northeastern county of the State. It is well drained; Neosho River enters from the northwest, and Spring River from the northeast. These two streams unite near

the center of the county, forming Grand River, which flows south in a tortuous course among limestone hills.

Eastern Ottawa County is hilly, being a plateau cut by the valleys of numerous streams flowing west into Spring and Grand rivers. The country west of these streams is generally level, or slightly rolling. The Boone chert, a limestone formation of Mississippian age, forms the surface rocks of the greater part of the region. This formation dips to the west and is succeeded by the sandstones and shales of Pennsylvanian age. Timber occurs chiefly in the eastern area.

Limestone is found in all the eastern townships, and might be quarried in numerous localities along the bluffs of the streams. On the level uplands however, there is little stone on the surface except fragments of chert, which have weathered out from the limestone ledges. The limestone is suitable for the manufacture of Portland cement and for burning into lime.

Sandstone, suitable for building, occurs in ledges along the bluffs in the western section. Shales and clays are common in most regions and might be used for the manufacture of a large variety of clay products.

The most valuable minerals now being produced in Ottawa County are lead and zinc, which are mined at Miami, Lincolnville and Quapaw. The value of the production of these minerals for 1910 was approximately $700,000. The field is yet practically undeveloped and it is altogether probable that, within a few years, it will produce much more than at present.

Coal is found in western Ottawa County.

Pawnee County

Pawnee County is located in the northeast-central part of Oklahoma. Arkansas River forms the northern boundary, flowing to the southeast in a tortuous course between high limestone and sandstone hills. Black Bear Creek flows east across the county, and Cimarron River touches the southeast corner. A number of small streams, tributaries of the Arkansas or the Cimarron, receive the drainage. The topography is quite broken; high hills, capped with limestone and sandstone, abound in all parts of the area. These hills are the southern continuation of the Flint Hills of Kansas.

The most valuable building stone of this region is limestone. There are also a number of ledges of sandstone. The sandstone is more abundant in the eastern section, while limestones are encountered farther westward.

A number of quarries have been opened in various parts of Pawnee County particularly near the towns of Pawnee and Cleveland. Stone buildings are found occasionally in the towns; likewise a number of houses, barns and small buildings have been constructed of this material. The shale is valuable for the manufacture of clay products. One of the largest brick plants in Oklahoma is located at Cleveland. The fact that oil and gas occur in large quantities at that city and in small amounts in other localities, lead to the belief that the mineral resources of Pawnee County will prove of considerable value.

Payne County

Payne County is located northeast of the center of Oklahoma. Cimarron River flows east across the county, Stillwater Creek being its largest tributary. A number of valleys of the smaller streams have dissected the level table land. There is considerable timber along the streams and among the sandstone hills.

The greater part of Payne County lies in the Redbeds area of Oklahoma. Several ledges of limestone of considerable importaance occur in the eastern part. One of these is a prominent ledge, which outcrops on Twin Mound, 12 miles east of Ingalls, crosses Cimarron River near the mouth of Stillwater Creek and is exposed between Ripley and Cushing. Stone crushers located along this ledge near Ripley have supplied ballast for the Santa Fe Railroad, as well as concrete rock and macadam paving material for Guthrie and Oklahoma City.

There is a large amount of sandstone in the county, the greater part of which is red in color, varying however, to a gray and white. A number of quarries have been opened in various regions, particularly near or at Stillwater. One of the latter furnished white sandstone for several of the buildings at the Agricultural and Mechanical College. Such towns as Cushing, Yale, Glenco, Ripley contain buildings constructed of red sandstone.

The red shales and clays occur abundantly and might be utilized for the manufacture of brick. At the present time there is no fuel found in Payne County, but it is possible oil and gas may be discovered in the eastern area. If so, it means the development of natural resources.

Pittsburg County

Pittsburg County lies southeast of the center of Oklahoma. Its northern boundary is South Canadian River. The southern area drains into Red River through the various branches of Boggy Creek. The greater part of this region is hilly, the southeastern part being mountainous. Timber is found along the streams and on the greater part of the upland slopes.

The northern part of Pittsburg County lies in the region of Coal Measures rocks and the southeastern half in the Ouachita Uplift. In the latter section the mountains rise to a height of from 1500 to 2000 feet above sea level.

A single ledge of limestone known as the Wapanucka limestone passes from northeast to southwest across the southern part

of the county. It outcrops near Hartshorne, Blanco, Pittsburg, and Reynolds. This limestone is about 500 feet thick and stands on edge. This material is suitable for the manufacture of a large variety of products, such as lime, Portland cement and building stone. A Portland cement company has recently erected a plant at Hartshorne. At the same place lime has been burned at various times. There are sites along this ledge for a number of cement plants and lime kilns.

The greater part of Pittsburg County is occupied by sandstone and shale rocks. Sandstone occurs chiefly as heavy massive ledges along the tops of high hills, or as cliffs along the streams. This stone is similar to that found in other counties in the eastern part of the State, being light gray to yellowish-brown in color, of fine texture, and durable. Such towns as McAlester, Crowder, Canadian, Krebs, Hartshorne, Haileyville, Alderson, Quinton, and Kiowa contain business blocks and residences built of this stone. It is found in inexhaustible quantities and makes a very good building material.

The widely distributed clays and shales are valuable for a large variety of products, chiefly brick and tile. Fire clay is reported from the northern part of the county. Brick plants are operated at McAlester, the product from which is used in the local street pavements.

Pittsburg County is located in the center of the coal fields of Oklahoma, nearly one-half of it being underlain with beds of this fuel. At least four workable veins are found to outcrop in this county. McAlester is the center of the coal mining industry of the State. The northern area lies in the region in which oil and gas may be expected to be found. The fact that coal is already plentiful and that oil and gas may occur, is of extreme importance in the development of the mineral resources of Pittsburg County.

Pontotoc County

Pontotoc County lies in the south central part of the State. Its north boundary is the Canadian River. The southern and eastern parts of the county are drained by Boggy Creek and Blue River. Timber covers a considerable area. The rocks in the northern portion consist of sandstones, conglomerates and shales of the Coal Measures age. The sandstone is suitable for building purposes and has been used to considerable extent at Ada, Francis, Center and other towns in this part. The shales and clays are suitable for the manufacture of brick. A successful brick plant, located at Ada, uses shale from the Carboniferous beds.

The southern half of the county lies in the Arbuckle Mountains Uplift. Here the rocks are chiefly massive ledges of limestone. The three prominent limestone formations of the Arbuckle Mountains are the Arbuckle, the Viola, and the Hunton, all of which outcrop in Pontotoc County. This rock may be used for building stone, for burning into lime, for the manufacture of Portland cement and for a large variety of other purposes. One of the three Portland cement plants of the State, located at Ada, utilizes the limestone from the Viola, and the shale from the Sylvan formation, obtained along the Frisco Railroad, 6 miles south of Ada.

The Simpson formation, part of the Arbuckle uplift, contains large deposits of glass sand. This material is found near Roff, Franks, and Fitzhugh. When developed, it will be a valuable commercial product.

There are large deposits of asphalt in Pontotoc County, particularly near Franks, Fitzhugh, and Ada. This material is used for street paving and other purposes. The shales and clays of the Sylvan formation in the southern townships are valuable for tile, brick, and other clay products.

Pottawatomie County

Pottawatomie County is located in central Oklahoma. North Canadian and South Canadian rivers touch the northern and southern part, respectively. Little River flows east across the county. The surface is rolling or hilly, and a considerable area is covered with timber.

The greater part of the area lies in the Redbeds region of Oklahoma; practically all the rocks belong to this series. Clay shales from which pressed brick has been manufactured, are abundant. Ledges of red sandstone are found in most parts of the county. In the eastern townships, however, the sandstones are often gray. Such towns as Shawnee, Tecumseh, Meeker, Earlsboro, and Wanette contain houses built of this stone. There is a heavy ledge of conglomerate exposed near Konawa, Hotulke and Earlsboro, suitable for gravel and concrete rock. There is an abundance of building stone in Pottawatomie County.

Pushmataha County

Pushmataha County lies in the southeastern part of Oklahoma, being separated from Arkansas by LeFlore County. The principal drainage is through Kiamichi River and the head waters of Little River.

All of the county, except the southern portion lies within the Ouachita Mountain Uplift. The rocks consist largely of ledges of sandstone and shale standing practically on edge; the hard sandstone has resisted erosion, and formed long and narrow ridges. The softer shales have worn out into intervening valleys. The stream courses are covered with heavy growths of timber.

The sandstone found in Pushmataha County is usually firm, rather hard and brittle; much of it will make durable building stone. In many places it forms conspicuous ledges standing out

in the form of great cliffs. A prominent example of this form of erosion is in the famous McKinley rocks on the extreme summit of the Kiamichi Mountains 4 miles south of Tuskahoma. At this point massive blocks of rugged sandstone nearly 100 feet high and one-fourth mile long cap the hill.

The shales and clays of Pushmataha County are suitable for brick and other manufactured clay products. So far as known there is no limestone in the region.

Roger Mills County

Roger Mills County is one of the western counties in Oklahoma. The South Canadian forms the northern boundary; Washita River courses east through the eastern area. The surface is a plain only broken by a number of river valleys. There is little native timber except a few groves of elm and cottonwood along the streams.

Roger Mills County lies in the Redbeds region of Oklahoma, consequently the greater part of the surface rocks are red shales and sandstones. In the western townships there are considerable areas covered with sand hills and other deposits of Tertiary age. Antelope Hills in the northwestern corner are outliers composed of Tertiary rocks.

There is considerable good building stone in the county, consisting of soft red sandstone belonging to the Quartermaster formation of the Redbeds. A number of buildings at Cheyenne, the county seat, and other towns have been constructed of this soft, red stone.

Gypsum, which is found along the breaks of the Canadian River in the northeastern part of the region, might be utilized for the manufacture of wall plaster, stucco and other similar products. The red clays would make a good quality of brick. Building sand is common.

Rogers County

Rogers County lies in the northeastern part of the State. The Verdigris which flows south across the county, and its tributaries, form the principal drainage of the region. The eastern part of the area is hilly and covered with timber, while the western portion is generally a rolling prairie, except along the wooded valleys of the streams.

The surface rocks of the county consist of shales, sandstones and limestones. Heavy beds of sandstone are exposed on the hills in the region east of Claremore. The Claremore formation, formerly known as the Fort Scott limestone, consisting of three ledges of limestone separated by shales, passes from northeast to southwest across Rogers County. Along the bluffs west of the Verdigris north of Claremore there is a ledge of limestone known as the Oolagah limestone. The country to the west of the outcrop of this ledge is a rolling prairie with sandstone hills and occasional ledges of this limestone.

The limestone is suitable for the manufacture of a large number of economic products. The ledges of the Claremore formation, which outcrop just west of the Frisco Railroad between Catoosa to Chelsea, would make an excellent quality of concrete rock and would also be suitable for the manufacture of Portland cement or for burning into lime.

The northern part of Rogers County lies in that part of the Oklahoma oil fields known as the Shallow Pool. Oil will also probably be found in the western townships. Coal has been mined at a number of localities.

The sandstone is similar to that of other parts of eastern Oklahoma, being fine-grained, gray to blue in color, and of good texture. Many of the buildings in such towns as Catoosa, Claremore, Sageeyah, Oolagah, Chelsea and Talala, have been built of this stone.

The shales and clays in the county are suitable for the manufacture of brick, tile and terra cotta. However, very little of this clay has been utilized, except at Claremore and Collinsville, and there for the manufacture of brick. Building sand is found in many localities.

Seminole County

Seminole County lies east of the center of Oklahoma. North and South Canadian rivers form its northern and southern boundary. Much of the area is timbered; the surface is rolling or hilly.

Sandstone, the chief building stone in the county, is very abundant, and has been used for structural purposes at Wewoka, Seminole, Sasakwa and a number of other points. This stone is gray to brown in color, of good texture, and makes a handsome and durable material for construction work.

Clay and shale, which occurs in all parts of Seminole County, might be utilized for the manufacture of brick and various other clay products. Building sand is abundant. A ledge of coarse conglomerate, outcropping in the west-central part of the region has been used for gravel and concrete work. It has been quarried along the Rock Island right of way 6 miles west of Wewoka.

A ledge of limestone crosses Seminole County from north to south, and outcrops on the hills a few miles southwest of Wewoka. A number of years ago stone from this ledge was burned into lime at Wewoka, and in recent years it has been utilized in a crusher and a lime kiln at Sasakwa.

A small amount of oil has been found at Wewoka. It is altogether possible that both oil and gas yet may be found in considerable quantities in various parts of the county.

Sequoyah County

Sequoyah County lies in extreme eastern Oklahoma. The state of Arkansas forms its east line, while Arkansas River is its southern boundary. All the drainage is into the latter stream, chiefly through Lees, Sallisaw, and Vian creeks and Illinois River. The surface is rough and broken. High hills occur in the northern townships, while the central and southern portion is largely a level prairie. Stream valleys and hills are timbered.

The hills of Sequoyah County lie in the southern part of the Ozark Uplift, and the rocks in the region are those usually found in these mountains, namely, the Boone formation, Fayetteville shales, and Pitkin limestone. The Boone formation, is from 150 to 300 feet thick, and consists chiefly of limestone, with much flint and chert in the upper parts. The Fayetteville shale is a black fissile shale. The Pitkin limestone is a hard, bluish to gray limestone, varying from 50 to 75 feet in thickness.

In several localities along Sallisaw Creek there are valuable deposits of marble, the best stone of the kind so far quarried in the State. The largest quarry is at Marble City. This stone has been quarried for a number of years, having been utilized chiefly for building stone. The Pioneer Telephone Building at Oklahoma City was constructed of marble obtained from this quarry. This marble might also be used for burning into lime or for the manufacture of Portland cement.

Sandstone of good quality occurs in practically all parts of Sequoyah County, and has been utilized for business blocks in such towns as Sallisaw, Muldrow, Hanson, Gans and Vian. This stone is gray to brown in color, easily worked and very durable. Clay and shale, which are found in practically all localities, when developed should make a large variety of valuable products.

Coal has been mined at or near Muldrow, Hanson, Sallisaw, and McKee . It is quite probable that oil and gas will eventually be encountered in considerable quantity.

Sequoyah County possesses the raw material and the fuel for the manufacture of a large variety of mineral products. These products only need development.

Stephens County

Stephens County is located in southern Oklahoma. No streams of importance flow across it. The principal drainage is east through Wild Horse Creek into the Washita and south through Mud and Beaver creeks into Red River. The surface, in general, is level. There is timber along the streams and on some of the sandy uplands in the eastern partof the county, but the greater part is prairie.

The only formations outcropping are the Redbeds consisting largely of red clay shale. There are, however, occasional ledges of red sandstone. These have been utilized locally for building purposes, at several localities. The red clay shales have been used for brick at Duncan, Comanche, and Marlow. Building sand is abundant in many parts of the region. A gypsum plaster mill has been in operation at Marlow for a number of years. Asphalt is found in several localities in the eastern townships. It is quite probable that oil and gas may be found in the same region.

Swanson County

The newly-created county of Swanson is in the southwestern part of the State. The surface is a plain, containing a number of scattered peaks and ranges of granite. The chief drainage is through Otter, Elk and other tributaries of North Fork of Red River. There is a little timber along the streams and among the rocky peaks, and a considerable amount of mesquite is found on the flat prairie.

The most valuable structural material in Swanson County is granite and the related rocks. In the northern section there is a range of hills extending east and west, consisting of black granite and gabbro. Farther south in the vicinity of Snyder and Mountain Park there are a number of scattered knobs and peaks composed of red granites. Quarries in the black granite have been opened at Cold Springs and near Roosevelt; the red granite is being operated near Mountain Park. There is enough good granite, both black and red, in Swanson County to supply the world for a thousand years.

The shales of the Redbeds, which make up the plain, among and between the granite peaks, would make good brick. Building sand is abundant . Coarse sand and stream gravel has been shipped from Mountain Park to various places in western Oklahoma. High grade kaolin or "potters clay" has been reported from the northeastern part of the county.

Texas County

This county occupies the central part of the Panhandle of Oklahoma or "No Man's Land." The surface consists of a high level plateau across which Beaver Creek has cut a valley averaging 75 feet deep and 1 mile in width. A few deposits of Redbed shales occur along this creek, but by far the greater part of the surface consists of soft sands and clays of Tertiary age. The entire county is a prairie region.

There is very little building stone of any kind in this county. Only occasional ledges of indurated Tertiary rocks outcrop along the edge of the plains, and an occasional deposit of red sandstone is found along the streams. There is plenty of clay for the manufacture of brick, but very little other building material occurs. Volcanic ash should be found in this county.

Tillman County

This county lies along Red River in the southwestern part of the State. The greater part of the region is drained by the tributaries of Deep Red Run, itself a tributary of the Red River. There is a little timber along the streams, but the greater part of the county is grass covered. All of the area is located in the Redbeds region of Oklahoma, hence there is exposed little hard rock of any kind. About all there is in the way of building stone consists of occasional thin ledges of soft red sandstone interbedded with the red clay shales. In the western and southern parts of the county there are considerable deposits of sand, usually in the form of sand hills. The red clay shale would make good brick.

Tulsa County

Tulsa County lies northeast of the center of Oklahoma. Arkansas River flows southeast across the county, and Bird Creek crosses the northeastern corner. The surface is generally rolling with occasional high hills or bluffs along Arkansas River and in the western and southern townships. The level lands are usually prairies, while the high hills and stream valleys are timbered.

Tulsa County lies in the Carboniferous region of Oklahoma. The rocks are limestone, sandstone and shales. Several ledges of limestone exist, one of which outcrops in the eastern part and extends from Catoosa to Broken Arrow. A second ledge is exposed in the town of Tulsa and passes southwestward to the Glenn Pool, while the third ledge forms a prominent exposure on the high hills south of Arkansas River a few miles southwest of Tulsa. At this place the formation is known as the Lost City limestone. Limestone has been utilized as ballast for some years at a quarry near Garnett, some 12 miles east of Tulsa. During the last few months a quarry has been opened at Lost City, from which material for ballast and concrete is obtained. The limestone is suitable for building stone, for burning into lime, for the manufacture of Portland cement, and for a large variety of purposes.

Sandstone is very abundant, particularly in the southern and western areas, where it forms high hills. It is usually fine-grained, durable, light brown in color making a handsome building stone. It has been used in Tulsa, Collinsville, Broken Arrow and a number of smaller towns for structural purposes. Clay and shale, which are widely distributed, might be utilized for a large variety of purposes, such as brick, tile, terra cotta, stone ware and pottery. Four brick plants, now in operation at Tulsa, are turning out a very superior product.

Coal has been mined at Collinsville, Mohawk and Dawson. Oil and gas is found in practically all parts of the county. The famous Glenn Pool, one of the most noted oil fields ever discovered, is located in the southern half of Tulsa County. Other important oil fields are the Tamaha, Flat Rock and Turley fields. It is quite probable that other pools of considerable importance will be located in this region. The abundant fuel, combined with the large variety of mineral products, warrants the prediction that Tulsa

County will eventually become one of the wealthiest counties in the State.

Wagoner County

Wagoner County lies in eastern Oklahoma. Grand River forms the eastern line; the Arkansas flows through the southwest corner and forms part of the southern boundary, while Verdigris River flows south across the county. The greater part of the surface is a level prairie.

Hills of considerable size occur in the western townships. The country adjacent to Grand River is cut by a number of small streams. The river valleys are timbered; the uplands are usually prairie.

Wagoner County is located in the region of Carboniferous rocks, and sandstones and shales are found in practically all parts of the county. Limestones also occur along the valley of Grand River in the eastern part and in the region between Coweta and Broken Arrow in the western townships.

Very little limestone has been developed in Wagoner County, but sandstone has been used locally at a number of points. Many buildings at Wagoner, Coweta and Porter have been constructed of a grayish or light brown sandstone, which occurs plentifully near these towns. The clays and shales are found in very large quantities and might be utilized in the manufacture of a large variety of clay products. The limestones and shales are suitable for the manufacture of Portland cement. Building sand is abundant.

There is considerable coal in Wagoner County. It has been used locally at a number of points. Oil and gas may eventually be found in considerable quantity in the western townships.

Washington County

This county is located in the northern part of Oklahoma, bordering Kansas on the north. On the west it is bounded by Osage County. Caney or Little Verdigris River drains the region to the south. The greater part of the surface consists of prairie-like plains, although there is considerable timber along the streams.

The rocks exposed on the surface are limestone, sandstone and shale. Several ledges of limestone pass from north to south across this area, while sandstone in considerable quantities covers a number of the high hills.

The limestone is suitable for a large variety of products. The largest Portland cement mill in the State, located at Dewey, uses limestone and shale. Like material is also found at Bartlesville, Ochelata, and Ramona for building purposes. Fine beds of shale be utilized for burning into lime, for concrete and ballast, and for building stone.

Sandstone which outcrops in various parts of the county, is

light gray or brown in color, hard and firm, and resists erosion well. It has been used locally in Copan, Dewey, Bartlesville, Ochelata, and Ramona for building purposes. Fine beds of shale many feet in thickness occur in several localities, and occupy the same horizon as those that are used farther north in Kansas for the manufacture of brick and tile. A brick plant is operated at Bartlesville; others were formerly operated at Ochelata and Ramona. The immense amounts of oil and gas found in this county are of extreme importance. With the limestone and shale suitable for the manufacture of a considerable number of different products and the large amount of gas accessible, there can be no doubt that Washington County will become one of the wealthy manufacturing counties in the State.

Washita County

Washita County was named from the river which flows southeast through this region. The principal drainage is into this stream. The small tributaries have cut rather deep valleys into the otherwise level plateau, making the surface in places irregular and broken. There is a little timber along the streams; but the greater part of the county is prairie.

Washita County is entirely included in the Redbeds area of Oklahoma. Red shales and sandstones outcrop throughout the whole area. In the eastern townships there is a large amount of gypsum, chiefly in the form of massive ledges, or as beds of earth or "gypsite." Farther west the gypsum disappears beneath red sandstone and shale, constituting that part of the Redbeds known as the Quartermaster formation. There is a small amount of Cretaceous limestone, known as shell rock, and occasional deposits of hard gray dolomite in various localities, but sandstone is the principal building stone. It has been utilized at Cordell and several smaller towns. In the southern portion there is a ledge of hard magnesian limestone, 10 or more feet thick, which, when developed, is destined to become valuable building stone. The red clay shale, that outcrops throughout the county, is suitable for the manufacture of brick.

Woods County

Woods County, located in the northwestern part of Oklahoma, is bounded on the southwest by Cimarron River and on the north by Kansas. The county is triangular in shape. The surface consists of a rather unevenly dissected plain. The drainage is chiefly through a number of small streams flowing into the Cimarron. Salt Fork of the Arkansas flows southeast across the northern part of the county. Strips of sand hills, averaging 10 miles wide, are found north of both the Cimarron and the Salt Fork. The surface rocks of the remainder of the region consist of red shales and clays of the Redbeds.

There is some timber among the sand hills and along the streams; the remainder of the county is prairie.

In the northern and western portion of Woods County occur the Gypsum Hills, made up of two massive ledges of white gypsum, 15 to 20 feet thick, separated by clay shales. There are in the western townships a number of ledges of hard red sandstone, giving rise to a number of outstanding buttes to which such names as Wild Cat Hill, Wall Sign Hill, and Potato Hill have been applied. There are also some ledges of hard dolomite, and occasional ledges of limestone in the northwest part of the region.

Woodward County

Woodward County lies in northwestern Oklahoma. Its northern boundary is Cimarron River. The North Canadian flows diagonally southeast across the county.

This county contains a considerable diversity of soil and topography. The northeast portion is rough. A number of streams averaging 15 to 20 miles in length, tributaries to the Cimarron, have cut the upland plain into a series of narrow valleys and hills. A strip of county averaging 15 miles in width lying north of the North Canadian is covered with sand hills. South of this river the rocks consist of Redbeds. In the southwestern corner occur sand hills and flat upland prairies. There is very little native timber in the county.

There is a large amount of gypsum in the northeastern townships, exposed as two massive white ledges averaging 15 to 20 feet in thickness outcropping for miles along the various creeks, tributaries to the Cimarron. On the tops of some of the high hills are exposures of massive white dolomites that would make excellent building stone or might be burned into lime. Ledges of red sandstone also occur in this region. In the country south and north of the Cimarron and along the north Canadian, there of good quality.
are extensive deposits of red clay shale, which would make brick