OKLAHOMA GEOLOGICAL SURVEY

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GRANITES OF OKLAHOMA.

BY

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GRANITES OF OKLAHOMA.

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INTRODUCTION.

Granite of commercial value is found in two small districts in Oklahoma, the locations of which are shown on the map (fig. 1). Though the total area of the outcrop is small, probably not over 300 square miles, there are at least six types of granite of good quality available. The statistics of production shown on the following page indicate the average annual value of the granite industry for the last decade in Oklahoma to have been about $35,000. Though production has been retarded by lack of equipment and capital, the ease of quarrying of several types of good granite has made it possible to operate a number of quarries in Oklahoma. It was believed that the character of the granites in Oklahoma justified a somewhat detailed description of their occurence, qualities, and usefulness. In this report the more important granite areas are described in detail, while briefer mention is made of those areas that give little promise of future development.

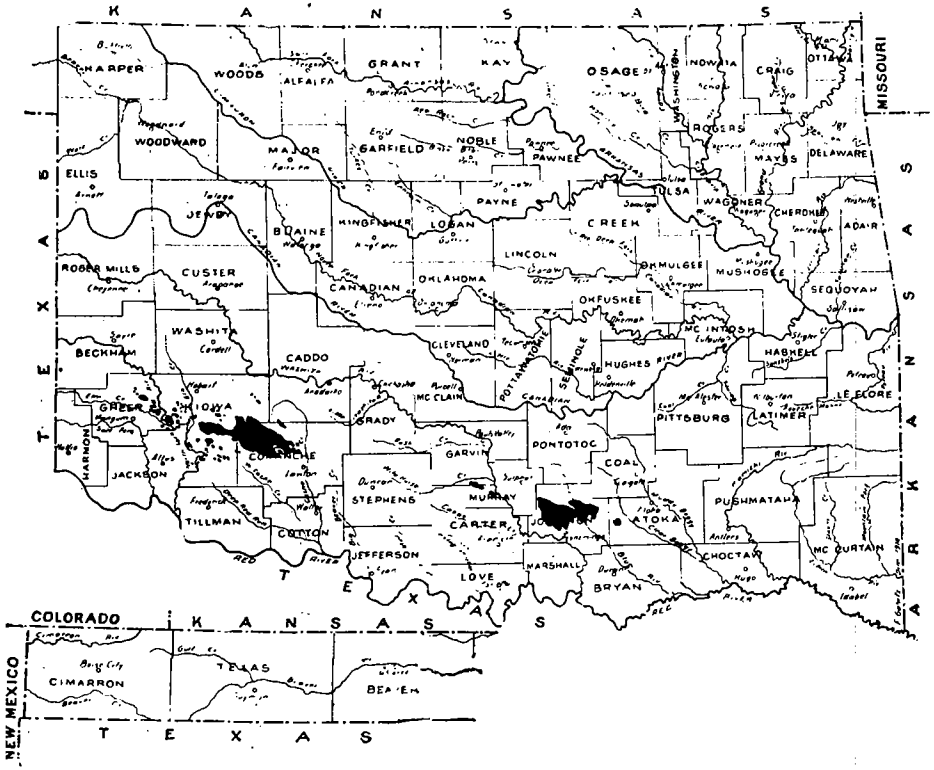

Figure 1. Map showing distribution of granite in Oklahoma. Black indicates granite areas.

The included table will give an idea of the general character of the granite and the amount and uses of granite produced in Oklahoma since 1903. The table also shows the location of quarries and the class of granite produced by each operator.

The field work which served as a basis for this report was done during 1909 and 1910 for the Oklahoma Geological Survey, and during the summers of 1911 and 1912 for the United States Geological Survey, operating with the Oklahoma Geological Survey. Further field work was done during the autumn of 1915. Besides visiting all of the quarries of the State, the writer has studied and mapped a large part of the granite areas which give promise of affording quarry sites for future development.

The physical and chemical tests, excepting chemical analyses, were made in the laboratories of the University of Oklahoma. The chemical analyses recorded on page 21 were made by J. G. Fairchild of the United States Geological Survey.

The petrographic investigation included the examination of 725 thin sections of igneous rocks, mostly granites, from Oklahoma.

The present work follows a plan similar to that of United States Geological Survey Bulletin 313, Granites of Maine, by T. N. Dale; Bulletin 354, The chief commercial granites of Massachusetts, New Hampshire and Rhode Island, by T. N. Dale; Bulletin 426, Granites of the southeastern Atlantic States, by T. L. Watson, and Bulletin 484, Granites of Connecticut, by T. N. Dale.

A general discussion of granite adapted to the average reader is included. Emphasis has been given to those points which seemed to merit particular attention in the discussion of this region. Considerable attention is given to colors in granite, because the variety in color now encountered in some of the quarries presents a perplexing problem to the operators. Also, considerable attention is given to the effects of changes in temperature, since the granite in Oklahoma has been subjected to marked changes in atmospheric temperature, and if used in the State will be still further subjected to those changes. On the other hand, the effects of freezing and thawing of water are not conspicuous enough to permit any positive conclusions as to how the granites of the State will behave when subjected to such tests.

The term "granite" here includes all quartz-feldspar varieties of igneous rock, but in the detailed discussion of the different areas the generally accepted scientific name is used.

A short description of a few types of rock not generally known as granites is included under the head of "Black Granite." Here also, the appropriate scientific name is used in the description.

The writer is indebted for much useful information to Joseph A. Taff's papers on the Arbuckle and Wichita mountains, published in Professional Paper 31 of the United States Geological Survey. For a more complete discussion, especially of the geology of these districts, the reader is referred to this report. Plates I, and XVIII, are adaptations of maps contained in this report. The published reports on granite by the various State Surveys and the United States Geological Survey have been freely used and much useful information derived therefrom.

M. L. McCance deserves great credit for the efficient manner in which he filled the position of field assistant during one field season. Charles N. Gould, former director of the Oklahoma Geological Survey, under whose direction the work was carried on, gave his hearty cooperation in the work. E. S. Larson of the United States Geological Survey has reviewed the petrographic determinations.

COMPOSITION AND PROPERTIES OF GRANITE.

GRANITE PROPER.

DEFINITION.

In the quarry industry any igneous rock which has a granular texture and whose minerals can be made out with the eye or with the aid of a hand lens is called a granite. In scientific usage, granite is a granular igneous rock composed mainly of feldspar and quartz with minor portions of hornblende or mica, or both. Other minerals are also present, generally in small amounts, but some of these are of great importance to the quarryman.

ORIGIN.

Granite is an igneous rock of deep-seated origin; that is, it was formed at considerable depth below the surface by the solidification of a mass of rock, molten at a high temperature. Large bodies of molten rock at considerable depth cool very slowly; smaller bodies, especially if at or near the surface, cool much more rapidly. As this molten rock cools, the different minerals crystallize out according to definite laws until the whole is solid. The size of the mineral crystals depends chiefly on the composition of the magna and the rate of cooling.

MINERAL COMPOSITION.

ESSENTIAL MINERALS.

FELDSPARS.

The feldspar group is the most abundant of minerals found in granite. For convenience in discussion the group is separated into two divisions, known as the potash feldspars and the soda-lime feldspars.

The potash feldspars, known as the orthoclase group, have the composition $KAlSi_3O_8$, but they differ in crystal form. The soda-

lime feldspars, known collectively as plagioclase, are isomorphous mixtures of albite ($NaAlSi_3O_8$) and anorthite ($CaAlSi_2O_8$). The following subdivisions of the plagioclase group have been made.

Subdivisions of the plagioclase group.

Per cent of Albite.	*Name.*	*Per cent of Anorthite.*
100	Albite	0
80	Oligoclase	20
60	Andesine	40
40	Labradorite	60
20	Bytownite	80
0	Anorthite	100

The feldspars as a group are harder than steel, if free from alterations, fuse at a very high temperature, are brittle, and have a specific gravity of 2.54 to 2.76, the lowest being in the potash feldspars and increasing in the plagioclase toward the calcium end of the group. In color they range from white to light gray, dark gray, and bluish gray in the plagioclase group. All the feldspars possess two good cleavage planes nearly at right angles to each other. These planes usually appear as bright, shiny flat planes on the surface of a freshly broken granite. The plagioclase feldspars often show fine parallel striations or grooves.

The feldspars may be known by their great hardness, good cleavage, and color. Microcline usually cannot be told from orthoclase except under the polarizing microscope. The feldspar crystals or individuals are generally short and thick. In some dark fine-grained rocks, however, the crystals are four to six times as long as broad.

QUARTZ.

Quartz (Silicon dioxide, SiO_2) is the second most abundant mineral in granite. It appears in irregular or rounded grains, filling the spaces between the feldspars. Quartz has no cleavage, but has a distinct conchoidal fracture, that is, it breaks like glass, with concave or convex surfaces. It 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.

AMPHIBOLES.

This group of complex silicates embraces several varieties, but they usually cannot be distinguished from each other without the polarizing microscope. They occur in prismatic crystals or irregular grains. The crystals are usually rather thick but may be long and slender. The amphiboles are characterized by two good cleavages making angles of 56° and 124° to each other; they are a little harder than steel, are brittle, and have a specific gravity of about 3.25. The amphiboles in granite are usually black, less commonly green or deep blue. Common hornblende, and riebeckite are varieties of amphibole found in Oklahoma granite.

MICAS.

The micas, next in abundance in granites of Oklahoma, are complex aluminum silicates with magnesium or potassium and more or less iron, lithium, fluorine, and hydrogen. The micas are found in flakes or tabular masses which have perfect cleavage. They characteristically split into thin elastic flakes. The micas are soft, being easily scratched with a knife, or even by the thumb nail. They range from 2.80 to 3.00 in specific gravity; and in color, from white in muscovite, to black in biotite, with intermediate shades of brown and green. In igneous rocks, usually, the dark colored varieties are called biotite and the light colored ones are called muscovite. The light colored muscovite in very fine flakes is called sericite. The dark color of biotite is usually due to the presence of iron.

PYROXENES.

The pyroxenes comprise a group of complex silicates found only rarely in granites but often comprising a large portion of some of the associated igneous rocks. They resemble the amphiboles but the cleavages make angles of nearly 90° to each other. Unless this cleavage can be observed they cannot be distinguished from the amphiboles except under the polarizing microscope. Enstatite, hypersthene, augite, diopside, and aegirite are varieties known in Oklahoma rocks.

ACCESSORY MINERALS.

Besides the foregoing list of minerals, any one of which may make up a considerable part of a granite, or of the associated igneous rocks, there are a large number of minerals which are usually of microscopic dimensions and are present in small amounts. Among those which deserve mention in this connection, the following are briefly described: Magnetite, hematite, limonite, pyrite, zircon, titanite, apatite, chlorite, fluorite, kaolin, and calcite.

MAGNETITE.

This mineral is found in small rounded or angular grains in igneous rocks. It is harder than steel, is brittle, has a specific gravity of 4.8 to 5.2, and is always black. It is an iron oxide corresponding to the formula Fe_3O_4. It is best recognized in being attracted by the magnet.

HEMATITE.

The red iron oxide, hematite, (Fe_2O_3) occurs in igneous rocks as a very fine dust disseminated through other minerals, filling fractures, or as irregular borders surrounding magnetite grains. In the latter case it is clearly secondary, being an alteration product of magnetite. Hematite has a specific graity of 4 to 5.2 and a hardness varying greatly, but sometimes as great as that of

steel. It is red to steel gray in color in its natural condition, but in fine powder is characteristically red.

LIMONITE.

Limonite is a hydrous iron oxide, ($2Fe_2O_3 + 3H_2O$) which is generally found as a yellow or brown coating on other minerals, or disseminated through some minerals in igneous rocks. It is formed as an alteration product of any of the minerals containing much iron. The color of sap rock on joint surfaces is largely due to limonite.

PYRITE.

Pyrite is an iron sulphide having the composition FeS_2. It is found in cubes or rounded grains, is as hard as steel, has a specific gravity of 5.2, has no cleavage, and is brittle. It is characterized by its crystal form, brass yellow color, great hardness and brittleness

ZIRCON.

Zircon is a zirconium silicate, $ZrSiO_4$, generally found in quadrangular microscopic prisms, terminated by pyramids. It has two cleavages at right angles to each other. Its hardness, which is greater than that of steel, aids in distinguishing it from other minerals. Zircon is brittle and has a gravity of 4.70. The most common colors range from light to dark brown.

TITANITE.

Titanite is a calcium silicate, $CaTiSiO_5$. It is a hard, brittle, brownish to black mineral with good cleavage and usually is found in microscopic wedge-shapped crystals.

APATITE.

This is a calcium phosphate containing fluorine or chlorine. It is about as hard as steel. Slender hexagonal prisms of this mineral of microscopic size are present in nearly all igneous rocks.

CHLORITE.

Chlorite is an iron-bearing hydrous magnesium aluminum silicate with a fibrous or massive texture and greenish color. It is usually an alteration product of the hornblendes, pyroxenes, or micas.

FLUORITE.

Fluorite or fluorspar is a calcium fluoride (CaF_2) having medium gravity and hardness and good octahedral cleavage. It is colorless, white, or violet. It usually occurs as a secondary mineral, rarely as a primary mineral in igneous rocks.

KAOLIN.

Kaolin is a hydrous aluminum silicate having the composition expressed by the formula $H_4Al_2Si_2O_9$. It may be an alteration product of any one of the aluminum silicates, especially the feldspars. It is white when pure, and generally soft and clay-like in appearance.

CALCITE.

Calcite is calcium carbonate ($CaCO_3$). It is relatively soft, has three directions of perfect cleavage at angles of about 75° to one another, giving beautiful rhombohedrons, and a gravity of 2.7. In color it varies from white to brown but is most often colorless. With a few possible exceptions calcite is a secondary mineral in igneous rocks, and forms by the breaking down of minerals carrying calcium.

MINERAL ANALYSES.

The mineral composition of some of the well known granites, as well as those from Oklahoma, is given in the following table.

Table of mineral percentages in granites.

Mineral Constituents.	1.	2.	3.	4.	5.
Feldspar	65.67	62.02	57.97	65.522	60.00
Quartz	23.04	30.60	35.82	26.578	33.00
Biotite	11.29	----------	----------	----------	trace
Riebeckite / Aegirite	----------	9.37	----------	----------	----------
Hornblende	----------	----------	----------	----------	5.5
	----------	----------	6.20	----------	----------
Mica	----------	----------	----------	7.900	----------
Magnetite	----------	----------	----------	----------	1.5

Mineral Constituents.	6.	7.	8.	9.
Orthoclase / Microperthite / Albite / Oligoclase	62.3	62.1	62.1	74.0
Andesine	----------			
Quartz	33.	18.3	31.0	25.5
Hornblende	.3	10.2	5.5	.5
Augite	----------			

Mineral Constituents.	6.	7.	8.	9.
Biotite	5.2	8.2	none	none
Magnetite	.2	1.2	1.2	trace
Hematite	much (1)	none	much (1)	much (1)
Zircon	trace	trace	trace	trace
Titanite	trace	trace	.20	trace
Fluorite	trace	none	none	none
Apatite	trace	trace	trace	trace
Pyrite	none	trace	none	none

1. Pink granite; Milford, Mass.; Bull. U. S. Geol. Survey No. 354, 1908. p. 78.
2. Quincy granite; Quincy, Mass.; Bull. U. S. Geol. Survey No. 354, 1908, p. 93.
3. Rockport gray granite; Rockport, Mass.; Bull. U. S. Geol. Survey No. 354, 1908, p. 123.
4. Barre granite; Washington County, Vermont; Bull. U. S. Geol. Survey No. 404, 1909, p. 51.
5. Reformatory granite; Granite, Oklahoma. Estimates of main constituents were made by Rosiwal method from a polished slab of six square inches. The minor constituents, such as albite, zircon, flourite, and titanite were estimated from examinations of thin sections.
6. Headquarters granite.
7. Cold Springs granite, or Quartz-monzonite; Cold Springs, Oklahoma. Average of three estimates. One from each of three different quarries at Cold Springs.
8. Lugert granite; abandoned quarry at railroad, one mile northwest of Mountain Park.
9. Quanah granite; seven miles north of Indiahoma.

It will be noted that all the Oklahoma granites contain hornblende. Numbers 6 and 9 contain less than one per cent. Number 9 undoubtedly will run above one per cent on the average. This estimate was made from only one thin section which evidently was below the average in hornblende. Number 7 contains both hornblende and biotite in abundance and for this reason is the darkest colored granite in the district. Very few of the granites show less than one per cent of magnetite.

CHEMICAL COMPOSITION.

Chemical analyses may suggest the presence of minerals of submicroscopic size, or they may corroborate microscopic determinations and in these respects they are of some importance in the economic study of granite. The chemical composition varies with the mineral composition in such a manner that any properties of granite governed by chemical composition will usually be suggested by the mineral composition.

CHEMICAL ANALYSES.

The folowing table gives the chemical analyses of four granites from well known localities outside of Oklahoma, and three from different localities within the State.

Chemical analyses of granites from seven different localities.

Constituents	1.	2.	3.	4.	5.	6.	7.
Silica (SiO_2)	69.44	69.89	73.48	74.62	73.61	74.14	63.04
Alumina (Al_2O_3)	15.46	15.08	15.26	10.01	11.97	12.97	14.30
Ferric Oxide (Fe_2O_3)	1.31	1.04	----	3.85	2.34	1.07	1.25
Ferrous Oxide (FeO)	1.43	1.46	1.42	1.72	1.51	1.20	6.12
Magnesia (MgO)	1.01	.66	.09	.33	.19	trace	1.75
Lime (CaO)	2.11	2.07	.88	2.43	1.38	0.48	4.38
Soda (Na_2O)	3.97	4.73	3.12	3.33	3.76	4.61	3.57
Potash (K_2O)	4.25	4.29	5.66	3.38	4.32	5.30	3.17
Water (H_2O) at 110°C	.07	.31	----	.24	0.32	0.12	0.05
Water (H_2O) plus 110°C	.29	.23	----	.24	0.35	0.19	0.72
Titanium dioxide (TiO_2)	.48	----	----	----	0.46	0.25	1.43
Manganese oxide (MnO)	.03	----	.10	----	0.09	0.03	0.09
Carbon Dioxide (CO_2)	trace	----	none	----	----	----	----
Phosphoric Acid (P_2O_5)	.22	trace	----	----	.15	trace	0.28
Barium oxide (BaO)	----	----	----	----	.04	----	----
Strontium oxide (SrO)	----	----	----	----	.02	----	----
	100.07	99.76	100.01	99.71	100.51	100.36	100.19

1. Medium-textured, medium-gray, biotite granite; McIntosh quarry, Chesterfield County, Va.; Wm. M. Thornton, Jr., analyst; Bull. U. S. Geol. Survey No. 426, 1910, p. 72.
2. "Dark Barre" granite; Washington County, Vermont; G. I. Finley, analyst; Bull. U. S. Geol. Survey No. 404, pp. 51-52.
3. Granite; Waldebora quarry, Lincoln County, Maine; Ricketts and Banks, analysts; Bull. U. S. Geol. Survey No. 313, p. 141.
4. Waushara granite; Waushara, Wis.; Samuel Weidman, analyst; Bull. Wisconsin Geological and Natural History Survey No. 4, p. 112.
5. Lugert granite (Toscanose); west of Mt. Sheridan, Wichita Mountains, Oklahoma; J. P. Iddings, collector; George Steiger, analyst; Bull. U. S. Geol. Survey No. 419, p. 41.
6. Reformatory granite (Liparose); Wichita Mountains, Oklahoma; J. G. Fairchild, analyst, U. S. Geol. Survey.
7. Cold Springs granite, or quartz-monzonite, (Harzose), Cold Springs, Wichita Mountains, Oklahoma; J. G. Fairchild, analyst, U. S. Geological Survey.

PHYSICAL PROPERTIES.

The mineral composition and texture of a rock are the largest factors in determining the physical properties. The importance of some of the physical properties will be noted briefly, although

not enough data have been secured to discuss all of the Oklahoma granites.

TEXTURE.

Texture relates to the size, form, and arrangements of mineral grains or crystals. It is one of the most important factors to consider in the selection of building or ornamental stone, for the strength, durability, and beauty of the stone are largely dependent on the texture.

Granites are composed chiefly of mineral grains or imperfectly developed crystals called anhedra. Equigranular rocks are those in which the grains are of equal size. If some mineral grains are distinctly larger than all the others the rock is said to be porphyritic. The larger crystals or grains are called phenocrysts and the remainder of the rock is called the ground-mass.

The size of the individual grain is an important factor in the texture of building or ornamental stone. It is now customary to consider a rock coarse-grained if the average diameter of the mineral grains is above one centimeter or 0.4 inch. Medium-grained rocks are those in which the average diameter of the mineral grains ranges from 0.5 to 1 cm., or from 0.2 to 0.4 inch. If the mineral grains are less than 0.5 cm. or 0.2 inch in average diameter, the rock is termed fine-grained. These terms will be used in this sense in the report.

POROSITY.

The porosity is the space between the mineral grains occupied by air or water, computed in percentage of the volume of the rock. The porosity of granite is always small, seldom attaining one per cent. To determine the porosity, the rock is first thoroughly dried at a temperature of 110° C. It is then weighed in air, after which it is saturated with pure water by placing it in a hot water bath under reduced atmospheric pressure. It is again weighed in air. The gain in weight will be the weight of water absorbed, from which the percentage pore space is determined. To determine the percentage pore space, multiply the weight of absorbed water by the true specific gravity. Divide this result by the sum of this product and the weight of the dry rock. The porosity of Oklahoma granites ranges from .091 to 1.108.

EXPANSION.

Minerals in rocks expand when the temperature is raised and contract when the temperature is lowered. This change in the volume of the minerals causes a corresponding change in the volume of the rock.

The coefficient of expansion of granite has been estimated at about .000001.* A change in temperature of one degree Fahrenheit would cause a change of .000001 of the total length of a slab of granite. A change in temperature of 100° F. would produce a change of about .01 foot in the length of a wall 100 feet long. This variation in volume probably would not be detrimental to a building as a whole, but in regions of sudden changes in temperature the differential changes in volume of the different minerals disintegrate rock as explained under weathering.

*Buckley, E. R., Mo. Geol. Survey, vol. 2, Second series, p. 20.

COHESION.

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 47,674 pounds per square inch. Even the lower figure is far in excess of that required by any building yet constructed.

Oklahoma granites range in crushing strength from 11,200 to 38,247 pounds per square inch.

What may be termed the transverse breaking strength is of far more importance than the crushing strength described above. This is the pressure a rock will sustain in its middle when supported at its ends. Tests of this nature might be used as a valuable criterion for judging the value of building stone. The many broken lentils, caps, and sills attest the fact that much stone does not possess the transverse crushing strength demanded of it.

The method employed in determining the transverse crushing strength is that used by Buckley.*

The following formula was used:

$$W = \frac{2bd^2R}{31}, \text{ from which } \qquad R = \frac{31\ 2W}{2bd}.$$

R=Modulus of rupture in pounds per square inch.
b=breadth of prism, in inches.
d=depth of prism, in inches.
l=length of prism, in inches.
w=concentrated load in pounds applied at the center.

The modulus of rupture for Wisconsin granites ranged from 2713 to 3909 pounds per square inch.

Only two tests have been made for modulus of rupture of Oklahoma granite. The lower 2749 and the higher 4690 probably express the range adequately.

FLEXIBILITY.

Flexibility is the resistance to fracture under sudden displacement of form. A quick hard blow will break a piece of quartz

*Buckley, E. R., On the building and ornamental stones of Wisconsin: Bull. Wis. Geol. and Nat. Hist. Survey, No. 4, 1898, p. 62.

more readily than a piece of feldspar. The quartz is less flexible than the feldspar. Mica is much more flexible than feldspar. The flexibility of a rock 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 that texture. Some of the gray granites in the western Wichita Mountains has an arrangement of minerals resembling ophitic texture and this aids in making it tough or flexible. The coarse pink granite from the town of Granite is one of the most brittle rocks in the State, chiefly because the mineral grains are equidimensional and therefore cannot interlock. The abundance of quartz also aids in making this rock brittle.

SPECIFIC GRAVITY.

The specific gravity of stone is determined by comparing the weight of the stone with the weight of an equal volume of water. 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 at 4° C.

It is an easy matter to determine the approximate or apparent specific gravity of a stone. Weigh a small piece in air, then suspend it in water and weigh again. The difference represents the weight of an equal volume of water. Divide the weight in air by this difference, the quotient being the specific gravity. If the weight per cubic foot is desired, multiply the specific gravity by 62.5, the weight of a cubic foot of water, and the product is the weight in pounds of a cubic foot of the stone.

For very accurate determination of specific gravity the stone is first exhuasted of its absorbed water by heating to 110° C., and then weighed. It is then immersed in warm water with the atmospheric pressure reduced to one-fourth. It is finally weighed in distilled water, and the dry weight in air is divided by the loss when weighed in water, the quotient being the true specific gravity.

Both apparent and true specific gravities are given where available. The former is more useful in estimating the shiping weigh of stone. It is important to know the specific gravity so as to estimate shipping weight and strength of structures.

Oklahoma granites range in specific gravity from 2.63 to 2.77 A few varieties of rock which are not true granites have even higher specific gravities.

COLOR.

Commercially, color is one of the most important properties of granite. Whether for decorative or structural purposes, it is the chief consideration in the selection of stone. For structural purposes a stone should be selected which in color harmonizes with the surroundings, as well as satisfies the taste of the individual. In the selection of stone for monuments, color is largely matter of individual taste. Gray, pink, red, and brown are the most popular shades, though black is sometimes used.

A matter of prime importance to the purchaser is to select

stone that will not change color on exposure to the atmosphere, or, if it changes color, will not be less pleasing than the original. The matter of prime importance to the operator is to know how the color of his stone will vary vertically and horizontically in the quarry, as well as how the color will change on exposure to the weather. The purchaser has little to rely on, except the mineral and chemical composition of the rock, while the operator in addition to mineral and chemical composition may study field and quarry conditions, and effects of weathering.

The color of any rock is determined by the color of the constituent minerals and the texture. The color of most granites is not a single, but a composite color due to the blending of several different colors. If the minerals composing the rock are of about the same color and the rock fine-grained it will have a solid uniform color. If the minerals are of distinctly different colors and the rock coarse-grained the stone will be mottled. If the mineral composition is the same, the finer the grain, the deeper color, whether polished or unpolished. As a rule the polished surface is deeper in color than the rough surface.

In granites of the same mineral composition the hammered face is lighter in color than the polished or rough surface but contrast is greatest in fine-grained and dark-colored stone.

The most common colors in granites are gray, pink, brown, and red, each of which is represented by several shades. Quartz is usually colorless, white, or gray, and the feldspars are often white or gray. If a granite is made up chiefly of these two minerals with such colors, it will be light gray. If biotite or hornblende, which are usually brown or black, be added, the gray becomes a mottled or speckled gray of darker shade. Feldspar, especially orthoclase, is often pink or red because of dustlike inclusions of hematite, and consequently gives a pink or red shade to the granite. The plagioclase feldspars are often medium to dark gray in color, and when present with magnetite, hornblende, or biotite, and augite, a dark gray to black rock results. Dark-colored granular rocks usually contain one or more of the dark-colored minerals, hornblende, pyroxene, biotite, and magnetite in considerable amount.

So far, we have considered only fresh unaltered rocks and the minerals which they contain. When account is taken of all the minerals formed by the processes of weathering and by the action of circulating ground water the subject of color becomes very complex.

In general it may be stated that near the surface iron compounds change to brown and yellow limonite and red hematite. Amphibole, pyroxene, and biotite change to one or more of the green minerals, chlorite, epidote, or serpentine, and the feldspars alter to white sericitic mica, kaolin, calcite, and epidote. The last is more likely to form from the plagioclase feldspars, if some iron and magnesium are present.

With these preliminary statements we are now ready to follow the changes in color which an ordinary granite undergoes in the

usual processes of alteration. Let us take a type of granite similar to several Oklahoma varieties, containing quartz, orthoclase feldspar, dark hornblende, magnetite, and a small amount of pyrite. The feldspar is colored pink by inclusions of hematite dust. First the pyrite oxidizes to red hematite and brown limonite, giving a deeper red shade to the rock. Magnetite oxidizes to hematite thereby deepening this color. The magnetite is not evenly distributed and as a consequence the red is found in patches. The feldspars then begin to break up into white sericite and kaolin and the hornblende to green chlorite. The effect of this is to obscure the deep shade of red and give the rock a greenish brown to yellow color. As the process goes further the chlorite breaks up into yellow iron oxide and kaolin, and the hematite, in part at least, alters to yellow and brown limonite. The result is a gray mass streaked with red and occasional green.

With the aid of circulating ground water introducing other substances, the color varieties are still greater. Often the ground water carries iron in solution, and on hillsides where it comes near to the surface, red hematite is precipitated in the cracks in the minerals and around the minerals transforming the granite into a brilliant red color. At greater depth, or away from zones of surface water circulation, green epidote and chlorite are formed, and here the granite is a dirty green, in marked contrast to the brilliant red.

Black rocks, containing much hornblende, pyroxene, and biotite almost invariably alter first to a green and then to a yellowish brown as the chlorite, magnetite, and feldspars break down, forming kaolin, sericite, and limonite.

Changes in color take place most rapidly just beneath the surface of the ground, where oxygen is accessible and where water usually is present. Dressed or polished stone sheds water and is not so subject to change in color. On the other hand, it must be remembered that some of these changes take place rapidly and a few years sometimes are sufficient to materially change the color of a polished stone. This is especially true if it contains the easily altered pyrite. Magnetite is less easily altered.

VARIETIES OF GRANITE.

Since the texture and the mineral composition are the chief factors in determining the qualities of a rock, these two characteristics form a convenient basis for a classification of rocks. According to common usage all granite contains quartz and feldspar; therefore a descriptive classification of granites will need to contain the names of only the non-essential minerals. It is convenient also to append terms indicating the texture. To illustrate: The Cold Springs granite is a fine-grained hornblende biotite granite and the Tishomingo granite is a slightly porphyritic, coarse-grained biotite granite.

Aplite or alaskite is a granite composed of quartz and orthoclase feldspar only. A graphic granite is one in which the feldspar and quartz are intimately intergrown instead of appearing as separate individuals. Rhyolite is a very fine-grained to glassy igneous rock having the same mineral and chemical composition as granite.

STRUCTURE.

Structure relates to the large features of a rock, such as joints, faults, rift, and grain.

JOINTS AND FAULTS.

Joints are the natural fractures or cracks in a rock which divide it into blocks. These fractures are usually open near the surface but are nearly closed at a depth of several feet. Single fractures vary from a few feet to a mile or more in length. If there is displacement parallel to a fracture plane it becomes a fault. Joints are vertical, horizontal, or inclined. There may be two sets at approximately right angles to each other, or a greater number at various angles. If joints are properly spaced so that the granite comes out in suitable sized blocks, they serve a useful purpose, otherwise the granite is rendered worthless for building purposes. If no joints are present quarrying is much more difficult for all splitting must then be done by the quarrymen.

Horizontal or gently inclined joints are often called sheet joints. These joints are often roughly parallel to slopes of the granite hills. They divide and unite in an intricate fashion, thus cutting the granite into horizontal or inclined lenses. (See Pl. III). They range from 2 to 25 feet or more in maximum thickness. In some districts these sheets or lenses are said to increase in thickness with depth, but sufficient depth has not yet been reached anywhere in the Oklahoma quarries to justify a generalization as to change with depth.

T. N. Dale* in his bulletin on the granites of Connecticut concludes that sheet joints are formed in relieving stresses set up in the granite mass at the time of its intrusion, or subsequently as erosion has removed the overlying load.

RIFT AND GRAIN.

Rift and grain are terms used by quarrymen to denote a tendency of rocks to split in rather constant direction. Rift is the direction of easiest splitting. Grain is the direction at right angles to this, in which the rock splits a little less easily than along the rift. Rift and grain are generally found to be due to systems of microscopic parallel fractures. The cracks pass through some minerals and around others, or pass through all indiscriminately. In

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* For a full discussion of the possible causes of sheet structure see U. S. Geol. Survey Bull. No. 484, pp. 29, 36.

granite the rift cracks generally coincide with sheets of microscopic bubbles within the rock. The rift is sometimes parallel to sheet joints but often crosses them. Microscopic examination of a number of thin sections of granite from Thos. L. Eggleston's quarry shows that there are systems of parallel microscopic fractures corresponding to the directions of rift and grain. Quarrymen take advantage of rift and grain when present, and are thereby able to operate more economically. In some of the quarries of Oklahoma they have been followed to advantage, but in others the quarrymen observed no difference in the ease of splitting.

ASSOCIATED ROCKS.

Associated with the granite are commonly found: (1) Intruded dikes, sills, and irregular masses, (2) included rounded and angular masses, and (3) nodules or masses due to segregations.

INTRUSIONS.

DIKES AND SILLS.

It is not an uncommon thing to find tabular masses of some other variety of igneous rock cutting the granite. These are called dikes unless the tabular mass is almost horizontal, in which case they are termed sills. There is really no sharp or essential difference between the two, either from an economic or scientific standpoint. With two exceptions all of the intruded tabular masses in the area under discussion have the position of dikes. They range in thickness from less than 1 inch to about 40 feet. The varieties of dike rocks which have been observed are aplite, pegmatite, normal granite, monzonite, gabbro, diorite, and diabase.

Aplite dikes differ from the normal granite in that they are fine grained and are almost entirely quartz and feldspar. These are found rather sparingly in all the districts except the Cold Springs area, where they are numerous and of great variety in form and size. Detailed description of them will be given in the discussion of each area.

Pegmatite dikes are coarse-grained aggregates of quartz and feldspar and may also contain other minerals. Pegmatites have been found at Cold Springs and Lugert. Normal granite dikes are also common, especially in the Cold Springs region. Gabbro dikes are found in the Cold Springs and Tishomingo areas. Monzonite dikes, though rare, are known in the Cold Springs area.

The diorite and diabase dikes include the latest intrusions in the Wichita and Arbuckle mountains, and can scarcely be distinguished from each other except under the polarizing microscope. They are all fine-grained and dark in color. These dikes are common in all of the regions excepting the Granite City area and the main Wichita range.

SEGREGATIONS.

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, biotite, or other dark minerals. There is no way of predicting where they will occur, and no method can be suggested for avoiding them. They do not seem to weaken the stone, but disfigure it for ornamental or building purposes. Segregations are common in almost all granite quarries in Oklahoma.

INCLUSIONS.

Inclusions consist of fragments of other rocks which may have fallen into the molten rock and on cooling were inclosed. Like segregations, their occurrence cannot be predicted, but they are generally localized. Unless the inclusions are almost identical with the inclosing rock in appearance, they disfigure a building or ornamental 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 Wichita Mountains, in the vicinity of Granite and Lugert, and locally in the main granite area.

BLACK GRANITES.

Under this head will be noted briefly certain varieties of igneous rock known to the trade as black or blue granites, but scientifically known as diorite, gabbro, and diabase.

DIORITE.

DEFINITION.

A diorite is a granular igneous rock composed chiefly of soda-lime feldspar and one or more of the minerals hornblende, biotite, and pyroxene. Magnetite, apatite, and some other minerals are usually present in small amounts.

PHYSICAL PROPERTIES.

Diorite is a heavy, fine to medium grained, dark gray to black rock. It is rather tough, weathers more readily than granite, and usually turns to a greenish gray color on weathering.

GABBRO.

DEFINITION.

Gabbro is a granular igneous rock composed chiefly of plagioclase feldspars and pyroxene with or without olivine. Magnetite, titanite, pyrite, and apatite are often present. The feldspar is predominantly labradorite. A variety of gabbro composed almost entirely of labradorite feldspar is called anorthosite.

PHYSICAL PROPERTIES.

Gabbro is a dark gray to black, medium coarse-grained rock that weathers readily, and on account of the abundance of iron is not usually very suitable for building purposes, though in some cases it is a very desirable monumental stone.

DIABASE.

DEFINITION.

Diabase is composed chiefly of plagioclase feldspar and augite with some magnetite and other minerals. It is a fine-grained dark colored rock, distinguished by its containing lath-shaped crystals of feldspar, which usually penetrate the augite giving an ophitic texture. It is that characteristic texture which distinguishes diabase from gabbro.

PHYSICAL PROPERTIES.

It is a heavy, tough rock which alters and discolors readily. It takes a smooth glossy polish.

WEATHERING OF GRANITES.

The disintegration of a rock due to changes in temperature, the freezing and thawing of water, and the action of ground water by carbonation, hydration, solution, and oxidation is known as weathering. The rate at which a rock disintegrates depends on its mineral composition, texture, the climate in which it is exposed, and the degree of exposure.

CHEMICAL CHANGES.

A moist, warm climate favors chemical changes by oxidation, hydration, carbonation, and solution. If a rock contains minerals bearing much iron, such as magnetite, pyrite, hematite, biotite, and some of the amphiboles 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 in color is due to the alteration of the above minerals, and the formation of yellow or brown iron oxides which are dissolved and carried to the surface. Pyrite, biotite, and magnetite are especially likely to undergo this change. It is therefore important to know whether a stone contains these minerals in large quantities, for their alteration not only weakens the stone but also causes it to take on displeasing colors. The feldspars generally alter to sericite and kaolin. This gives a lighter shade to the rock. Chlorite and epidote often form as alteration products of biotite and hornblende, but also may form from the feldspars if some iron and magnesium are present. Chlorite and epidote tend to give a greenish shade to the rock. It is impossible to predict what will be the change in color unless the mineral composition is known. On the other hand, it is possible to predict the color of the fresh rock from a knowledge of the mineral composition of an altered rock.

PHYSICAL CHANGES.

Differential expansion and contraction of the minerals due to sudden changes in temperature is an important factor in the disintegration of granite in Oklahoma. It may be observed in the field that the coarse, red granite exfoliates and disintegrates most

readily of any Oklahoma granite because of changes of temperature. The finer the grain, the less the rock is disintegrated.

Tests on several varieties of Oklahoma granite show that the finer-grained varieties disintegrate less readily than the coarser varieties.

Freezing and thawing of water have had but little opportunity in the State to show what the effect would be on the different rocks.

GRANITES OF OKLAHOMA.

WICHITA MOUNTAINS DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Wichita Mountains district lies in Comanche, Kiowa, Greer, and Jackson counties in southwestern Oklahoma. The Wichita Mountains consist of ridges, groups of dome-like hills, and isolated peaks of igneous rock, chiefly granite, which rise with steep slopes from the flat Redbeds plains.

The distribution of the various types of igneous rocks may be learned from the map. The area of gabbro-anorthosite is in general, more moderate in relief than the granite areas. Much of the gabbro outcrops on a low, rolling plain, which rises gradually to ridges 200 to 400 feet in height in the center of the range. The granite hills rise abruptly from the plains to various altitudes the maximum being about 900 feet. Well records show that the steep slopes of the granite hills continue for several hundred feet beneath the present Redbeds surface. At the State Reformatory near the town of Granite, in a well 500 feet from the granite hill, the granite was reached at a depth of 200 feet. At Lugert similar conditions were found to prevail.

This district is drained by Elm Fork and Salt Fork of Red River, together with a number of minor and usually intermittent streams which discharge into Red River after flowing some distance across the plain.

Usually the streams flow out from the mountains into open valleys which denote long continued erosion. The presence of Redbeds in some of these open valleys shows that they are of pre-Redbeds age. In a few instances streams are maintaining their courses in canyon-like valleys across granite ridges. The narrows of Cache Creek and the narrows of Otter Creek are the work of streams of this type. The canyon-like portions of the valleys evidently are of post-Redbeds age and are probably of post-Cretaceous age.

GEOLOGY.

The rocks of the Wichita Mountains district fall naturally into four groups: (1) Pre-Cambrian sedimentary rocks, consisting of quartzite and sandstone, (2) pre-Cambrian igneous rocks, consist-

ing of rhyolites, granites, gabbros, quartz-monzonites, diorite, and diabase, (3) Paleozoic sandstones and limestones of Cambrian and Ordovician age, greatly folded and faulted, (4) horizontally bedded red sandstones and shales, probably of Permian age.

The pre-Cambrian sediments consist of sandstone and quartzite of unknown thickness which are cut by granite and gabbro of undoubted pre-middle Cambrian age. Blocks of the quartzite are also found inclosed in the gabbro and granite. The relations show clearly that the quartzite is older than the gabbro and granite. The quartzite under the microscope is found to be composed chiefly of grains of quartz, with a little magnetite and sillimanite.

The igneous rocks of the Wichita Mountains consist chiefly of granite, rhyolite, gabbro, and anorthosite, with the associated dikes and sills of aplite, granite, monzonite, diorite, diabase, and gabbro. The granites in large masses are known to represent five periods of igneous activity. The anorthosite is a phase of the gabbro, and grades into it insensibly. Of the area shown in Plate I as gabbro-anorthosite, approximately 25 per cent may be called anorthosite.

The gabbro-anorthosite is the oldest igneous rock exposed in the Wichita Mountains. At Meers approximately 800 feet of gabbro is exposed. Small masses of the quartzite are found inclosed in the gabbro.

The first determinable igneous activity subsequent to the solidification of the gabbro is recorded in a series of diabase and quartz-diorite dikes and small masses of intruded material. Later the fine-grained granite of Headquarters Mountain was probably intruded into the gabbro in the form of a large batholith.

After the solidification of the Headquarters Mountain granite, the Reformatory granite was intruded, probably in the form of batholiths, and it in turn was followed by the intrusion of the Lugert granite, which is probably the same age as the granite in the Mount Scott area. In the area south of Mount Scott the rhyolite porphyry is found overlying the quartzite. The age of the Cold Springs granite relative to the other granites cannot be stated with certainty, for its outcrops are separated from them by considerable areas of gabbro. Granite dikes which appear to be the same as the Lugert granite, cut the Cold Springs granite. If this correlation is correct the Lugert granite is next to the youngest granite in the disrict. The latest granite mass is represented by the Elk Mountain intrusion, probably in the form of a batholith.

Following these periods of igneous activity there was fracturing and intrusion of dikes of diabase and quartz diorite, granite, pegmatite, and diabase-diorite in the order given.

The gabbro-anorthosite has been locally metamorphosed, imposing upon it a distinctly schistose structure. The rhyolite has

PLATE II.

A. VIEW OF PRE-CAMBRIAN QUARTZITE NEAR MEERS.

B. CLOSE VIEW OF PRE-CAMBIAN QUARTZITE NEAR MEERS.

been completely devitrified, otherwise the rocks of this region still maintain their original texture.

Lying unconformably above the granite is the Reagan sandstone which, according to O. E. Ulrich, is Middle Cambrian.*

Following the deposition of the Reagan sandstone, several thousand feet of limestones, sandstones, and shales were laid down in this area. Following this, probably toward the close of Pennsylvanian times, the region was uplifted, folded, faulted, and truncated by erosion.

The Redbeds, probably of Permian age, were then laid down across the upturned edges of the deformed sedimentary rock and on the lower exposed portions of the igneous rock. These rocks have remained in essentially the same position to the present time.

DISTRIBUTION OF GRANITE.

All of the granite quarries of the Wichita Mountains are located either at Granite or along the St. Louis and San Francisco Railroad between Mountain Park and Roosevelt. There are other granite areas which have furnished small quantities of granite, or are suitable localities for profitable quarries. The granite of commercial quality and quantity may be discussed by districts designated as follows: (1) Granite area, (2) Lugert area, (3) Mountain Park area, (4) Cold Springs area, (5) Cooperaton area, (6) Elk Mountain area, (7) Mount Scott area, (8) Navajoe Mountain area.

The granites from areas nos. 2, 5, 6, and 8 have been worked only in a very limited way. Three varieties of granite have been used in the Granite area, four at Mountain Park, and two at Cold Springs. In the Lugert area there are three varieties available, while at each of the other places there is but one variety available.

VARIETIES OF GRANITE.

TEXTURE.

All of the granites of the Wichita Mountain district which are used, or which occur in commercial quantity and quality may be classed as even-grained. In grain they vary from fine to medium. The Cold Springs granite is the finest-grained of the Oklahoma granites. The average diameter of the different individual minerals is about .20 mm. In some places it averages .14 mm. The Headquarters granite is only slightly coarser-grained. The Lugert granite varies in size of grains from 1 mm. to 3 mm. average diameter. The Reformatory granite is the coarsest granite in the

* Ulrich, O. E., Preliminary report on the geology of the Arbuckle and Wichita mountains, in Indian Territory and Oklahoma, by J. A. Taff, with appendix on reported ore deposits of the Wichita Mountains, by H. F. Bain: Prof. Paper U. S. Geol. Survey No. 31, 1904, pp. 22-53.

PLATE III.

A. GRANITE HILL NORTHWEST OF GRANITE, SHOWING SHEET JOINTS CUTTING THE GRANITE INTO LENTICULAR BLOCKS.

B. LARGE GRANITE HILL NORTHWEST OF GRANITE, SHOWING LARGE BARREN SURFACES AND WIDELY SPACED FRACTURES.

Wichita Mountains. It has an average grain of about 5 mm. The Quanah granite is a little finer grained than the Reformatory granite.

COLOR.

The granites of the Wichita Mountains district are flesh-red, reddish-brown, medium to dark gray, and bluish-black in color. The red granite predominates, though the dark-gray and reddish brown granites are quarried in several localities.

The mineral and chemical composition may be learned from the tables on pages 19 to 21.

STRUCTURE OF THE GRANITES.

JOINTS.

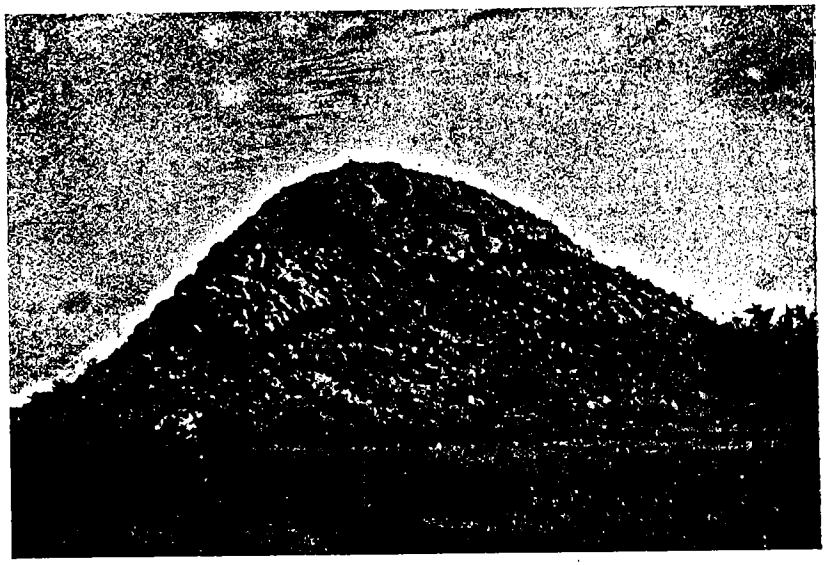
Practically everywhere in the Wichita Mountains there are two systems of vertical or nearly vertical joints, and one system of slightly inclined joints. The main vertical joints often make angles of 85° to 90° to each other. Usually these two systems lie in north-south and east-west directions, but in some parts of the area they lie in intermediate directions.

The spacing of the vertical joints varies from a few inches to 50 feet. In the quarry districts the joints are spaced from 6 to 20 feet. They are often uniformly spaced at 6 to 8 feet, both horizontally and vertically.

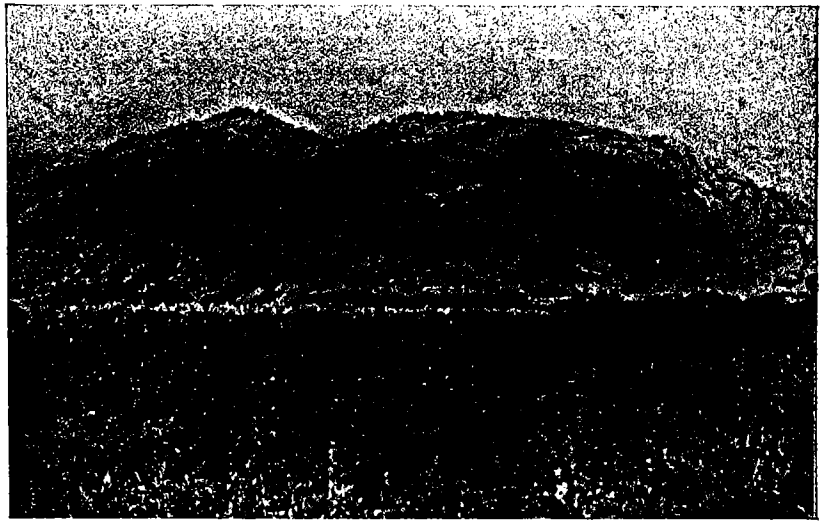
The major joints are often continuous and in a plane for long distances. In a few cases slight vertical displacements were determined. A throw of about 25 feet is shown on the east slope of Mount Sheridan. At the west end of Quartz Mountain, near Lugert, slickensides on a fissure wall suggest vertical displacement, but there was no means of determining the amount of displacement. The stronger joints are open to considerable depths, sometimes for 25 feet or more, especially near the tops of the mountains. As a rule, the joints in the granites of the Forest and Game Reserve are more closely spaced than in the isolated granite areas farther west. This is especially true of the north-central part of the Reserve. (See Pl. V.) A notable exception to this rule is found in the Elk Mountain district where the joints are as widely spaced as anywhere in the Wichita Mountains.

Horizontal or inclined joints appear to be best developed in the areas where the vertical joints are most widely spaced. At any rate, they are most conspicuous in such areas. These joints in many places cut the Wichita Mountain granites into lenticular blocks. The joint planes usually dip away from the hill with a dip approximately parallel to the slope of the hill, but in some cases there are two sets, one of which dips with low angles toward the hill. The joints are spaced 4 to 25 feet apart; that is, the lense like blocks have an average thickness ranging from 4 to 25 feet.

PLATE IV.



A. GRANITE HILL WEST OF LUGERT, RISING ABRUPTLY FROM THE LEVEL PLAINS SURROUNDING THE WICHITA MOUNTAINS.



B. QUARTZ MOUNTAIN WEST OF LUGERT, SHOWING LARGE MASSES OF LITTLE-FRACTURED GRANITE, RISING ABRUPTLY FROM THE PLAINS.

With the present opportunity for observation in this region the sheet joints are not more closely spaced near the surface than they are deeper down. However, only three quarries have been opened up to depths of 50 feet, but in these there was no evidence of a thickening of the sheets or lenses, as is reported in other states.

Sheet joints are the most important structural features in the granite quarries of the Wichita Mountains. Without them the labor of quarrying would be greatly increased. For a full discussion of the origin of sheet joints see United States Geological Survey Bulletin 484, pages 29-36.

RIFT AND GRAIN.

At only three quarries in this district have rift and grain been noted. At the Oklahoma Rose Granite Company's quarries rift and grain are recognized and followed. The rift lies N. 80° W. vertically, while the grain is north-south vertical. At the Southwestern Granite Company's quarry, rift is reported as having a strike of N. 20° W., and dipping W. 85°; with grain east-west vertical. Microscopic examination shows the rift and grain to be due to microscopic parallel fractures.

DIKES AND VEINS.

QUARTZ VEINS.

In several localities in the Wichita Mountains small quartz veins were observed, but at no place were they persistent enough to be mapped except in a small area one mile north of the Oklahoma Rose Granite Company's quarries near the town of Granite. Here there are several branching quartz veins which can be followed for one-half mile or so. The average width is not over 6 to 8 inches, but in places they expand to 16 inches in thickness. They are vertical, or dip at high angles to the north. A microscopic section shows granular quartz with a trace of orthoclase and magnetite.

PEGMATITE DIKES.

In the Cold Springs and Mount Scott areas there are a few east-west almost vertical pegmatite dikes, 6 inches to 4 feet wide, composed of quartz, orthoclase, microcline, hornblende, and zircon.

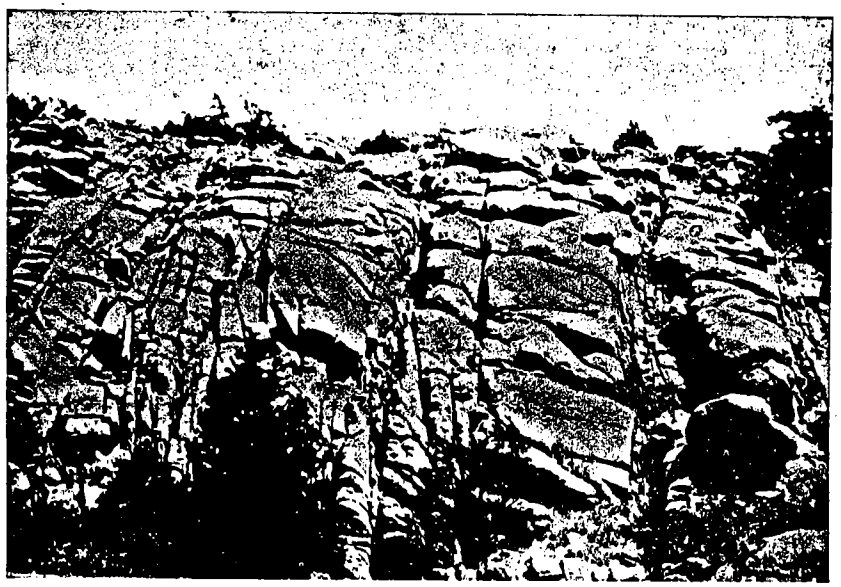
APLITE DIKES.

Aplite dikes are found in all parts of the Wichita Mountains but they are most abundant in the Cold Springs area. As a rule the dikes are variable in thickness and direction, and are not persistent for any great distance. In the Cold Springs area they cut the gray granite, diorite, diabase, and gabbro. The dikes vary from a fraction of an inch to a maximum of a foot or more in width. The larger ones are commonly vertical and bear W. to N. 70° W.

GRANITE DIKES.

Normal granite dikes occur over the entire Wichita Mountain

PLATE V.



A. THE SOUTHEAST FACE OF ELK MOUNTAIN, SHOWING ZONES OF WIDELY SPACED FRACTURES ALTERNATING WITH ZONES OF CLOSELY SPACED FRACTURES.

B. LUGERT GRANITE IN THE NORTHWEST PART OF THE FOREST RESERVE SHOWING THE INTENSE FRACTURING IN THIS AREA.

range. They rarely occur as distinct dikes in the eastern or main part of the range, except in the vicinity of the gabbro-granite contact.

In the Granite area riebeckite-aegirite granite dikes are the most persistent of any in the area. This granite is a fine-grained pinkish-gray granite made up of orthoclase, quartz, riebeckite, aegirite, and magnetite. The dikes vary from 1 to 16 inches in thickness, and dip 25° to 40° N. Usually the blue hornblende is found in distinct prismatic crystals not over 2 mm. in length. At the Thos. L. Eggleston quarry near Granite, there is a 4-inch dike containing hornblende or riebeckite crystals occasionally 2 inches long and one-half inch thick. The dike pinches out rapidly both east and west of this point, and the hornblendes soon become of microscopic dimensions.

In the east-central part of sec. 22, T. 6 N., R. 21 W., there are 8 parallel dikes of the riebeckite-aegirite granite, dipping 30° to 35° NE. They vary from 3 to 16 inches in thickness.

Distinct dikes of granite in the Lugert and Mountain Park areas are relatively rare and not persistent when present.

Granite and monzonite dikes from a fraction of an inch to 8 feet in thickness are numerous in the Cold Springs area. They strike in various directions, often east-west and northwest-southeast, and are generally about vertical, though sometimes are nearly horizontal.

In the central portion of the main Wichita Mountain range granite dikes are not well defined.

DIABASE-DIORITE DIKES.

This type of dikes is the most persistent of any in the region. At least two periods of fracturing with the intrusion of basic dikes are shown. The earlier are diorite or diabase-diorite, while the latter are usually typical diabase characterized by ophitic texture. These dikes are usually vertical, or almost so, and trend east-west, north-south, northwest-southeast and N. 15° W. They always weather more readily than the inclosing rock.

INDIVIDUAL QUARRY AREAS.

GRANITE AREA.

TOPOGRAPHY.

The seven more or less isolated granite outcrops lying chiefly to the northwest of the town of Granite, have been designated the Headquarters Mountain group. Headquarters Mountain, somewhat to the west of the center of the largest outcrop, rises as the highest peak to an altitude of 2260 feet above sea-level, and about 500 feet above the surrounding Redbeds plain. The group as a whole consists of barren dome-like hills which rise abruptly 200 to 400 feet above the Redbeds plains. The different types of granite manifest themselves in the topography. The granite is cut by strong, widely-spaced joint planes. Immense boulders are produc-

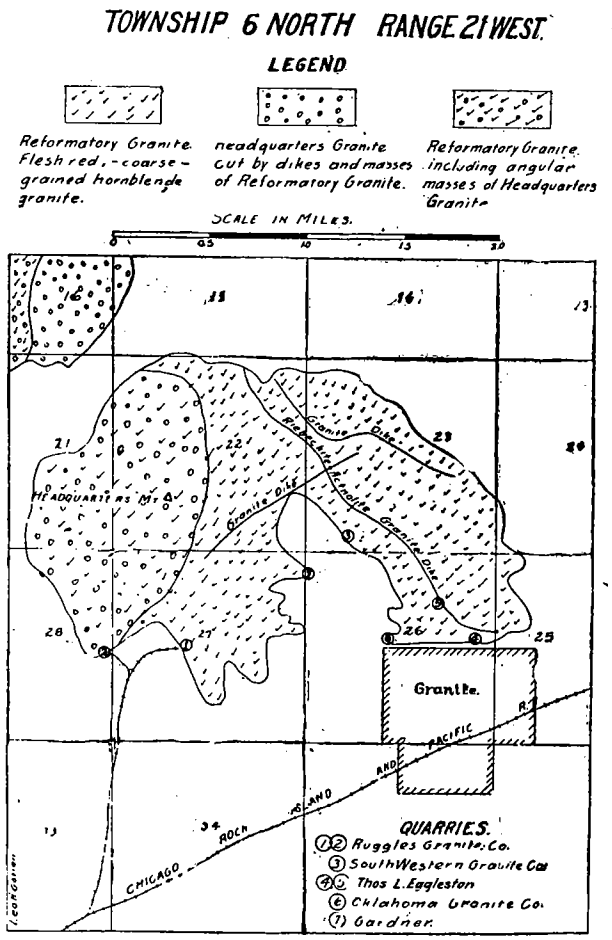


Figure 2. Sketch map of a part of the Granite (City) area, showing distribution of granite and location of quarries.

ed by weathering and are of very common occurence, but areas of bare, unfractured rock are found. Over much of the Reformatory granite area, which is the most southern of the group, soil, mantle rock, and vegetation are lacking.

The hills composed of Headquarters granite rise abruptly from the plains, but their steep slopes are covered with subangular boulders usually less than 10 feet in diameter, and bare surfaces are rare.

Drainage in the granite areas is accomplished through short canyon-like valleys which soon reach the bordering plains and widen out into open valleys with low gradients. Much of this drainage is controlled by the strong east-west and north-south fractures.

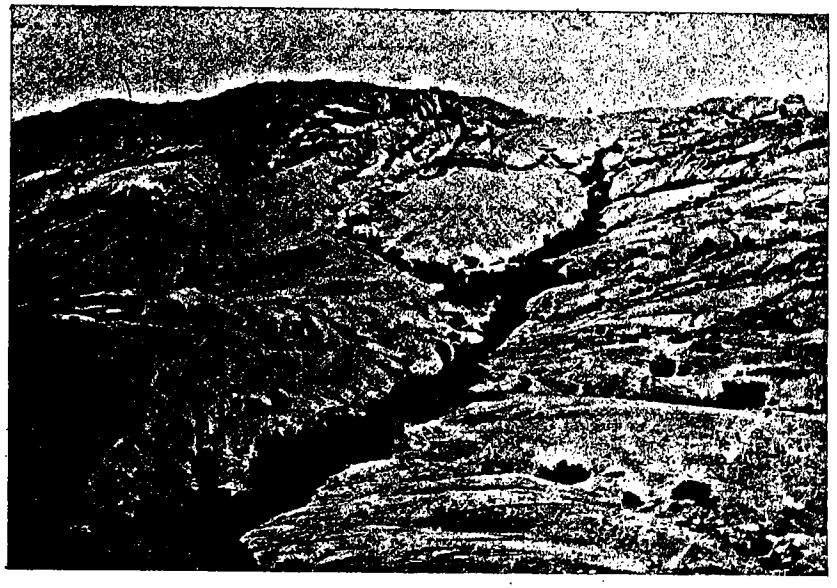
GEOLOGY.

There are two main types of granite in this area. The earlier, called the Headquarters granite, is a fine-grained brownish-red granite. The later, known as the Reformatory granite, is a medium-grained flesh-red granite. The large area of this granite to the east of Headquarters Mountain appears to be a batholitic mass intruded into the earlier granite. At the west end of this area the Reformatory granite includes angular and subangular masses of the Headquarters granite ranging in size from a few inches to several feet across. In the hills to the northwest the earlier granite becomes relatively more important and in a part of the area makes up the major portion of the granite mass. In such cases the Reformatory granite takes the part of a binding or cementing material for the fragments of Headquarters granite.

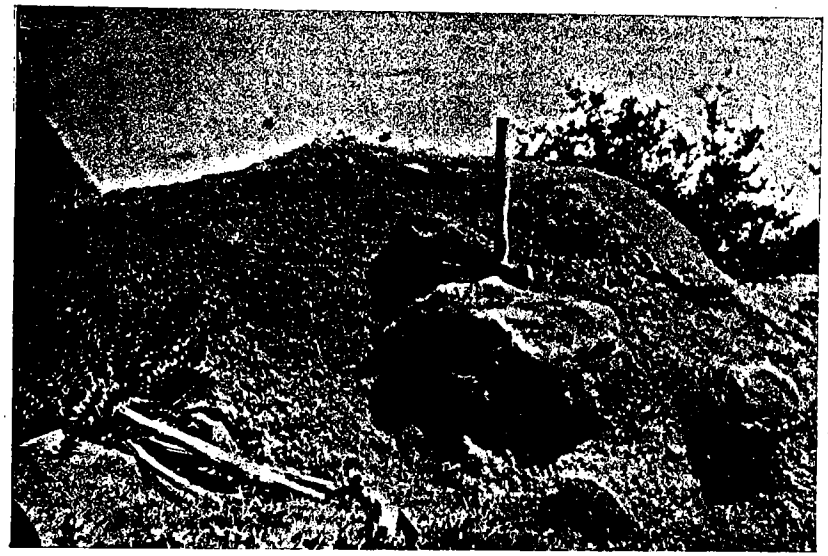
Following the solidification of the Reformatory granite there were at least two periods of fracturing and intrusion of dikes. During the earlier period several small aplite dikes and quartz veins were intruded. The most persistent are shown on the map. They are never much over one foot wide, but vary greatly in thickness from place to place, often branching and uniting. The dike rock consists chiefly of orthoclase, quartz, and albite, with a small amount of magnetite and a trace of an altered ferro-magnesian mineral, probably hornblende. Following the intrusion of aplite dikes there was fracturing and intrusion of riebeckite-aegirite granite dikes. These dikes strike in a northwest-southeast direction and dip northeast at 25° to 40°. Like the aplite dikes they vary greatly in width, but are never over 2 feet and are usually less than 1 foot. Only one persistent dike of this character was found. Its course is shown on the map. In the west-central part of section 23 it divides and forms 8 parallel dikelets, varying from 3 to 16 inches in thickness. This is a fine-grained gray granite composed of feldspar, quartz, riebeckite, aegirite, and magnetite.

The Reformatory granite is cut by widely spaced, strong vertical joint systems bearing approximately north-south, east-west,

PLATE VI.



A. GRANITE AREAS NORTHWEST OF GRANITE, SHOWING DRAINAGE CONTROLLED BY JOINTS.



B. GRANITE HILL WEST OF GRANITE, SHOWING BOULDERS OF FINE-GRAINED HEADQUARTERS GRANITE INCLUDED IN THE COARSE REFORMATORY GRANITE.

PLATE VII-A.

RIEBECKITE-AEGIRITE GRANITE DIKES CUTTING THE REFORMATORY GRANITE NEAR GRANITE.

northeast-southwest, and northwest-southeast. The sheet joints are best developed here of anywhere in the Wichita Mountains.

REFORMATORY GRANITE.

CHARACTER.

The fresh, unaltered Reformatory granite in this area is all essentially of the same character. At some of the quarries altered rock is used, which has given the impression that there are two types of rock here. The fresh granite is an even, medium-grained flesh-red granite, which, megascopically, reveals flesh-colored feldspar, colorless to slightly smoky quartz and clusters of greenish-black hornblende and magnetite.

By microscopic examination of 35 thin sections of the Reformatory granite, selected from 6 different quarries, it was found that this granite is composed chiefly of orthoclase, microperthite, albite, microcline, quartz, hornblende, and magnetite. Microscopic hematite, zircon, titanite, fluorite, sericite, kaolin, limonite, chlorite, calcite, and biotite amount to less than one per cent. The sericite,

kaolin, limonite, chlorite, calcite, and biotite are all secondary, and the others are always primary with the exception of fluorite which may be primary in some cases, but is undoubtedly secondary in others. Estimates made by the Rosiwal method applied to a polished surface of 6 square inches showed that this granite contains 60 per cent feldspar, 33 per cent quartz, 5.5 per cent hornblende, and 1.5 per cent magnetite.

Usually 1 to 2 per cent of the feldspar present is albite and microcline and the remainder microperthite and orthoclase. The microperthite individuals are irregular to prismoidal in form and show two perfect cleavage surfaces. The flesh-red color is found to be due to disseminated microscopic particles of red hematite. The hematite dust is sometimes evenly distributed throughout the

PLATE VII-B.

THOS. L. EGGLESTON'S GRANITE QUARRY AT GRANITE, SHOWING STRONG, REGULARLY SPACED FRACTURES DIPPING TOWARD THE FACE OF THE QUARRY.

feldspar, but it is also often concentrated along cleavage planes giving the feldspar a banded appearance. Often the hematite is found in streaks and blotches scattered through the feldspar, probably as a secondary deposit. In the more altered rock there is much red hematite in the cracks and around the feldspar, giving it a deep reddish hue.

The quartz is found in irregular and rounded grains, which are usually colorless or faintly smoky in color. In cases where secondary deposition of hematite has taken place the quartz may be coated with a film of this mineral giving it a brilliant red color

The hornblende is greenish-black and occurs in rough prismatic crystals. It is usually altered badly, forming chlorite, iron oxide, and quartz.

Magnetite in grains of rounded and subangular form are often found associated with groups of hornblende anhedra. Occasionally the magnetite is found imbedded in the feldspar and isolated from the hornblende. The zircon is almost invariably associated with the hornblende-magnetite clusters. Titanite is always associated with the magnetite and in some cases is probably derived from it. It is not uncommon to find it as a fringe around the magnetite grains. Fluorite is most often associated with the magnetite-hornblende groups, but has been found entirely surrounded by feldspar.

The sericite, kaolin, calcite, and chlorite are abundant only in the altered surface rock. The sericite and kaolin when developed in the Reformatory granite give it a pale pink color. Much of the pink granite put on the market from this region is the altered rock in which the feldspars have been partly altered to sericite and kaolin. The hornblende is often partly altered to chlorite but the quantity of hornblende is not sufficient to alter the color of the granite. Later, as the chlorite breaks down, producing limonite, the resulting yellow stain is sufficient to discolor the rock.

Chemical analyses of the Reformatory granite are shown on page 21 of this report.

In texture the Reformatory granite is an even, medium-grained rock. The feldspar individuals range from about 2 to 15 mm. average diameter, and in a broad way are evenly distributed throughout the rock. The quartz ranges from .05 to 10 mm. in average diameter for individual grains. Though the quartz and feldspar are evenly distributed in this granite, the quartz grains have a characteristic radiate grouping, which is clearly shown on the hammered face. This granite because of its equidimensional mineral constituents and its content of quartz is a rather brittle granite. Small pieces when given a sharp blow with a hammer break and often shatter to fragments because of the separation of the individual minerals. Cubes heated to 1000° F. and cooled slowly were distinctly weakened so that a few light blows caused them to break up into incoherent masses of quartz and feldspar. The color was also changed to a dull brick-red. When heated to 1000° F. and cooled suddenly by immersion in cold water, the cube was greatly weakened and changed to a dull brick-red color.

When heated to redness for 10 minutes and permitted to cool slowly, its strength is almost entirely gone.

Cubes tested in the University of Oklahoma crushing machine showed a crushing strength ranging from 11,400 to 16,800 pounds per square inch. The transverse crushing strength or modulus of rupture was determined for one prism and found to be 2749 pounds per square inch.

The apparent specific gravity was found to be 2.628, with the true specific gravity of 2.633. The pore space was found to be 0.673 per cent.

The fresh stone takes a brilliant polish. The altered magnetite-hornblende groups usually give a slight irregularity of surface. When the altered stone is encountered this difficulty will be partly obviated. The hammered face shows a decided contrast to the polished face, thus permitting satisfactory lettering or carving. Workmen report it a satisfactory stone to cut and dress.

STRUCTURE.

Joints are strong and widely spaced, and cut the rock into rectangular wedge-shaped masses. The vertical joints are spaced from 3 to 30 feet apart, with an average of about 10 or 12 feet. The sheet joints are spaced from 3 to 30 feet apart, with an average of about 10 feet. The sheet joints usually diverge and converge rather regularly so that the thick portion of one sheet lies over the thin portion of the ones below. In most cases the sheet joints dip from the granite hills.

Rift and grain are poorly developed but are observed and followed at the Thos. L. Eggleston quarry. This granite splits with considerable regularity and rather even surfaces so that dressing for plane surfaces requires no great amount of labor.

The weathering of the Reformatory granite is largely accomplished by changes of temperature and by chemical decomposition. Its course, even-grained texture seems to favor physical disintegration. The usual method is for slabs of 1 to 4 inches in thickness to exfoliate and then to break down into a mass of feldspar and quartz crystals, which sometimes accumulate at the bases of steep slopes. This material is used in macadamising the streets of Granite. Plate VIII shows examples of weathering by this method. Weathering by chemical decay is best shown wherever by chance a depression is formed which holds water for a short time. Such basins are often greatly deepened and enlarged, apparently largely by this process. (See Pl. VIII-B.)

HEADQUARTERS GRANITE.

CHARACTER.

Unaltered samples of Headquarters granite show it to be a fine-grained, often porphyritic, brownish-red granite which mega-

scopically reveals dark flesh-colored to brownish cleavage surfaces of feldspar, rounded grains of colorless, yellowish, or slightly smoky quartz, and small specks of a black mineral which on microscopic examination proves to be biotite or hornblende.

Microscopic examination shows that the predominating type of this granite is composed of the following primary minerals named in the order of abundance: Microperthite and orthoclase, quartz, biotite, albite, oligoclase, hornblende, magnetite, and hematite, with minute quantities of microscopic zircon, titanite and fluorite. Estimates by the Rosiwal method on a thin section which seemed to be an average for the Headquarters granite showed the following mineral percentages: Microperthite and orthoclase, 57.6; quartz, 33; biotite, 5.2; albite-oligoclase, 3.7; hornblende, .30; and magnetite .20. This is probably a little below the average in magnetite and a little above the average for biotite, but it represents, as well as any single specimen can, the mineral composition of this rock in an unaltered condition. The hematite is present in fine dust-like particles disseminated through the feldspars and its quantity cannot be estimated. More or less sericite, kaolin, hematite, muscovite, and chlorite have been developed in the process of alteration. This granite alters very slowly and the stone which has been put on the market shows very little of the secondary minerals.

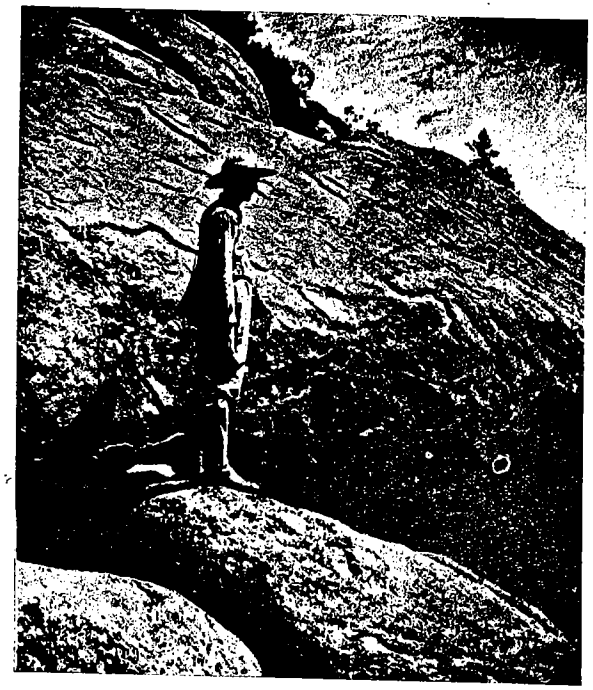
The orthoclase and microperthite which constitute the chief part of the feldspar of this granite are usually in graphic intergrowth with quartz. When not in this condition their grains are roughly prismatic in form and stand out like phenocrysts in the graphic intergrowth.

The quartz, like the feldspar, consists of both individual grains and graphic intergrowth with microperthite and orthoclase. It is clear or slightly smoky in color and, except the larger individuals, is not readily observed without a hand lens. Under the microscope it is observed that the larger individuals are rounded grains, while the individuals of the intergrowth take various forms common to such intergrowths.

Some of the albite is not intergrown with quartz and constitutes a part of the larger feldspar crystals. It shows the albite twinning striations and in some cases is twinned according to the carlsbad and pericline laws. The biotite is found as flakes and thin tabular masses of usually not over a millimeter in greatest width. It is dark-brown to black and strongly pleochroic. The magnetite is invariably in small rounded grains a fraction of a millimeter in diameter. They are evenly distributed through the rock.

This may be classed as a fine-grained, inequigranular granite.

PLATE VIII.



A. LARGE BOULDERS ON THE SLOPE OF MOUNT SCOTT, SHOWING EXFOLIATE WEATHERING OF THE GRANITE.

B. BASIN IN THE REFORMATORY GRANITE AT GRANITE, SHOWING EXAMPLE OF WEATHERING CHIEFLY BY CHEMICAL DECAY.

The large individuals of quartz and feldspar are usually not over 1.5 mm. in diameter, but occasionally they are as much as 4 mm.

In certain phases of this granite there is a distinct porphyritic texture displayed, 1 to 5 per cent of the quartz and feldspar individuals being distinctly larger than all the remainder. In other phases it is one entire mass of graphic intergrowth without any of the larger individuals. Still another phase shows a very fine-grained granite, not intergrown, with only here and there a phenocryst of feldspar 2 or more millimeters long. The most common type, however, and the only one utilized commercially, consists chiefly of a graphic intergrowth of quartz and feldspar, making up perhaps 80 per cent of the rock, and the remainder of individual grains of feldspar, quartz, and biotite of varying sizes ranging up to 4 or 5 mm. in maximum diameter.

This granite breaks with a conchoidal fracture. It is medium brittle, has a true specific gravity of 2.630 and an apparent specific gravity of 2.627. Its porosity is 0.305. The one cube tested showed a crushing strength in excess of 19,324 pounds per square inch. The machine limit was reached before the cube was crushed.

Cubes when heated to about 1000° F. and cooled slowly were weakened slightly on the edges, and the color changed to a dull flesh-red. When heated to the same temperature and cooled suddenly by immersion in cold water the cubes appeared firm, but a few slight blows showed that they were greatly weakened. They broke with a rough granular surface. No sharp edges appeared. The sparkle was all gone and they assumed a dull-pinkish-red color. When heated to a red heat for five minutes the cubes were greatly weakened but still retained their form and a considerable part of their strength. This granite stands the heat test better than the Reformatory granite.

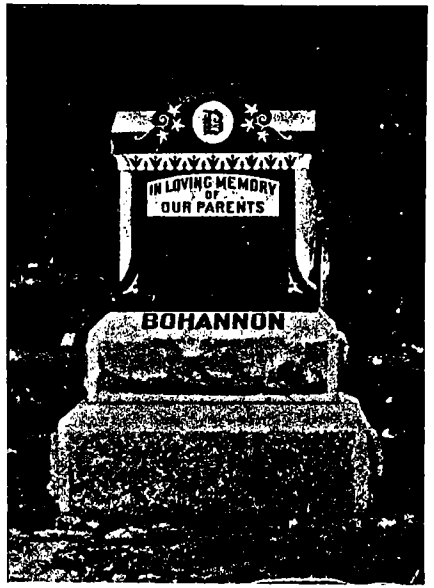
The Headquarters granite takes a good polish, and the polished surface is in good contrast to the hammered face so that lettering shows up well. (See Pl. IX-A.) It is not a difficult stone to polish.

Weathering is accomplished chiefly by chemical decay; therefore the weathered surfaces of the exposed boulders are smooth and do not exfoliate. It weathers less rapidly than the Reformatory granite.

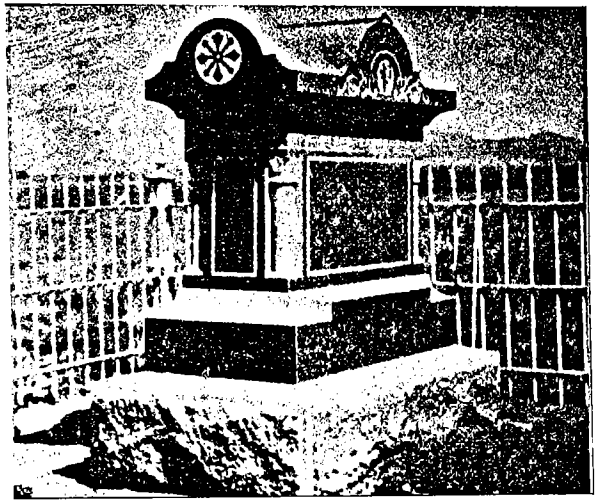
STRUCTURE.

The Headquarters granite is cut by many systems of irregular fractures so that it generally is unfit for quarrying where large dimension stone is required. In the NW. 1-4 sec. 16, and the SW. 1-4 sec. 9, T. 6 N., R. 21 W., there are considerable masses of this rock with fractures spaced from 4 to 6 feet apart. Intrusions of the Reformatory granite are so intimately mingled with this gra-

PLATE IX.



A. MONUMENT OF HEADQUARTERS GRANITE.



B. MONUMENT OF THE REFORMATORY GRANITE IN THE CEMETERY NORTH OF INDIAHOMA. THIS SHOWS THE CONTRAST BETWEEN THE POLISHED AND HAMMERED SURFACES OF THIS GRANITE.

nite that it is impossible to find an area composed wholly of Headquarters granite that is of suitable size for a quarry site.

DESCRIPTION OF QUARRIES.

RUGGLES' QUARRIES.

The Ruggles Company has opened up quarries at two places about a mile northwest of the town of Granite. One of these openings, now abandoned, was in the Headquarters granite, and the other in the Reformatory granite. (See fig. 2.)

The Ruggles quarry in the Reformatory granite is located in the SW. 1-4 NW. 1-4 sec. 27, T. 6 N., R. 21 W. There are here two openings 200 feet apart. At the west opening a face 100 feet long and 30 feet high has been made. The opening has been sunk 14 feet below the level working surface. The rock here is all somewhat altered. It is cut by two vertical joint systems spaced from 6 to 20 feet apart and bearing N. 25° to 30° E., and N. 60° to 70° W. There is also a poorly developed fracture plane dipping 25° S. At the east opening a face 30 feet high and 50 feet long has been formed. Jointing is much the same as at the west opening. The discolored sap rock has been the chief product so far. At the time of visiting this quarry the deeper colored, unaltered rock was just being reached toward the center of a large unfractured block. Black segregations 3 to 5 inches in diameter were observed but they are not sufficiently abundant to depreciate the value of the quarry.

The equipment here consists of one derrick, one steam engine, one air compressor, one stone crusher, a work shed, and a blacksmith shop.

The quarry is reached by a three-fourths mile spur of the Chicago, Rock Island & Pacific Railway, and stone is loaded directly on the cars for shipment.

This quarry was opened up in 1905 but had not been operated from September, 1910 to November, 1915.

The product of the quarry consisted of dimension stone, monuments, columns, rough stone for ballast, paving blocks, and crushed stone for concrete and paving.

The character and quality is the usual type of the Reformatory granite, which is a suitable stone for monuments, columns, fountains, and dimension stone. It is too coarse and brittle for first class paving blocks, or crushed stone.

The Ruggles Company has an opening in the Headquarters granite located near the southeast corner of the NE. 1-4 sec. 28, T. 6 N., R. 21 W. A projecting point of the mountain was formerly reached by a spur of the railroad, but the track has been removed and the quarry abandoned since 1910.

The opening was along a face 50 feet high and 80 feet long. The rock here is the average red, fine-grained Headquarters granite. It is intensely fractured and locally cut by dikes of Reformatory granite so that few blocks as great as 5 feet in diameter are left.

This stone was used by the Chicago, Rock Island & Pacific Railway for ballast, and to a small extent by the Ruggles Company for monumental work. It was dressed and polished at the main Ruggles quarry. At present there is no equipment at this opening.

SOUTHWESTERN GRANITE COMPANY'S QUARRY.

The Southwestern Granite Company, with headquarters at Michigan City, Indiana, opened up a quarry on the south slope of the granite hill in the S. 1-2 of SW. 1-4 sec. 2, T. 6 N., R. 21 W. The opening is approximately 65 feet deep and 100 feet in diameter cut into the side of the hill which slopes south at about 15°.

The chief structural features of this quarry are the strong sheet joints which dip to the south at about 15°. These sheet joints cut a large part of the granite in this quarry into large southward dipping lenses of varying thickness. The surface sheet at its maximum is 14 feet in thickness. It thins to 7 feet at a distance of 100 feet down the dip, and at 100 feet up the dip it thins to 9 feet. Here it begins to thicken again and then disappears beneath the overlying sheets. The next two sheets are somewhat thinner, while the fourth is about 14 feet thick. At the west side of the quarry the granite is cut by four strong joint planes striking N. 30° E., and dipping 20° to the east. Along these joints the granite is badly weathered and discolored.

The granite splits with fairly plane surfaces. A "cleavage" or rift is recognized, which strikes N. 20° W. and dips 85° W. This is termed the "free way" by the quarrymen. The grain strikes east-west and is called the "cleaving way." The stone does not split readily parallel to the sheet surfaces.

This is the normal type of Reformatory granite composed mainly of feldspar, quartz, hornblende, and magnetite.

The freshest, and therefore the most satisfactory Reformatory granite yet put on the market came from this quarry. The color is of a deeper, more uniform flesh-red than the more altered rock. It works well under the hammer and chisel, takes an excellent polish, and exhibits a good contrast between polished and hammered faces. A few black segregations are present. Blocks of any desired size may be procured. This is a desirable stone for monuments, columns, fountains, and dimension stone. It is not so satisfactory for road material or paving blocks because of its brittleness.

The equipment consists of one 40-horsepower gasoline engine, three air compressors yielding 600 cubic feet of air per minute, and two derricks. Blasting was done with black powder.

Transportation was by cartage to the railroad one mile. Near-

ly all the product was shipped to Michigan City, Ind., where is was dressed and polished by convict labor.

The quarry was opened in 1905, but it has been in operation only about 5 years since it started. In 1912, 10 men were employed. It has been shut down since early in 1914.

The Post Office and the Odd Fellows Hall at Granite are constructed partly of this granite. It was also used in the Abraham Lincoln monument at Chicago.

THOS. L. EGGLESTON'S QUARRY.

This quarry is the property formerly owned by the Oklahoma Rose Granite Company. It was taken over by Thomas L. Eggleston in 1915, but had not been operated for some time previous to the transfer. There are two openings about 600 feet apart in the S. 1-2 NE. 1-4 sec. 26, T. 6 N., R. 21 W. Opening No. 1 lies at the north end of Main Street of the town of Granite.Opening No. 2 is about 600 feet northwest of No. 1. All the equipment except a derrick is located at No. 1. This quarry is opened up on the south slope of a hill 300 feet high. The quarry face which runs east-west is about 150 feet long and 60 feet high at the highest point At the base the quarry has been extended into the hill 50 to 60 feet. The bottom of the opening is about on a level with the base of the hill where the shops are situated.

The granite is cut by a system of strong joints striking N 80° W., and dipping about 65° S. Another system a little less persistent, and vertical, strikes at right angles to the former. A third system of joints dips at an angle of 23°N., 50° E. (See Pl. VII-B.) Besides these principal fracture systems there are two persistent fractures at the east end of the quarry that strike N. 42° E. and dip NW. at 80°. The east-west vertical joints are spaced 2 to 20 feet apart with an average of about 6 feet. The north-south joints are spaced 8 to 25 feet apart, seldom less than 15 feet, and the third set dipping N. 23° are spaced 20 to 22 feet apart. The jointing at this quarry is unusually favorable for quarrying. The joint planes dipping gently to the north afford excellent benches on which the quarrymen work. Blocks of any dimensions that can be handled may be quarried here. The jointing is so spaced that there is but little waste in cutting. No stripping is required. In a rift striking N. 60° W., vertical and a horizontal grain are observed and usually followed.

One riebeckite-aegirite granite dike averaging about one inch thick and dipping N. 20° cuts the quarry face from east to west. There are also a number of other dikes one-tenth to one inch thick, which dip north at about 20°. They are inconstant both in thickness and dip. They are somewhat darker than the granite, but are composed chiefly of the same minerals.

Objectionable segregations, both of the fine-grained brown granite similar to the dikes, and also of a fine-grained black rock are present, but only in a small amount. They range in size from a mere speck up to a foot or more in diameter. The brown segregations, besides being very fine-grained, contain more hornblende and biotite than the normal granite. The black segregations are also very fine-grained and differ from the normal granite in containing much more magnetite and hornblende.

The granite is the normal Reformatory granite. Away from the surface and joint exposures it is reasonably fresh. Weathering in the upper part of the quarry is observable to a depth of 1 to 6 inches along the joint planes, and in favorable localities to greater depth.

This stone takes a good polish, works well under the hammer. and chisel, and letters well on polished surfaces. It is suitable for monuments, columns, and dimension stone, but not of the best quality for paving blocks and road material because of its brittleness.

The equipment consists of one steam boiler, one 35-horsepower double drum steam hoisting engine, one 12-horsepower and one 26-horsepower gasoline engine, two air compressors with combined capacity of 180 cubit feet per minute, one turning lathe for columns, one polishing lathe for columns, four polishing machines. two surfacing machines, one 10-ton traveler, two tripod drills operated by steam, nine plug drills operated by air, three guy derricks at the quarry, and one stiff leg derrick at the station for loading Transportation is by cartage one-forth mile to the railroad.

At present the equipment is in charge of Baxter L. Smith, who is putting on the market some monumental stone.

Seventy-five per cent of the output has been building stone, the remainder being monumental stone and paving blocks. Among the buildings which have been partly or wholly constructed of this stone may be mentioned the folowing: First story of Butler Bros. store, Dallas, Texas; Street Railway Terminal Building, Oklahoma City, Oklahoma; Court Houses at Altus, Enid, and Muskogee; Bliss Building at Tulsa; Masonic Temple at Guthrie, and drinking fountain at Hobart. Much stone also goes to Kansas and Iowa for construction and monumental work. Kansas City uses paving blocks from this quarry.

Opening No. 2, about 600 feet to the northwest, is on a west slope of about 40°. The opening is 100 feet long and 25 feet high. The rock is here cut by sheet joints into large flat-lying lenses having a maximum thickness of 16 feet. Strong joints strike N. 60° W., and north-south. One large sheet joint dips 25° W.

The stone here is fresh Reformatory granite. A few segrega-

tions are present. A small granite dike about 1 inch thick cuts the quarry face.

The equipment consists of a derrick only. Transportation is by cartage one-half mile to the railroad.

OKLAHOMA GRANITE COMPANY'S QUARRY.

The Bennett Brothers of Chicago compose this company and own the property at the point of the mountain in the southeast part of the NW. 1-4 sec 26, T. 6 N., R. 21 W. For the last year the Pellow Brothers have held a lease on the quarry and have taken out monumental and finished building stone. The opening shows a face 100 feet long and 20 feet high. The granite is cut by a set of fractures striking N. 80° W., and another set N. 15° W., both nearly vertical. These joints are spaced 6 to 20 feet apart and cut the stone into favorably sized blocks for quarrying. No sheet joints were observed. This is the normal Reformatory granite. The equipment remaining consists of sheds, one steam boiler, two derricks, one gasoline engine of 25-horsepower, one air compressor with capacity of 130 feet per minute, one polisher, drills, and carving tools.

GARDNER'S QUARRY.

This quarry has been operated intermittently by local quarrymen. The opening is near the southeast corner of sec. 22, T. 6 N., R. 21 W., about one mile northwest of Granite. The property is owned by M. Gardner of Charlestown, West Virginia. The excavation is 40 by 20 feet long and 12 feet deep. Three sets of strong, nearly vertical joint planes cut the granite into rectangular blocks 10 feet square. One set strikes N. 20° E., another N. 55° E., and the third S. 18° E.

Sheet joints approximately parallel to the westward sloping hill dip 20° W. The rock is normal Reformatory granite. The bottom of the opening is now down to fairly fresh rock.

The equipment consists of a gasoline engine, air compressors, one derrick and windlass, and sheds for polishing and cutting. None of this equipment has been used recently, except the windlass and derrick which are operated by horse power. Transportation was by cartage. The stone was used chiefly for building purposes.

REFORMATORY QUARRY.

This quarry is located one mile southeast of the town of Granite, near the west line of the NW. 1-4 sec. 31, T. 6 N., R. 20 W., on property owned by the State of Oklahoma. It is operated by the State with convict labor from the Reformatory located at this place.

The quarry is opened at the base of a southward sloping hill, and stone is secured at four different points a short distance apart.

The total length of quarry face now worked is about 400 feet. The present maximum height of the quarry face is about 30 feet. The largest opening has been extended into the hill about 75 feet. The rock is cut by joint planes, very irregular in direction, and spaced 1 to 6 feet apart. The most persistent set slopes irregularly to the south, with an average dip of 15° to 20°. The numerous irregular fractures cut the quarry face so that much of the stone is secured in small angular blocks, though some blocks as much as 5 by 5 by 15 feet have been secured.

This is doubtless a part of the same granite mass as that at the quarries north and west of the town of Granite, but it differs from the usual Reformatory granite both physically and chemically. At present there are two fairly distinct varieties of granite quarried, one light and the other dark colored. The lighter colored variety is essentially like the normal Reformatory granite, except the feldspar is largely gray and is tinged with red only along fractures. The quartz, which is less abundant than in some of the Reformatory granite, is considerably discolored with hematite. The hornblende and magnetite are altered and occur rather sparingly in irregular bunches. When observed at a distance of a foot or more the rock in the rough appears medium-gray tinged with violet and specked with black.

The darker colored variety is much finer-grained than the other, and the feldspar and quartz are more colored with red and violet and the magnetite and black hornblende are much more abundant. The quartz is more evenly distributed through this rock than it is in the normal Reformatory granite. When observed at a distance of 2 feet or more this variety presents a violet-red surface specked with black and light gray. A polished sample of rock from this quarry, less highly colored with iron than the average, appears distinctly speckled. The darker colored quartz and black hornblende and magnetite are sharply in contrast with the light gray and slightly pinkish feldspar. It polishes with a smooth brilliant surface and would make a handsome monumental stone.

The different varieties at this quarry appear to be merely local differentiation products of one granite body. Their contact is not sharp, though the gradation from one to the other takes place in the space of a few inches. At present the quarry face is made up more largely of the coarser, lighter variety. The darker colored variety is found only in irregular roughly vertical zones 6 to 15 feet wide.

As the quarry is extended farther into the hill different shades of rock will probably be found. The red coloration along fractures will diminish, but it is likely that the feldspar will be uniformly darker colored. It is believed from observations in the vicinity of

the quarry that the coarser-grained variety will continue to predominate and may entirely replace the other.

Both varieties of granite quarried here make handsome building or monumental stone. The color in the rough is especially desirable for large buildings. Though no tests have been made, the composition and texture indicate a strong, durable stone.

As a monumental stone it is decidedly different from any other variety yet put on the market from Oklahoma. It finishes with a smooth surface which takes a superior polish. The darker colored variety will letter well.

The output from this quarry has been used in the construction of the State Buildings at the Reformatory as well as to supply the trade in north Texas, Oklahoma, and southern Kansas. This quarry puts out crushed stone, rip-rap and rubble, dimension and monumental stone.

The equipment consist of one air compressor of 800 cubic feet capacity, one surfacer, one polisher, one granite saw, one crusher with 200 cubic yards daily capacity, drills operated by air, and five derricks. All machinery is run by electric power supplied from a central station. One hundred fifteen men are regularly employed in the quarry, which is reached by one half mile spur from the Chicago, Rock Island & Pacific Railway.

NEW MONTELLO GRANITE COMPANY'S QUARRY.

During the summer of 1915 the New Montello Granite Company leased 4 acres of quarry land in the SW. 1-4 of sec. 15, T. 6 N., R. 21 W., situated about 2 miles northwest of the town of Granite. This company has been operating continuously and is putting on the market rough stone for monumental work. Charles J. F. Kraft is the local manager of the quarry. The equipment consist of one gas engine, one derrick, one air compressor, and drills.

The granite quarried here is the usual medium-grained Headquarters granite. It takes a beautiful polish and very closely resembles the Montello, Wisconsin granite. Without a direct comparison, monument dealers would not recognize any difference between this and the Montello, Wisconsin granite.

Although the granite at this place is considerably fractured, the spacing is fairly regular and blocks of sufficient size for ordinary monumental work can easily be secured. The superior finish and excellent lettering qualities should make this one of the most popular monumental granites secured in the State.

LUGERT AREA.

TOPOGRAPHY.

All of the granite in the vicinity of Lugert, a small town on the Kansas City, Mexico and Orient Railway, in the southwest corner of Kiowa County, and also the isolated outcrops stretching 10 miles or more to the northeast are included in the discussion of the Lugert area. These outcrops for the most part consist of rounded or dome-like hills of granite but are covered with large boulders of badly fractured granite. These hills rise from the level Redbeds plains to heights varying from 5 to 600 feet. The greatest height is reached on King Mountain and Soldier Mountain. (See map Pl. I.) Mount Tepee rises to almost 600 feet, while Quartz Mountain has a nearly equal altitude. As a rule the granite hills are too steep for soil to accumulate, and hence are essentially de-

PLATE X.

ALLUVIAL CONE EAST OF LUGERT. THE AREA BARREN OF VEGETATION IS COMPOSED OF GRAVEL AND SMALL BOULDERS.

void of vegetation. In part, the slopes are gentle enough for soil to accumulate in the depressions between the boulders, so that there is found a partial covering of grass. These hills all have small summit areas excepting the larger outcrops to the south and southeast of Lugert, and lying north of Red River. Here, at an altitude of near 450 feet above the Redbeds plains there are considerable areas that are gently sloping or flat and grass covered. King and Soldier mountains rise with steep rocky slopes 175 feet higher. These flat areas are undoubtedly remnants of a post Redbeds peneplain. Subsequent to the peneplanation, streams descending from this flat to the plain below deposited their loads at

the base of the steep slopes forming, in a number of instances, immense alluvial cones. (See Pl. X.) Another interesting feature of this area are the ancient beach marks developed previous to the deposition of the Redbeds. (See Pl. XI.) In a few places, notably in the SE. 1-4 sec. 26, T. 5 N., R. 20 W., there are large areas of barren, unfractured granite similar to those in the Granite City area.

All the drainage of this granite area takes place through rather steep canyon-like valleys with beds and slopes strewn with boulders. These valleys are all necessarily short for, as the margins of the granite areas are reached, the valleys give place to a shallow ditch meandering across the level plain to Red River or its tributaries.

GEOLOGY.

There are two chief types of granite in this area: One a portion of the Reformatory granite of the Granite area, similar in character to it; the other a younger, finer-grained red granite, which varies locally in texture and mineral content and which has been termed the Lugert granite. The latter granite is probably part of the same mass as the granite in the Mount Scott and Navajoe Mountain area farther east. The Lugert granite includes boulders of a finer red granite, boulders of a dark gray granite, and in places masses of gabbro. It is cut by a few fine-grained granite and diorite dikes. A few large lenses of quartz have been found in the Quartz Mountain area.

The granite areas in the western portion of secs. 16, 17, and 21, T. 5 N., R. 20 W., are but little fractured, and large surfaces of solid granite are exposed. The remainder of the area is, in the main, much more intensely fractured. The most intense fracturing occurs in zones which often leave considerable areas with fractures spaced 10, 15, or even 25 feet apart.

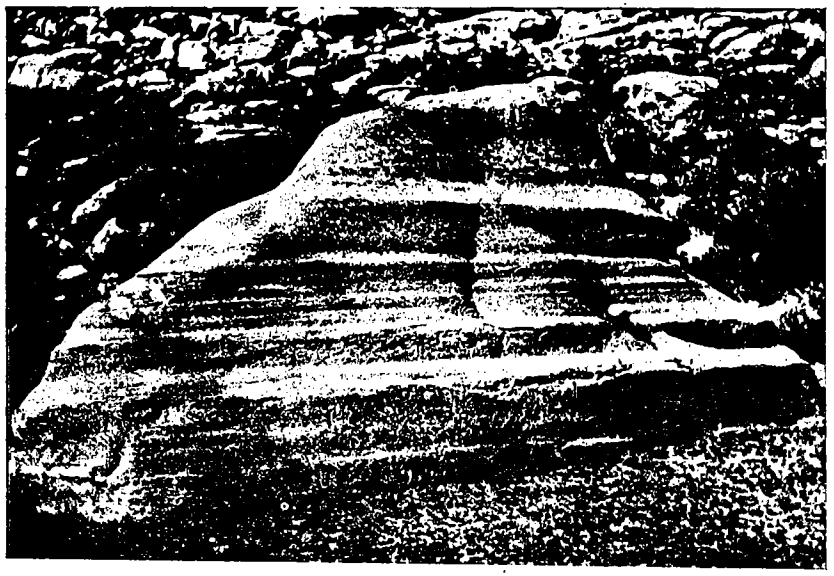
TYPES OF GRANITE.

REFORMATORY GRANITE.

The area of Reformatory granite is indicated on the map, (Pl. I.) This granite is designated Reformatory granite because the texture, mineral compositon, and physical properties, so far as they could be determined in the main, are the same as the Reformatory granite at the town of Granite.

In the northwestern part of the Lugert area a sharp, definite contact can be traced between the Reformatory granite and the Lugert granite. In this area the Reformatory granite when fresh is identical with the Reforamtory granite at the town of Granite. It consists of flesh-red feldspar, quartz, green, and brown hornblende, magnetite, and traces of zircon. The feldspar, which predominates, owes its deep flesh-red color to disseminated hematite dust. The quartz, which is second in abundance, occurs in round-

PLATE XI.



A. A LARGE BOULDER TWO MILES SOUTH OF LUGERT, SHOWING PARALLEL GROOVES ENCIRCLING THE BOULDER, PROBABLY DUE TO WAVE ACTION.

B. GRANITE CLIFF WEST OF LUGERT, SHOWING ANCIENT BEACH MARKS.

ed grains which are colorless or slightly smoky. The hornblende is found in clusters asociated with magnetite. In secs. 20 and 21, T. 5 N., R. 20 W., the physical properties and mineral composition are essentially the same as farther northwest, but the color changes to a gray with occasionally a pinkish hue. The feldspars are also more fractured.

LUGERT GRANITE.

The prevailing type of this granite is fine, subequigranular to equigranular red granite composed dominantly of feldspar and quartz with subordinate amounts of augite, hornblende, magnetite, biotite, and microscopic hematite, zircon, and titanite.

The feldspar is chiefly orthoclase and microperthite but occasionally 1 or 2 per cent of plagioclase is present. Probably about 60 per cent of the rock is feldspar. The amount of quartz present varies somewhat with the texture, but averages about 30 per cent. The hornblende, biotite, and magnetite occur in their usual forms and seldom attain a combined total of over 5 per cent.

In texture the Lugert granite varies considerably. The prevailing type, however, is a fine-grained intergrowth of quartz and microperthite. In some places this graphic intergrowth constitutes almost the entire rock, while in a few places it is found where the quartz and feldspar are not intergrown at all. An average sample shows the non-intergrown feldspars seldom to exceed 2 mm. in average diameter, and the quartz grains seldom exceed 1 mm. in average diameter, the average grain of the entire non-intergrown portion being about 1 mm.

There is associated with the usual type of Lugert granite a finer grained phase which contains largely biotite in the place of hornblende. This finer grained phase is sometimes seen as included angular boulders and masses in the typical Lugert granite. Because of its limited occurrence and its similarity to the average type of Lugent granite it was not deemed practicable to attempt to map it separately.

Another variation from the usual type of Lugert granite is found in Little Bow Mountain in sec. 32, T. 5 N., R. 18 W. Besides some included boulders of early gabbro this mountain consists of two types of granite. The older of the two is a fine-grained, medium dark-gray granite consisting of microperthite, orthoclase, quartz, plagioclase, hornblende, pyroxene, and biotite. The plagioclase makes up 20 per cent or more of the rock, while there are 4 to 6 per cent each of the hornblende and biotite. It breaks easily, but is fresh and unaltered near the surface. It is found in large boulders from 6 to 20 feet in diameter on the northwest slope of Little Bow Mountain and reaches a height of about 200 feet, or nearly to the top of the mountain. On the northeast slope of the

mountain it is found as included angular boulders and fractured masses cut by pink granite dikes. The remainder of the hill is composed of a type of granite much like the normal Lugert granite, but slightly richer in albite, hornblende, and biotite. It will also average a little coarser in grain. The fractures are, in places, widely spaced, cutting the granite into large rectangular boulders suitable for quarrying.

QUARRY SITES.

No granite has been quarried in this entire area, though there are several accessible quarry sites which would supply good commercial grades of granite. (See Pl. I.) Suitable sites for quarrying the coarser grained Reformatory granite may be found at various points in secs. 16, 17, 18, 20, and 21, T. 5 N., R. 20 W. The only difficulty is that transportation to shipping point is not satisfactory. There are also large, unfractured masses of the fine red granite in secs. 25 and 26, T. 5 N., R. 20 W., and in secs. 2 and 15, T. 5 N., R. 19 W. In secs. 25 and 26 transportation to a shipping point would be very satisfactory.

The medium-gray hornblende biotite granite of Little Bow Mountain in sec. 32 is of such quality and occurrence as to make it a profitable quarry proposition if a shipping point were made accessible.

NAVAJOE MOUNTAIN AREA.

TOPOGRAPHY.

This area includes the Navajoe Mountain 3 miles north of Headrick, and the group of a dozen hills immediately across Red River to the northeast. Like the other granite hills of the Wichita Mountains district, these hills rise from the level plains with steep and barren or boulder covered slopes. The top of Navajoe Mountain is about 500 feet above the surrounding plain. The hills to the northeast are not so high but rise in several instances as high as 100 to 200 feet.

GEOLOGY.

The prevailing type of granite for this area is a fine-grained, grayish-red, hornblende granite, essentially like the prevailing type in the Lugert area. On Navajoe Mountain there is a finer grained phase of hornblende granite with a predominating micropegmatitic texture. The northwest portion of the mountain and the tops of the higher peaks to the south are made up largely of this rock. Near the tops of the hills the coarser rocks cut the finer in vertical, horizontal and inclined dikes of various sizes. Angular boulders with sharp contact and no sign of absorption or gradation are found in the coarse granite.

Besides these two slightly different granites no other types of igneous rocks were found. Fracturing has been intense, especially in the finer grained phase of the granite. There is a zone about

one-fourth mile wide extending from the northwest corner of sec 6, T. 2 N., R. 18 W., northwestward across the mountain, in which the fractures are widely spaced. The strongest system of joints runs northwest-southeast with another system at right angles to it. These fractures are spaced 6 to 20 feet apart. On both sides of this zone the granite is greatly fractured by closely spaced joints. This is especially true of the southeastern portion of Navajoe Mountain.

TYPES OF GRANITE.

The coarser grained phase of granite here is a reddish-brown, fine-grained rock, mottled with gray and black. Megascopically on the fracture surface it reveals cleavage surfaces from 3 to 6 mms. in length, of a tabular gray feldspar, irregular patches of a slightly smoky quartz all imbedded in a mass of intergrown feldspar and quartz. The microscope shows the feldspar to be greater in abundance than quartz, with hornblende, magnetite, and zircon in subordinate amounts. Secondary kaolin, hematite, fluorite, and chlorite are present. This granite weathers into rounded reddish-gray boulders with rough surfaces on which the larger crystals of feldspar stand out conspicuously. Quartz is not noticeable on the weathered surface.

The fine-grained type is of light pinkish-gray color where exposed, but it is probable that if fresher samples could be obtained they would be a much darker gray. The surface reveals a few individuals of colorless quartz and gray to colorless feldspar 1 to 2 mms. in diameter imbedded in a groundmass of intergrown quartz and feldspar. Microscopically the rock is found to be composed chiefly of feldspar and quartz, the greater part of which is microperthitic-micropegmatite, with traces of hornblende, zircon, and titanite. The finer granite weathers into angular boulders with pinkish-gray surface on which individuals of quartz and feldspar can be plainly seen.

QUARRY SITES.

Because of the intense fracturing in this region there is but limited area that will afford quarry sites favorable for producing granite for commercial uses. There is a zone about 80 rods wide, beginning in the northwest corner of sec. 6, T. 2 N., R. 18 W. and extending northwestward for half a mile or more, which contains the coarser grained variety in quantity and quality suitable for quarrying. This region is accessible but would necessitate a haul of about 4 miles to Headrick for shipping.

MOUNTAIN PARK AREA.

TOPOGRAPHY.

Under this head are included all of the scattered granite hills within a radius of about 7 miles of Mountain Park, including Twin Mountain on the northwest and Long Mountain on the southwest.

The topography of this group is like that of the Navajoe group. Granite hills with steep slopes covered with boulders rise from the level plains to heights of 10 to 300 feet. With few exceptions the granite outcrops have small summit areas which are covered with large blocks of granite and are essentially barren of vegetation. Brush Mountain, southeast of Snyder, is flat-topped and covered with cedar. Sheet structure at the west end of Mount Radzminski is responsible for large, steep, barren surfaces of granite. (See Pl. XII.)

PLATE XII.

SOUTHWEST FACE OF MOUNT RADZMINSKI NEAR MOUNTAIN PARK, SHOWING STRONG SHEET STRUCTURE.

Otter Creek, the only stream of any importance which crosses the granite, flows in a young canyon-like valley for a mile or more.

GEOLOGY.

The dominant type of granite in the Mountain Park area incloses irregular and often indefinitely bounded masses of a finer-grained granite, which in turn includes boulders of a dark basic rock.

The strongest fractures in the district have a northwest-southeast direction. A northeast-southwest system is only a little less strong.

TYPES OF GRANITE.

Only one type of granite in this area is likely to be of commer-

cial importance. Though this granite differs slightly in texture and greatly in color from place to place, it is, when unaltered or unaffected by circulating ground water, essentially the same type of granite wherever found in this area. The prevailing type when unaltered, is a mottled pink and gray with a violet tinge to the pink. The surace shows cleavage surfaces of a brownish-gray feldspar, very small individuals of yellowish and smoky quartz, and an intimate intergrowth and mixture of pinkish feldspar and quartz. Rarely small dark patches of hornblende are seen.

The microscope shows an average sample of this rock to be composed of orthoclase and microperthite 57 per cent, quartz 31 per cent, plagioclase 5 per cent, hornblende 5.5 per cent, magnetite 1.2 per cent, and titanite about .2 per cent, with a few scattered grains of apatite, augite, and zircon, and much disseminated hematite in the feldspar.

The feldspar, excepting some of the larger crystals of plagioclase, are colored pink or red with disseminated hematite. The albite is sometimes zonally arranged with another plagioclase, probably oligoclase. The quartz occurs invariably in relatively small rounded individuals which are often a yellowish or smoky color. The hornblende is found in groups of brown and green roughly prismatic individuals which are strongly pleochroic. The magnetite occurs in rounded grains associated with titanite.

The average grain of the samples studied was 0.42 mms. The feldspars are often 2 mms. in length and occasionally 5 or 6 mms. A part of the quartz is intergrown with the feldspars.

The apparent specific gravity was found to be 2.678, while the true specific gravity was 2.68. The porosity or ratio of absorption was .513 per cent. The crushing strength was 20,600 pounds per square inch. The transverse crushing strength or modulus of rupture was 4690 pounds. This latter figure is seen to be exceptionally high. Cubes heated to 1000° F. and cooled slowly were not appreciably affected. When heated to redness for five minutes and allowed to cool slowly the cubes were materially weakened but still retained a good measure of strength. Tests show that the Lugert granite of the Mountain Park area withstands high temperatures better than either the Reformatory or the Headquarters granite.

On exposure to the weather this granite does not stain or discolor rapidly. The many firm boulders on the surface of the granite hills show its resistance to weathering.

This granite works well under the hammer and chisel, and takes a superior polish which exhibts a good contrast to the hammered face. It is suitable for monuments, construction work, or paving blocks.

DESCRIPTION OF QUARRIES.

C. JECK'S QUARRY (ABANDONED).

This opening is near the St. Louis and San Francisco Railroad on the east point of the hill one mile northwest of Mountain Park. The property is owned by C. Jecks. The rock here is about the average type of rock for this area. There is an opening 15 feet high and 25 feet long on the side of the hill. The rock is cut by a system of vertical east-west fractures spaced 4 to 8 feet apart, and by another system dipping 25° E. The quarry has not yet been opened beneath the zone of weathering and open joint planes. It is what is termed a boulder quarry.

The rock is the normal mottled pinkish-gray, medium-grained granite for this area. On long exposure to weathering it has here become a pinkish color with a shade of gray.

At present there is no equipment here, the quarry having been abandoned for two years. The stone was hauled to Mountain Park for shipment. A monument in the Snyder cemetery made of stone from this quarry shows a smooth grayish-red surface with an excellent polish.

PARSONS BROTHERS GRANITE COMPANY'S QUARRY.

This quarry in August, 1911, was operated and worked by Parsons Brothers. In August, 1912, the equipment had been partly moved away and the quarry temporarily abandoned. The property controlled by this company is the W. 1-2 of NE. 1-4 sec. 22, T. 3 N., R. 17 W. The quarry is about 40 rods from the east side of the property. The quarry is opened about 300 feet from the base of a gentle eastward sloping hill. The opening is not over 8 feet deep and covers an area 20 feet east-west by 30 feet north-south.

One system of joints dips S. 75° W. at 10°. There are also two vertical systems which strike N. 30° W. and S. 70° W. The inclined fractures are spaced from 6 to 20 feet apart, with an average of about 15 feet.

The granite produced here is a fine-grained rock of blood-red or mottled red and pink color which from field and quarry observations and microscopic examination is known to be the normal type of granite of this region discolored by alteration and the formation of hematite.

When it was first observed that the color of the rock was due to the hematite in the cracks and surrounding the minerals it was thought that secondary iron may have been introduced by circulating waters so that such zones contained above the normal percentage of iron. Chemical analysis, however, shows that the reverse is likely to be the case. Analyses by J. G. Fairchild of the United States Geological Survey, show that the normal granite of this

area contains a total of 3.01 per cent of iron oxides, while the highly colored variety from the Parsons' quarry contains a total of only 2.58 per cent of iron oxides.

The deep-red color is due apparently to the abundance of hematite rather than the total amount of iron oxide present. The change in color is brought about largely by changing the black iron oxide to red hematite.

It appears from investigation that the first change that takes place in the normal rock is the formation of epidote and chlorite, which gives the rock a uniform olive-green color. Later, by the breaking down of the epidote and chlorite and the oxidation of magnetite, red hematite is formed. This changes the rock completely from an olive-green to a deep-red color. Later, on exposure and weathering, the red changes first to yellow because of hydration and later to gray, much of the hematite being removed and the feldspars altering to sericite and kaolin. In support of this theory it was observed at the Parsons Brothers' quarry that the olive-green phase of the granite was never found at the surface or near the joint planes at a depth of 6 feet. The green rock is found in the middle of the larger blocks which do not afford channels of water circulation or ready exposure to the air. In depth the green becomes more abundant because of this fact.

At other points in this mountain the same red rock was studied and in all instances the granite was found to be cut by one set of closely spaced fractures dipping with the slope of the hill and another set dipping steeply toward the hill. Water was seeping out along the zones of discoloration. It was further observed that the red rock was found only at points well toward the bases of long slopes where the circulating ground water might readily be deflected upward along the inclined fractures dipping toward the hill.

If the foregoing theories are correct we may safely draw the following conclusions with respect to the occurrence of this granite: (1) The red granite will be found in quantity only on the long slopes of the larger granite hills, (2) it will be found only locally where there are suitable channels for vigorous water circulation, (3) it will be found only near the surace, (4) it will not be uniform in color for any considerable distance, but will change to olive-green with depth, and remote from channels of water circulation.

This granite works exceptionally well under the hammer and chisel, polishes easily with a brilliant surface. The polished face is in marked contrast with the hammered surface.

The deep-red granite from this quarry showed a crushing strength of 20,600 pounds per square inch. Its true specific gravity

is 2.635 and the apparent specific gravity is 2.631. The porosity of 1.108 per cent is the highest of any Oklahoma granite yet tested.

It is suitable monumental, building, or paving granite.

The quarry equipment in August, 1911, consisted of one 6-horsepower gasoline engine, one polisher, 2 derricks, a work shed, and blacksmith shop. Transportation was by wagon to Mountain Park, a shipping point, 2 miles away.

Most of the stone produced has gone to dealers in Oklahoma. Considerable granite in the rough state has been sent to Winterset, Iowa.

JOHN M. HAZEL QUARRIES.

Opening No. 1.—During the summer of 1912, Mr. John M. Hazel started an opening on property in the SW. 1-4 sec. 23, T. 3 N., R. 17 W., leased from C. Jecks.

At this place the granite is cut by two systems of vertical fractures, one striking northwest-southeast and the other northeast-southwest. Another system dips 25° southwest. There is also one strong horizontal fracture. All the fractures are irregular in direction. They are spaced from 1 to 12 feet apart. Large sized blocks can be secured but there is much waste stone. No stripping is required. The average thickness of the sap rock is only 2 to 3 inches, though occasionally along incipient joints it penetrates a foot or more.

There are at present two fairly distinct varieties of stone here. One is essentially like the prevailing granite of the area, or the granite from the abandoned quarry described above, while the other is more even grained and is of a rather uniform flesh-red color specked with black hornblende and magnetite. The average grain of the flesh-red variety is about the same as that described above, but there is less of the intergrowth of feldspar and quartz and the large gray feldspar crystals are absent. The intricately interlocking red feldspar constitutes about 65 per cent of this granite, while the small round quartz grains and irregular bodies of hornblende and magnetite make up the remainder.

The composition and texture indicate that this will be an exceedingly strong, durable granite. The color is a good clear flesh-red to brownish-red specked with black, and polishes with a superior finish. The contrast between the polished and hammered face is strong, permitting effective lettering or carving.

Development has not gone far enough to show how much of the quarry is of this type. At the time it was visited the two varieties were about equally abundant. At one place they were sharply separated by a band of quartz one-sixteenth of an inch thick. It is thought that they will be found to grade into each other.

The equipment consisted of one derrick, one 15-horsepower gasoline engine, one air compressor with a capacity of 75 cubic feet per minute, and two drills operated by air. Only rough stone was produced, which was shipped to Chicago and points in Iowa.

Opening No 2.—During August, 1912, quarrying operations were begun in a boulder quarry on the W. A. Mitchell property 1 1-2 miles northwest of Mountain Park. This property is located on the south slope of a 400-foot hill in the SW. 1-4 sec. 22, T. 3 N., R. 17 W.

At this place there is a large barren granite surface in which is developed a strong sheet structure dipping south and southeast at from 25° to 40°. The slope of the hill is the same as the dip of the sheet joints and appears to be determined by them. Large masses of granite have moved down this slope and accumulated at its base. Many of the boulders range from 20 to 40 feet in diameter.

Equipment similar to that installed at the Hazel quarry No. 1 was installed here for a time but was removed in November, 1915. Operations were confined to work on one boulder 25 feet in diameter. The granite in this boulder in texture and composition is essentialy like the gray variety at quarry No. 1, but here it is of a medium-gray color specked with red. It may be classed as a medium-textured, slightly inequigranular gray granite, composed of gray feldspar, colorless and smoky quartz and rarely grains of magnetite or hornblende. The feldspar is prevailingly a medium-gray color but is occasionally specked with pink. Other boulders were noted where the pink spots were abundant and as much as 5 mms. in diameter. They are irregular to prismatic in form and range in average diameter from a fraction of a millimeter up to 4 or 5 mms. The quartz occurs in small rounded grains usually less than a millimeter in average diameter.

The abundance of feldspar and quartz and the intricate manner in which they interlock should make this a strong, durable building stone. The rather dull gray of the feldspar would likely not present a pleasing appearance when polished. The gray color of this boulder is undoubtedly due to the leaching out of the iron and the alteration of the feldspars to kaolin. A quarry extended into the bluff beyond the zone of active weathering would undoubtedly secure a red or grayish-red granite. The stone splits well and would make a very desirable building stone.

OTHER QUARRY SITES.

There are a number of good quarry sites in the south half of sec. 22, T. 3 N., R. 17 W. The fractures are widely spaced, making the stone favorable for quarying. The granite is in places discolored by secondary hematite. At one locality the normal grayish-pink granite was spotted with light red, producing a very

pleasing combination of red and gray. It is not known how much there is of this, but it appears to be in considerable quantities and should prove a valuable stone for monumental work. The stone is accessible and not far from a shipping point.

COLD SPRINGS AREA.

TOPOGRAPHY.

The granite hills of this area rise with moderate grass-covered slopes from the flat plains. But few of the hills are above 200 feet in height, and the highest is the Gabbro hill in sec. 5, T. 4 N., R. 17 W., which rises to a height of about 300 feet above the plains. The gabbro is less resistant than the granite, and where the two are in contact it generally appears on the lower, level land surrounding the granite. In several cases granite and gabbro dikes, which are more resistent to weathering than are the surrounding rock, stand out as ridges. The diabase-diorite dikes usually give rise to depressions or valleys.

GEOLOGY.

The igneous geology of the Cold Springs area is the most complex of any in Oklahoma. The oldest and most abundant igneous rock of this area belongs to the gabbro family. It is in part an olivine gabbro, in part augite gabbro, and in part anorthosite. During the second period of igneous activity the gabbro was cut by quartz, diorite, and diabase dikes and irregular masses. Later the Cold Springs granite, which is near to a quartz monzonite but has a more basic marginal phase, was intruded into the gabbro and diabase-diorite. Included boulders of diabase-diorite and gabbro are abundant, especially near the margins of the granite masses. (See Pl. XIII.) Subsequent to the intrusion of the granitic masses the region was fractured and all rocks of the region were cut by granite dikes and sills which were followed by the intrusion of quartz diorite dikes. These later granite dikes are much more abundant in the region of earlier intrusions, though they are not entirely absent in the gabbro area to the eastward.

In secs. 13, 14, 23, and 24, T. 4 N., R. 17 W., the older gabbro is cut by a gabbro sill and a granite sill, as well as by several strong gabbro dikes.

The entire region is cut by strong joints, trending in various directions and spaced from 2 to 20 feet apart. The prevailing directions for the major joints are east-west and north-south

The gabbro and anorthosite in places have assumed a distinctly schistose structure but the other rocks are not metamorphosed.

TYPES OF GRANITE.

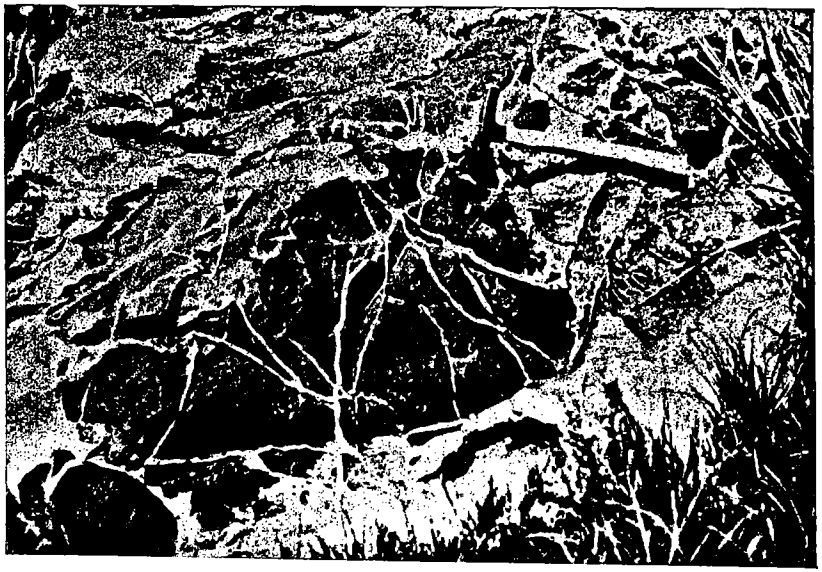
COLD SPRINGS GRANITE.

The only granite of commercial importance in this area has been termed the Cold Springs granite. Although it varies considerably

in texture and mineral composition in the different parts of the area, it is everywhere a fine-grained gray hornblende-biotite granite very similar to quartz-monozonite in composition.

The light gray surface on close megascopic inspection reveals specks of dark hornblende and biotite uniformly distributed through the fine-grained white and gray feldspar and quartz.

PLATE XIII.



VIEW WEST OF COLD SPRINGS, SHOWING DIABASE BOULDER CUT BY GRAY GRANITE, BOTH OF WHICH ARE CUT BY PINK GRANITES.

Microscopic examination shows it to contain the following minerals in varying proportions in the different quarries: Orthoclase, albite, oligoclase, andesine, quartz, hornblende, biotite, magnetite, pyrite, apatite, titanite, and secondary chlorite, hematite, sericite, and kaolin. Feldspar is always the most abundant of all the minerals found in granite. Estimates by the Rosiwal method on four different samples show that feldspar composes from 57.3 to 64.4 per cent of the rock. The orthoclase is formed with irregular and prismatic outlines ranging from about .05 to .60 mms maximum diameter. The individuals are nearly always less than twice as long as broad. The larger grains often entirely inclose crystals of plagioclase. The orthoclase is relatively free from inclusions and is always colorless to light-gray in color.

The plagioclase individuals are nearly always prismatic in outline and range from about .03 to .50 mms. in length. They are

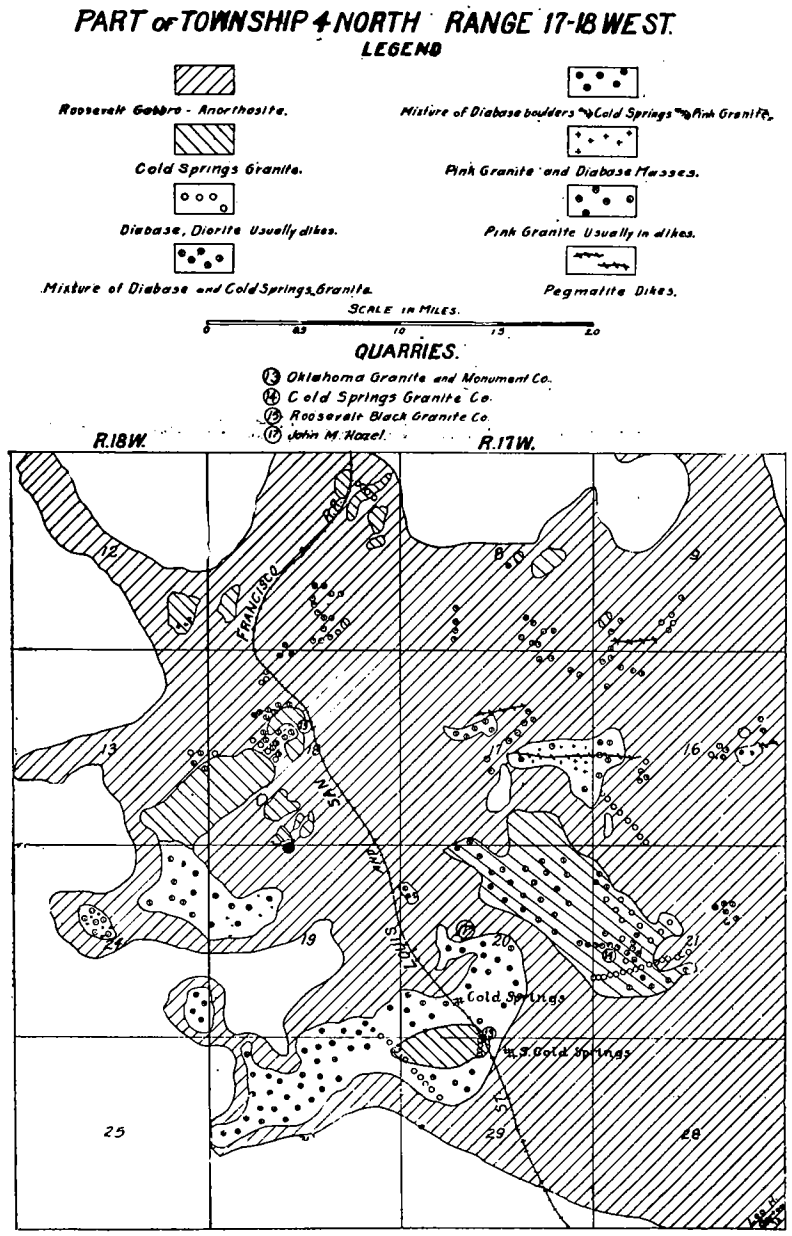


Figure 3. Sketch map of Cold Springs area, showing distribution of granite and location of quarries.

usually from 2 to 4 times as long as broad. The plagioclase grains often penetrate or are completely inclosed by the orthoclase and quartz, giving the rock a somewhat poikolitic texture. The plagioclase, like the orthoclase, is colorless or light-gray. Albite twinning striations are usually present and are sometimes combined with Carlsbad twinning. In composition they are chiefly andesine with borders of oligoclase.

Quartz constitutes 17.6 to 20.5 per cent of this granite. The individuals are usually irregular or rounded in outline, and rang-from .03 to .60 mms. in greatest diameter. The quartz is colorless and relatively free from inclusions.

Brownish-green and green hornblende compose from 9.7 to 12.5 per cent of this granite. The individuals are roughly prismatic in outline and usually range from .1 to 1 mm. in length, and project into or through all the other chief minerals which must have crystallized later. In some specimens the hornblende is in part altered to chlorite.

Biotite composes 5.3 to 10.5 per cent of the Cold Springs granite. It is found in tabular masses .05 to .50 mms. thick. It is brown to black in color.

Magnetite occurs in rounded grains from .01 to .25 mms. in maximum diameter, and composes from .31 to 3.2 per cent of this granite. It is usually fresh, seldom ever showing any traces of alteration to hematite.

Apatite occurs only in traces as slender prismatic crystals imbedded in other minerals. Titanite is often present associated with magnetite.

The average grain for each of the four specimens was computed and found to range from .14 to .27 mms. None of this granite with a grain about .20 mms. has yet been put on the market.

The only available chemical analysis of the Cold Springs granite is given on page 21.

Tests of crushing strength of Cold Springs granite show that it compares favorably with other well known granites. Cubes tested showed a crushing strength of 21,569 pounds per square inch.

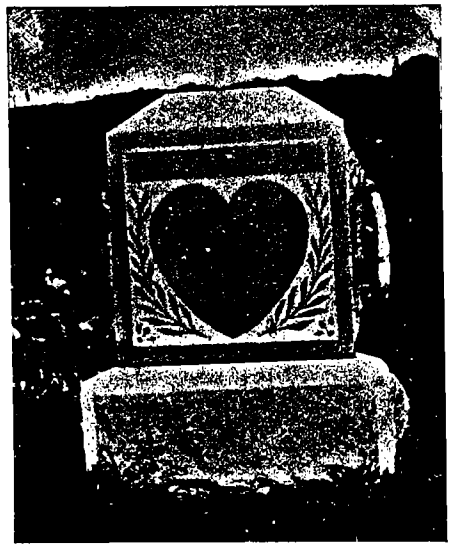
The apparent specific gravity is 2.773 and the true specific gravity is 2.776. The percentage pore space was found to be .590 per cent.

Cubes heated to 1000° F. and allowed to cool slowly showed no appreciable change. When heated 1000° F. and cooled suddenly by immersion in cold water there was no apparent change. Cubes heated to redness for 5 minutes and allowed to cool slowly were duller in color and considerably weakened though they were

still quite firm and resistent. This granite stands high temperatures better than any other granite yet put on the market from Oklahoma.

This granite takes a superior finish with a medium-gray to dark-gray shade, but is said to be a difficult stone to polish. The hammered face shows a good contrast to the polished face.(See Pl. XIV.) It splits regularly with smooth plane surfaces. It is suitable for monumental, construction, and paving work.

PLATE XIV.



MONUMENT OF COLD SPRINGS GRANITE, SHOWING CONTRAST BETWEEN HAMMERED AND POLISHED SURFACES.

ROOSEVELT BLACK GRANITE.

The other type of commercial granite in the Cold Springs area is a gabbro-anorthosite known to the trade as a blue or black granite. The rocks of this class found in the Cold Springs area vary considerably both mineralogically and texturally, and include anorthosite, gabbro, olivine-gabbro and norite. In the field there is apparently a gradual transition from one kind to the other.

The gabbro varies in color from medium-gray to black. The unaltered rock is almost black. In zones of fracturing and metamorphism the gabbro and anorthosite become much lighter gray. Megascopically the surface reveals large cleavage surfaces of a dark-gray feldspar often coarsely striated, and occasionally a cleavage surface of a dark-gray to black augite. In several limited areas

olivine and magnetite become important constituents, but ordinarily they cannot be detected with the naked eye. Microscopically the gabbro is found to be composed of plagioclase feldspar, augite, magnetite, olivine, and titanite. The feldspar which composes 50 to 100 per cent of the rock is largely labradorite with sometimes subordinate amounts of andesine and bytownite. The prevailing short thick sections of the feldspar are often roughly rectangular.

Broad twinning lamina, twinned according to the albite and pericline laws are always present. This feldspar is filled with very minute brown needle-like inclusions of a mineral taken to be augite. The longest one found measured only .22 mm. in length, and it was perhaps 10 times as long as the average. They have a parallel dimensional arrangement conforming to the planes of the twinning lamina.

The augite when in small quantities fills the space between the feldspar crystals. When in larger quantities it takes on a roughly prismatic form. When fresh it is brown to almost black in color, but on alteration it becomes a light-green color, due to the formation of green hornblende or chlorite.

The olivine usually occurs in rounded grains which are light-green to colorless. Magnetite and titanite are found in rounded grains associated with the augite.

This rock is not very hard, but tough. It works easily under the hammer and chisel, and polishes easily with a smooth glossy surface of dark, bluish-gray color. It has a true specific gravity of 2.734, an apparent specific gravity of 2.733, and a porosity of .259 per cent. It is a suitable building and monumental stone but not very satisfactory for paving blocks.

DESCRIPTION OF QUARRIES.

OKLAHOMA GRANITE AND MONUMENTAL COMPANY'S QUARRY.

This company has an opening in the gray hornblende-biotite granite in the NE. 1-4 of NW. 1-4 of sec. 20, T. 4 N., R. 17 W. The quarry opening is on a north slope of a low hill about 400 feet from the St. Louis and San Francisco Railroad track, and about 700 feet south of the railroad depot. (See Pl. XV.)

From the opening, which has been worked intermittently for a number of years, the loose and more or less altered boulders, to a depth of 5 to 8 feet, have been stripped over an area about 60 feet square. Beneath these surface boulders the solid granite is reached. Much of the surface material furnishes unaltered stone of a good quality, especially at the west side of the quarry. (See Pl. XV.) The largest factors in quarrying here are the sheet joints which dip north at an average of 12°. They are spaced 1 to 5 feet apart at the present working surface, but may change with

PLATE XV.

OKLAHOMA GRANITE AND MONUMENTAL COMPANY'S QUARRY, COLD SPRINGS, SHOWING WELL-DEVELOPED SHEET STRUCTURE. THE JOINT PLANES DIP GENTLY TOWARD THE FRONT OF THE QUARRY.

greater depth. On the east side of the quarry the sheet joints are more closely spaced and more irregular than on the west. Much of the rock from the east side is waste, while on the west the sheet joints are persistent and regular, and permit the quarrying of large blocks. The most important vertical joints are those striking N. 45° W., and diping 80° E. These are well developed fractures, and are spaced from 1 to 15 feet apart. At the west side of the quarry another set of joints less well developed than the above strike S. 18° W. with a dip of 80° E., while at the east side the same system strikes 40° W. These joints are spaced, on an average, about 6 feet apart, but in places they are 25 to 30 feet apart.

Near the east side of the opening there is a quartz monozonite dike, 1 inch across, striking N. 12° W. and dipping 85° W. Besides this dikelet there are still smaller stringers or veinlets composed chiefly of white quartz, which traverse the granite in all directions, but most abundantly in directions parallel to the prominent joint planes. They are both vertical and horizontal, and vary greatly in direction and size, but are seldom over one-eighth of an inch thick. Where the joints are more closely spaced, the veinlets are more abundant.

The granite from this quarry is a dark-gray, very fine-grained hornblende-biotite granite. The finest grained specimen of the Cold Springs granite examined came from this quarry. The following is the estimated percentages:

Estimated mineral percentages of fine-grained granite from Cold Springs.

Feldspar	64.4
Quartz	18.9
Hornblende	9.81
Biotite	5.31
Magnetite	1.6
Pyrite	trace

The estimated grain was .14 mm.

When exposed for several months it takes on a yellowish-green tinge, which, though slight, can be detected easily when compared with a fresh fracture. The rock within 5 feet of the original hill surface is discolored by alteration along the joint planes to a depth usually less than half an inch. The change in color is due chiefly to the development of a yellow iron oxide and the alteration of hornblende to chlorite, which gives a greenish-yellow hue to the weathered surface.

The granite polishes with a very smooth dark-gray finish, which is in marked contrast to the light-gray hammered surface. It letters exceptionally well. When free from veinlets this is a first-class monumental stone. It is a good building and paving stone, and makes excellent concrete or road material when crushed.

Equipment at this quarry consists of one 175-horsepower steam engine, one 40-horsepower steam engine, one air compressor with a capacity of 40 feet per minute, one polisher, one surfacer, one disc crusher having a daily capacity of 30 cars, air plug and steam tripod drills, also workshed and shops. It is equipped to produce crushed stone and building or monumental stone in any quantity desired.

The quarry was idle during the greater part of 1911, but began operations in July, 1912, and continued for a year. It has been idle since the summer of 1913, on account of financial troubles.

Stone from this quarry has been used chiefly for monumental purposes, facing, and crushed stone for concrete. Some difficulty is experienced in securing stone free from quartz veins, but when secured it makes a high grade monumental or trimming stone. As a crushed stone for concrete or road material it is unexcelled by any other granite in the State. It is hard, fairly tough, and breaks easily into sharp angular fragments.

COLD SPRINGS GRANITE COMPANY'S QUARRY.

This quarry for a number of years was operated by Pete Johnson on property leased by him in the NW. 1-4 of SW. 1-4 sec. 21, T. 4 N., R. 17 W., one-half mile northeast of Cold Springs. This property was recently sold to Higdon & Son and is now operated by them. The opening is on a gentle westward slope which is parallel to well defined sheet joints dipping westward at 10°. No stripping is required, the surface layer of boulders being used without appreciable waste. The sheet layer now being used is the first continuous layer at the surface. It has been removed over an area about 35 feet square. At the east end of the quarry this sheet has its maximum thickness of 5 feet but thins to 2 feet 6 inches at about 20 feet down the slope to the westward. It is probable that the sheets beneath are also lenticular in shape.

The strongest and most persistent set of joints are vertical and, on an average, strikes S. 80° W., but they vary considerably. They are spaced from 3 to 12 feet, and blocks 10 feet thick are not uncommon. Another less persistent vertical system strikes N. 20° W. Those which continue across this hill are spaced from 35 to 40 feet apart. Forty feet north of the quarry the gray granite is cut by a light-gray to pink granite dike 4 feet thick, which strikes N. 70° W. and dips 80° S. All of the granite in this section is cut by granite stringers and masses variable in direction and thickness. They are pink near the surface and in places constitute 10 per cent of the rock. Besides these there are many branching irregular quartz veinlets, the majority of which extend in an east-west direction. The immediate quarry site is relatively free from quartz veinlets.

The granite here is a fine-grained gray hornblende-biotite granite. Estimates by the Rosiwal method on a sample from this quarry give the following mineral percentages:

Estimated mineral percentages of fine-grained gray hornblende-biotite granite from Cold Springs.

Feldspar	61.2
Quartz	18.3
Hornblende	9.7
Biotite	10.5
Magnetite	.3
Apatite	trace

It will be noted that there is less magnetite and more biotite than the average of the Cold Springs granite. The average grain is .165 mm. This rock is a considerably lighter shade of gray than the granite from the Oklahoma Granite and Monumental Company's quarry. When polished it becomes a medium-gray with a very smooth surface. The polished face letters and carves well.

At this quarry the granite splits very regularly in a north-south vertical plane, but splits most easily in a horizontical plane. It works well under the hammer and chisel, though it is said to be a stone that cannot be worked rapidly.

The equipment here consists of one derrick and a small shop. All work is done by hand. Most of the stone is shipped unfinished, for monuments. A few pieces have been hauled to the Parsons Brothers' quarry at Mountain Park for polishing. All the cutting and lettering is done at a finishing plant in Cold Springs. This quarry has been operated intermittently and has never worked more than four men, consequently the output is small. Most of the stone goes to Texas, Kansas, and Oklahoma dealers. The material is transported by wagons over good roads to Cold Springs, one mile away.

ROOSEVELT BLACK GRANITE COMPANY'S QUARRY.

The Roosevelt Black Granite Company quarries two kinds of stone—one a typical Cold Springs granite, and the other black granite or gabbro. This quarry is on the St. Louis and San Francisco Railroad, near the center of sec. 18, T. 4 N., R. 17 W. Lenartz & Schwartz, owners and operators, control 140 acres in the center of the section.

The quarry face is on the east side of a 40-foot bluff above the railroad. In testing the stone an excavation 18 feet deep had been made but later was filled, it was said, in the process of working down the bluff to get more room. At present there is hardly room for a derrick between the main track and the bluff. The granite is cut by east-west and north-south systems of vertical

joints, spaced 5 to 8 feet apart. A third system of almost horizontical joints, spaced 5 to 10 feet apart, cuts the granite into rectangular blocks. Rift is recognized in a horizontal plane. No stripping is required to secure building stone. Twenty feet above the base of the quarry face a horizontal tabular mass of gabbro cuts the gray granite. Pink granite and white quartz stringers are numerous and run in all directions. Occasionally a good sized block is found free from these materials.

The granite is of the same character as that at the Oklahoma Granite and Monumental Company's quarry at Cold Springs.

Equipment consists of one 80-horsepower boiler, one 50-horsepower engine, one air compressor with a capacity of 150 cubic feet per minute, five drills operated by compressed air, one derrick, and 400 feet of switch. Cars are loaded from the derrick.

The quarry has been idle since 1911. When in operation 10 men were worked. The output has been used chiefly as riprap for the St. Louis and San Francisco Railroad. Some stone for monuments has been shipped in the rough to points in Oklahoma and Iowa. The plan is to begin operations when trade conditions are improved.

GABBRO QUARRY.

Some years ago gabbro was quarried from the bed of a creek in the west-central part of sec. 28, T. 4 N., R. 17 W., about 1 mile southeast of Cold Springs. The owner of this property has moved from the region and it could not be learned who operated the quarry or how much stone had been removed.

The opening was in the bed of the creek, on a rock surface sloping 10° W. The gabbro is cut by two strong systems of vertical fractures, one striking north-south, and the other east-west. A third and weaker system strikes northwest-southeast. The joints are spaced from 5 to 10 feet apart. Joints cutting the gabbro into sheets dip 10° W. No stripping is required.

The gabbro here is a medium to coarse-grained dark-gray to black rock composed of labradorite, feldspar and augite, with a little magnetite and titanite. In places the augite is almost entirely lacking, while in others it constitutes almost one-half the rock. The greater part of the gabbro, however, contains but a small per cent of augite. This rock has a slight schistose structure developed parallel to the sheet joints and along this plane it splits most easily. It has a specific gravity of 2.734 and a pore space of .259 per cent.

The stone containing small amounts of augite would make a good monumental stone. It works easily and takes a good polish. Most of this stone which contains augite, discolors rapidly on exposure to the weather. No equipment other than a small der-

rick has ever been installed here. It is not a favorable place for a quarry, as the stone must be lifted 15 feet out of the creek bed for loading, and in times of high water the quarry will fill with water and debris.

Small amounts of gabbro have been taken out at different places in and near Cold Springs. This quarry has, in part, supplied the local demand for foundation stone and a small amount has been used for monuments. At the present time John M. Hazel is quarrying a small amount of gabbro about one-half mile northeast of Cold Springs. A 15-horsepower gasoline engine and one derrick have been installed. But little stone has as yet been put on the market.

QUARRY SITES.

Satisfactory sites for quarries are hard to find in the Cold Springs district. The gray granite is all near the railroad and fairly accessable, but it is so cut by veinlets and filled with diabase boulders that good quarry sites are rare. The gabbro, while relatively free from inclusions, is cut by many veinlets and small dikes. Though much of the gabbro outcrops near the railroad it appears on gentle slopes and is badly weathered at the surface. In the higher hills, some miles from the present railroads, good exposures of unaltered gabbro are plentiful. In some cases these are accessable for wagon transportation. In secs. 10, 14, and 15, T. 4 N., R. 17 E., there are large exposures of gabbro which might furnish suitable quarry sites.

COOPERTON AREA.

TOPOGRAPHY.

In this area we shall include, for convenience of discussion, all of the northwest portion of the main range, embracing the scattered granite outcrops northwest of Cooperton, and all the area between Haystack Mountain and Saddle Mountain on the north and Military Pass on the south. The granite hills northwest of Cooperton, and the somewhat detached Haystack and Saddle mountain groups are topographically similar to the granite hills already discussed. They consist of boulder covered hills rising abruptly 50 to 300 feet from the level Redbeds plains. The remainder of this area consists of a maturely dissected granite plateau, characterized by broad grassy intermontane valleys with a number of sparsely vegetated hills rising 100 to 400 feet above the broad valleys. The drainage from these intermontane valleys at the west and north borders of the mountain range descends rapidly, often through boulder-filled channels to the plains 100 to 200 feet below. It is a characteristic feature in this area that the highest peaks, Bear Mountain and Mount Baker, are on the margin of the granite area. To the east and southeast of Mount Baker flat

or gently rolling areas are more extensive, the difference being due to the fact that in the interior of the range the granite has been intensely fractured causing more rapid and uniform weathering.

GEOLOGY.

We have in this area the border zone between the gabbro-anorthosite and the later red granite which is correlated with the Lugert granite. On the south side of Bear Mountain, on the north of Mount Baker, and on other intervening points the gabbro is found lying beneath the red granite. The more rapid weathering of the gabbro has given rise to cliffs on each of these mountains on the side of the gabbro exposure. South of Mount Baker this granite is found including boulders of a gray granite very much like the Cold Springs gray granite. The red Lugert granite also includes boulders of diabase-diorite. From this evidence it appears that the early gabbro was cut by diabase-diorite dikes. Later there was intruded a more silicious magma forming the gray hornblende-biotite granite. Following this was the intrusion of the red hornblende granite magma. As an aftermath of this intrusion there folowed first the intrusion of a few granite dikes of variable form and size and later strong diabase dikes.

CHARACTER OF GRANITE.

The prevailing igneous rock of this area is a medium fine-grained dull grayish-red, hornblende granite, which varies somewhat in texture in the different parts of the area. Northwest of Cooperton it is in places found to include a finer-grained variety of the same type, in other places nearby it is found grading into this fine-grained variety. In sec. 36, T. 5 N., R. 15. W., and sec. 31, T. 5 N., R. 14 W., a porphyritic rhyolite with spherulitic base is found. In the western part of sec. 8, T. 4 N., R. 15 W. the red granite is found overlying the older gabbro and sending apophyses into the gabbro. Near the contact the granite includes masses of diorite and itself becomes darker colored and apparently more basic.

Microscopic examination shows that the granite is composed of approximately 63 per cent feldspar, 30 per cent quartz, 4 per cent hornblende, 1 per cent magnetite, and 1 per cent biotite, titanite, zircon, and apatite combined. The feldspar and quartz are largely intergrown. The hornblende is partly a deep green variety with low birefringence. Titanite borders much of the magnetite and becomes more abundant near the granite-gabbro contact. Microscopic examination shows that at the south side of Bear Mountain a large portion of the feldspar and quartz are graphically intergrown. The hornblende shows a number of fairly good prismatic forms and the magnetite is found in rounded and irregular grains. Two miles farther north the graphic intergrowth is even more intimate, with a marked tendency for the individuals to orient themselves with respect to well defined crystal faces. The

hornblende outlines are less definite. On the south slope of Saddle Mountain all of the feldspar excepting a few well defined crystals is very intricately intergrown with quartz. In most cases the graphic intergrowth is oriented with respect to the feldspar grains. Hornblende occurs partly in poorly defined prismatic crystals, and partly as rough or branching rods and feather forms. On the north side of Saddle Mountain there are a few definite feldspar crystals, while the remainder or base is a mass of spherulites and very fine granular quartz and probably feldspar. The hornblende and magnetites occur chiefly as groups of rods and branching feather-like forms. The spherulites vary greatly in size and form. Many show perfect radiate extinction. Some of the larger ones have quartz or feldspar grains as neuclei.

This granite and the rhyolite both weather into subangular and rounded reddish-gray boulders. Weathering is largely by chemical decay, and from the freshness of the loose boulders appears to be taking place very slowly. Cubes from surface boulders on this mountain showed a crushing strength of 38,247 pounds per square inch, the highest yet recorded for Oklahoma.

QUARRY SITES.

There are no good quarry sites easily accessible for even wagon transportation. There are, however, several good exposures of slightly fractured granite on the west side of Bear Mountain and southwest of Mount Baker, which could be reached with little expense. Suitable granite for ordinary construction work can be secured anywhere from the granite northwest of Cooperton, or in this part of the main range.

ELK MOUNTAIN AREA.

TOPOGRAPHY.

We shall include in this area that portion of the main range of the Wichita mountains south of Military Pass and west of West Cache Creek of which Elk Mountain is the center and highest point. In the Elk Mountain area rounded dome-like hills prevail. Barren and little fractured granite surfaces and immense boulders are common. With the exception of Elk Mountain the higher elevations have but little summit area. West Cache Creek and its tributaries drain the area through valleys with steep side slopes and high gradients. All are intermittent excepting West Cache Creek.

GEOLOGY.

A limited study of this area indicates that with the exception of a few dikes there are found here two types of granite, each varying somewhat in texture. The dikes are composed of a granite containing blue-green microscopic hornblende. These dikes are small, usually vertical and have a prevailing east-west direction. Elk Mountain is cut by two systems of strong fractures. One set of fractures striking N. 15° to 40° E. with dip of 88° W. are spaced 4 to 30 feet apart. The other, vertical and at right angles to the former, are spaced from 30 to 200 feet apart. Boulders 150 feet long and 30 feet in diameter are found on the very summit of the mountain. Sheet joints on the south slope of Elk Mountain dip at 35° to 50° with the slope of the hill. To the south of Elk Mountain there are zones 200 feet wide of closely spaced fractures alternating with zones of widely spaced fractures striking N. 10° E. and dipping 85° to 90° W. (See Pl. V-A.) To the northwest and also to the east of Elk Mountain the granite becomes finer-grained and fractures are more closely spaced.

CHARACTER OF GRANITE.

The chief type of rock in the Elk Mountain area is a medium-grained flesh-red hornblende granite termed the Quanah granite from Quanah Mountain. On a fresh fracture surface it shows cleavage surfaces of a flesh-colored feldspar up to a centimeter or more across, rounded grains of clear and slightly smoky quartz up to 4 mms. in diameter, and prominent irregular patches of greenish-black hornblende. Many of the smaller quartz grains are included poikilitically in the feldspar crystals.

Microscopically this granite is found to consist chiefly of orthoclase, microperthite, albite, and quartz, with subordinate amounts of hornblende, zircon, and magnetite. Feldspar constitutes about 65 per cent of the rock. The albite is in part intergrown with the orthoclase and in part inclosed in it. Some of the quartz is intergrown with feldspar but a large part is merely inclosed, without regular orientation.

The hornblende occurs as small fragments with a prismatic outline. Magnetite in rounded grains is rare. Several good crystals of zircon were noted. The feldspar, especially, and to a less extent the quartz, are filled with disseminated, hematite dust. The feldspars are somewhat altered to kaolin.

No physical tests were made on this granite, but its composition and texture suggest that in every way it is a most excellent building and monumental granite. It is a medium flesh-red color, of good clear tone. Its poikilitic texture makes it unique among Oklahoma granites.

QUARRY SITES.

Both the southern and eastern sides of Elk Mountain are accessible by wagon road and could be reached by railroad. (See Pl. XVI.) There are here numerous quarry sites where without stripping, unaltered granite can be secured in blocks of any size desired.

MOUNT SCOTT AREA

TOPOGRAPHY.

In this area is included all of the igneous rocks lying east of a line running from Cache on the south to the eastern part of Saddle Mountain on the north. Three types of topography are included. First, the mature rolling topography of the gabbro areas is seen in the Medicine Creek valley on the north of the range and in the intermontane valley extending from the northeast base of Elk Mountain about 6 miles to the eastward. Second, Mounts Scott, Wall, Sheridan, Marcy, and Lauramat rise to an altitude of over 2000 feet. On the north they rise from the rolling gabbro plain with almost perpendicular cliffs. On the other three sides they rise with steep boulder-covered slopes. (See Pl. VIII-A.) Third, as we pass to the southeast from this range of hills to the Carleton Mountains there is, along with a change in texture and structure of the granite, a rapid transition to rounded grassy hills of uniform slopes with broad open valleys between. Embayments of sedimentary rocks extend, in the open valleys, well into the granite range.

GEOLOGY.

Excepting the diabase and granite dikes the igneous rocks of this area appear to represent but two distinct periods of igneous activity. The earlier period is represented by gabbro and the later period by granite and rhyolite. Subsequent to the solidification of the granite and rhyolite the region was fractured and invaded by granitic and diabase-diorite dikes. The granite dikes are the earlier and less abundant of the two.

The granite later was again intensely fractured and faulted. The dominant direction of fracturing was N. 75° to 85°W., essentially parallel to the granite-gabbro contact on the north side of the range. One fault with a throw of 25 feet was observed near the northeast side of Mount Sheridan.

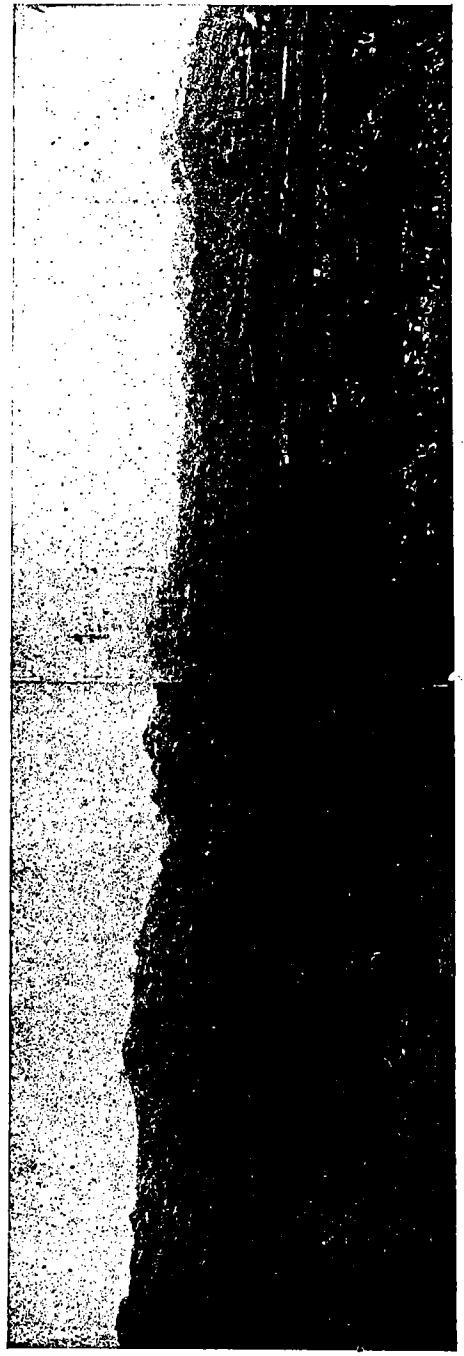
The finer-grained granite and especially the porphyritic rhyolite is so intensely fractured that for large areas it is difficult to find an unfractured piece a foot in diameter. The intensity of the later deformation is suggested by the intense folding of the sedimentary rocks to the north of Mount Scott, as shown in the accompanying plate.

CHARACTER OF GRANITE.

LUGERT GRANITE.

The red granite of this area is, in its coarser phases, almost identical to the red granite of the Cooperton and Mountain Park areas. Samples taken one-fourth mile south of Mount Sheridan were fine-grained pink to red specked with black. Cleavage surfaces of feldspar rarely as much as 4 mms. across are observed. Quartz shows in gray and colorless rounded grains much less con

PLATE XVI.



ELK MOUNTAIN AREA FROM THE SOUTH, SHOWING THE EASY APPROACH TO THE MOUNTAINS FROM THE SOUTH.

spicuously than the feldspar. The microscope shows in these samples chiefly microperthite with some plagioclase, magnetite, and zircon. Much of the hornblende is of a greenish-brown color.

The feldspar and quartz are little intergrown. Samples taken on the south slope and at the top of Mount Scott are much the same but the feldspars and quartz are largely graphically intergrown. The feldspars always contain much disseminated hematite dust.

The chemical composition of a specimen of this granite collected from west of Mount Sheridan is shown by analysis (p. 21) to be a normal granite.

The porphyritic rhyolite in Canyon Creek and southeast of Mount Scott is dark brownish-gray in the least altered samples collected. It shows phenocrysts of feldspar up to 3 mms. in diameter. On weathering it becomes brick-red in color. The groundmass at present is composed of fine, granular quartz and feldspar.

The granite takes a fine polish and should be a desirable monumental and structural stone.

GABBRO (BLACK GRANITE).

Most of the gabbro in this area is essentially identical with the normal black medium-grained gabbro found so abundantly in the Cold Springs area. To the northwest of Mount Sheridan near the granite-gabbro contact the gabbro assumes a speckled pinkish appearance due to the presence of quartz and orthoclase. This rock when polished makes a beautiful decorative material.

QUARRY SITES.

Suitable sites for quarries are rare in this district, because of the intense fracturing of much of the granite and the difficulty of access to that not so greatly fractured.

ARBUCKLE MOUNTAINS DISTRICT.

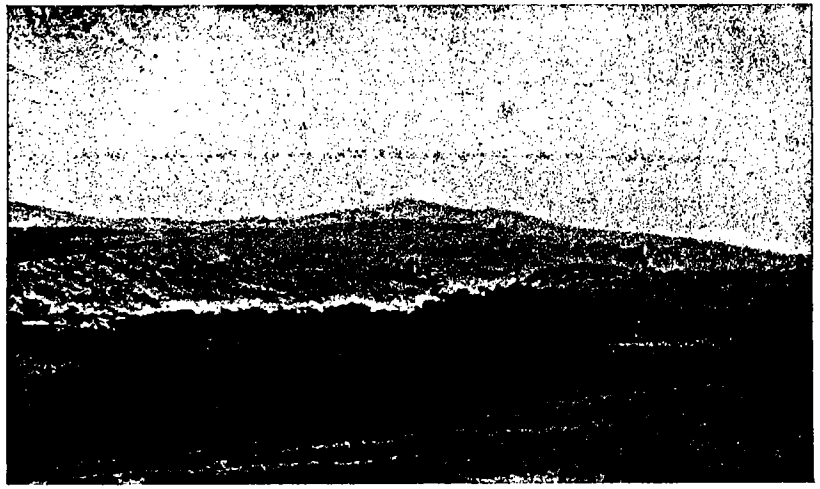
GEOGRAPHY AND TOPOGRAPHY.

The granites of this district are located in Murray, Johnston, and Atoka counties, in the south-central part of Oklahoma. All of the commercial granite of this district is found on the southeastern flank of the exposed portion of the Arbuckle uplift. The district is far from being mountainous for the granite outcrops are found on a gently rolling plain which slopes to the south at a low angle.

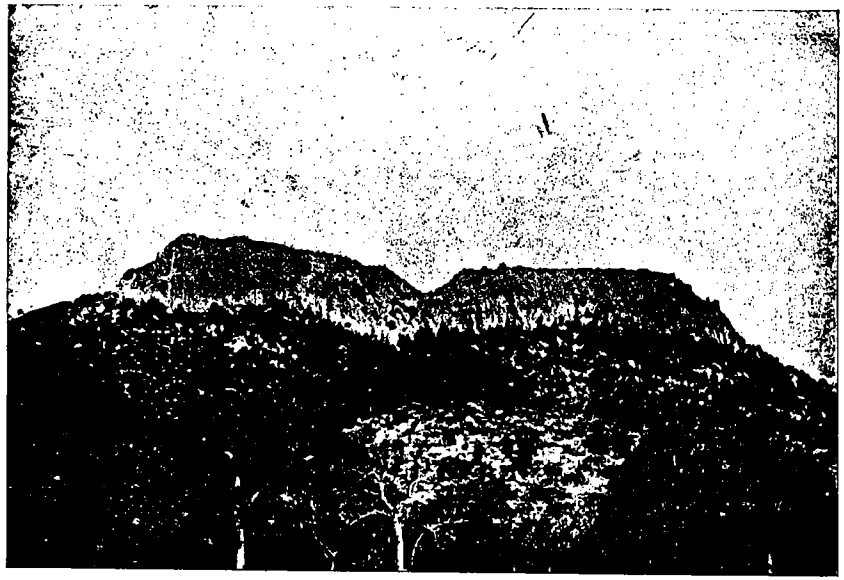
Blue River, Pennington, Rock, and Mill creeks flow southward across the main granite area. These streams all flow in open valleys with moderate gradients. Besides these chief streams there are a number of tributaries which, in open valleys, flow in a southerly direction until they join the main streams.

Outcrops of granite are frequent along or near the stream val-

PLATE XVII.



A. LIMESTONE HILLS NORTH OF MOUNT SHERIDAN, SHOWING THE INTENSELY FOLDED ARBUCKLE LIMESTONE.



B. MOUNT SHERIDAN FROM THE EAST, SHOWING NOTCH IN THE MOUNTAIN CAUSED BY FAULTING, STEEP GRANITE SLOPES ABOVE, AND THE GENTLER WOODED GABBRO SLOPES BELOW.

leys but in the interstream areas the outcrops are small and widely scattered, for on these gentler slopes the granite is covered with a residuum of weathered granite and remnants of the Trinity sandstone.

Where the granite is not concealed by this residual mantle it appears as low mounds or as large oval or flat-topped boulders standing a few feet above the plain. Near the major streams and especially along Pennington Creek, the granite is cut by vertical joints into immense boulders which on weathering stand out as conspicuous local features. (See Pl. XIX-B.)

The granite area embraces about 80 square miles of territory, a large portion, perhaps one-half, of which is still covered by a growth of native timber and is used only for pasture.

GEOLOGY.

All of the igneous rocks of the Arbuckle Mountain district are older than the middle-Cambrian Reagan sandstone which lies unconformably above them. They were, however, uplifted into essentially their present position during the Carboniferous period as is shown by nearly horizontal position of the post-Carboniferous rocks. On the western and northern margins of the main granite area they are usually found in fault contact with the younger sedimentary rocks.

There are here two varieties of granite of commercial importance which constitute the chief portion of the igneous rocks of this district. One, a coarse-grained gray granite known as the Tishomingo granite, and the other a medium to fine-grained gray granite which has been termed the Troy granite.

DISTRIBUTION OF GRANITE.

The larger portion of the commercial granites of the district are found in Johnston County, an area of a few square miles only, being situated in Atoka County to the east. The map, Plate XVIII, shows the distribution of the two types of granite. The coarse-grained variety occupies a north-south belt in the central part of the main area, with the finer-grained variety to the east and to the west. The only quarrying on a commercial scale has been done on Pennington Creek north of Tishomingo and at Troy. Small quantities of granite have also been taken out at Mill Creek, and Ravia.

VARIETIES OF GRANITE.

TISHOMINGO GRANITE.

Commercially there are two distinct types of granite in this district, though they are probably parts of the same intrusive body. In the central portion, bounded roughly by the Blue River on the east and Rock Creek on the west, there is a coarse-grained pinkish-gray biotite granite. The remainder of the main granite area is composed chiefly of a fine-grained pinkish-gray biotite granite.

A. TISHOMINGO GRANITE NORTH OF TISHOMINGO, SHOWING LARGE BARREN UNFRACTURED MASSES OF GRANITE.

B. LARGE GRANITE BOULDERS OF TISHOMINGO GRANITE ON PENNINGTON CREEK NORTH OF TISHOMINGO.

These two varieties are much alike except in texture. The finer-grained variety, contains usually more biotite than the other. The transition from the coarse-grained variety to the fine is rapid, and though it could not be traced completely because of lack of exposure, enough evidence was secured to indicate that the transition was affected through the decrease in the number of large feldspar individuals, and the increase in the number of small quartz and feldspar individuals. As a consequence of these changes the rock in the transition zone becomes distinctly porphyritic.

Examination of five thin sections of granite from the Harris quarry neighborhood 2 miles north of Tishomingo, and of three thin sections of granite from "Ten Acre Rock" on Rock Creek, east of Troy, shows the coarse-grained granite to contain the following minerals: Orthoclase, microcline, albite, quartz, biotite, hornblende, magnetite, titanite, apatite, rutile, zircon, and pyrite, and secondary epidote, sericite, chlorite, and kaolin. The amount of orthoclase varies considerably. It probably nowhere makes up more than half of the feldspar of this granite. At the Harris quarry north of Tishomingo microcline is far more abundant than orthoclase. At "Ten Acre Rock" there is little microcline but orthoclase and albite are the chief feldspars. Oligoclase is present in small amounts at both places. Quartz constitutes 30 to 35 per cent of the coarse granite. Biotite makes up 3 to 5 per cent, while magnetite, pyrite, and titanite are found together and are always present in small amounts. Hornblende and zircon were found only in one instance in a basic segregation. Apatite is usually present in traces. Rutile in needle crystals in quartz is often present. The secondary minerals, epidote, sericite, and calcite were usually present in the sections examined.

In texture this granite is coarse-grained and decidedly inequigranular. The marked features of its texture is the presence of large feldspar crystals often more than 2 cms. across, surrounded by smaller feldspars, quartz, and biotite. Though the feldspars vary in size from .5 cm. to more than 2 cms. there are enough of the larger ones which are several times as large as the quartz and biotite crystals to give the granite a somewhat porphyritic texture. The quartz and biotite are seldom over .5 cms. in diameter.

When fresh the feldspars are gray with a slight pinkish tint, which combined with colorless quartz and black biotite gives a light pinkish-gray rock specked with black. The hammered face gives a light gray effect.

This granite is somewhat brittle and does not readily polish with a smooth surface on account of the biotite scaling off. It has a true specific gravity of 2.701 and a pore space of .345 per cent.

Cubes heated to 1000° F. and cooled slowly were only very slightly cracked and weakened. When heated to 1000° F. and cooled suddenly by immersion in cold water it was somewhat weakened by cracking, the color remaining the same. On heating to redness for 5 minutes and cooling slowly the cube fell to an incoherent mass of quartz and feldspars, which shows it is not well suited to withstand high temperatures. It is suitable stone for structural work and large columns, though its coarse texture makes it undesirable for monumental work.

TROY GRANITE.

When unaltered this granite is colored medium-gray specked with black. Megascopically it shows cleavage surfaces of a gray feldspar usually less than .5 mms. broad, with occasionally a pinkish individual more than 1 cm. across, rounded grains of colorless quartz and many small black specks of biotite evenly distributed.

Microscopic examination of 10 thin sections shows that perhaps 55 per cent of this rock is feldspar, chiefly orthoclase, microcline, and plagioclase, ranging from oligoclase to andesine. Quartz composes about 35 per cent, with biotite about 9 per cent, and magnetite, pyrite, apatite, and zircon making up the remainder. Epidote, calcite, sericite, and chlorite often appear as secondary minerals. The approximate average grain of this granite is 2 mms., but the individuals vary from 1 mm. up to 15 mms. as a maximum.

This granite has a true specific gravity of 2.663 and a porosity of .091 per cent. One trial showed a crushing strength of 15,869 pounds per square inch. Cubes heated to 1000° F. and cooled slowly were not appreciably affected. When heated to 1000° F. and cooled suddenly by immersion in cold water they were appreciably weakened, but not cracked or discolored. When heated to redness for 5 minutes and cooled slowly the cube lost most of its strength and fell to fragments when struck by a slight blow.

This granite takes a good polish and will letter fairly well. Its composition and texture indicate that it is a strong and durable building stone.

STRUCTURE OF GRANITE.

JOINTS.

Everywhere in the main granite area there are at least two strong systems of nearly vertical joints spaced from 2 to 40 feet apart, usually at right angles to each other. They vary in direction in the different parts of the area, but commonly strike N. 40° to 70° W., and N. 20° to 50° E. A third system was noted at the Harris quarry striking N. 30° W., and dipping 65° SW., though these joints are not persistent. Strong sheet joints are found parallel, or nearly parallel, to the slopes of the granite hills. These seldom dip more than 10° to 15°, and are usually spaced 10 to 25 feet apart.

RIFT AND GRAIN.

Rift and grain are noted parallel to the two main systems of vertical joints.

ASSOCIATED ROCKS.

PORPHYRITIC-RHYOLITE MASSES.

There are two small areas of porphyritic rhyolite in the western part of the Arbuckle Mountain district known locally as East and West Timbered Hills. This is a brownish-gray to red porphyritic rock of which 10 per cent is quartz and feldspar phenocrysts, and the remainder finely granular quartz, feldspar, and other undetermined material, resulting from the devitrification of glassy groundmass. Though isolated from the main granite area it appears to be of approximately the same age and to have the same stratigraphic relations to the Cambrian sediments as the granite. Its relation to the granite of this district is not certainly known but the marked similarity of this rhyolite to a dike on Rock Creek east of Ravia indicates that it is the youngest known igneous rock of this district. The dike in question is 25 feet wide, strikes northwest and cuts all other rocks of that area. Though both of these rocks are badly altered, they now appear to be identical in composition and texture.

East and West Timbered Hills do not promise to be of any commercial importance, because of the badly fractured and weathered condition of the rock and because of their inaccessibility to market.

DIKES.

Diabase, gabbro, quartz diorite, aplite-granite, and porphyritic rhyolite dikes cut the granite of this district. As a whole, dikes become more abundant from east to west in the main granite area. The greater number have an approximate east-west direction, though in a number of instances they vary as much as 50° from this direction.

DIABASE-GABBRO DIKES.

The most common dikes found in this district consist of a fine-grained grayish-black to black rock composed of plagioclase feldspar, augite, magnetite, olivine, apatite, and titanite. The individual minerals usually range in size from a fraction of a mm. to about 3 mms. in length. Rarely the borders of the dikes become glassy, in which case they become basalts. In the coarser-grained portion they are often decidedly porphyritic in texture. The medium and coarser grained portions have an ophitic texture.

These dikes usually are vertical, have a general east-west strike and range from a few inches up to 40 feet in thickness. Their prevalence is apparently independent of the type of inclosing granite. As a rule they weather more readily than the inclosing granite, perhaps largely because they are more fractured. Stream erosion

is often less effective in cutting them away than the granite, and as a consequence they stand out as ridges in some stream channels.

QUARTZ DIORITE DIKES.

Only one true quartz diorite dike was observed in the district. It occurs as a vertical 40-foot dike striking S. 70° W., and cutting the fine-grained granite at the excavation along the Chicago, Rock Island & Pacific Railway in sec. 2, T. 3 N., R. 8 E. It is cut by aplite dikes. Megascopically it is a gray-black, medium fine-grained rock which shows gray feldspar and biotite. Microscopic examinations show it to be composed of oligoclase, andesine, hornblende, biotite, quartz, titanite, magnetite, and apatite. Titanite is exceptionally abundant.

APLITE DIKES.

Aplite dikes, though in places somewhat numerous, are never large or persistent. They usually are found ranging from 2 to 8 inches in thickness, and often pinch out or grade into country rock in short distances. Their direction is variable but they usually strike east-west. They are fine-grained and pink-gray in color. Biotite is sometimes present. Albite is an important constituent.

PORPHYRITIC-RHYOLITE DIKES.

But one dike of this type was found. It is located on Rock Creek west of Tishomingo. The dike is 25 feet wide, vertical, and strikes N. 65° W. The weathered, exposed portion has a brick-red to rusty-brown color and shows small phenocrysts of feldspar and quartz in a fine groundmass. The base is composed of fine granular quartz, probably feldspar, and other undetermined material. It is unlikely that the unaltered rock would be a brownish-gray corresponding to similar rocks in the Wichita Mountains.

SEGREGATIONS.

At several localities in both the fine and the coarse-grained granite basic segregations were noted. Sometimes these take the form of sheets or schlieren as at the Harris quarry, and again they are rounded boulder-like masses 10 to 15 feet in diameter. The latter form is found on Rock Creek southeast of Troy, and one-half mile below the reservoir dam on Pennington Creek north of Tishomingo. These differ from the normal granite, it being finer-grained, and more basic. Especially titanite, albite, biotite, magnetite, and apatite are greatly increased. At the Harris quarry considerable hornblende was found in a segregation, the only occurrence of hornblende noted in the district except in the quartz diorite mentioned above. These segregations approach quartz monzonite in composition.

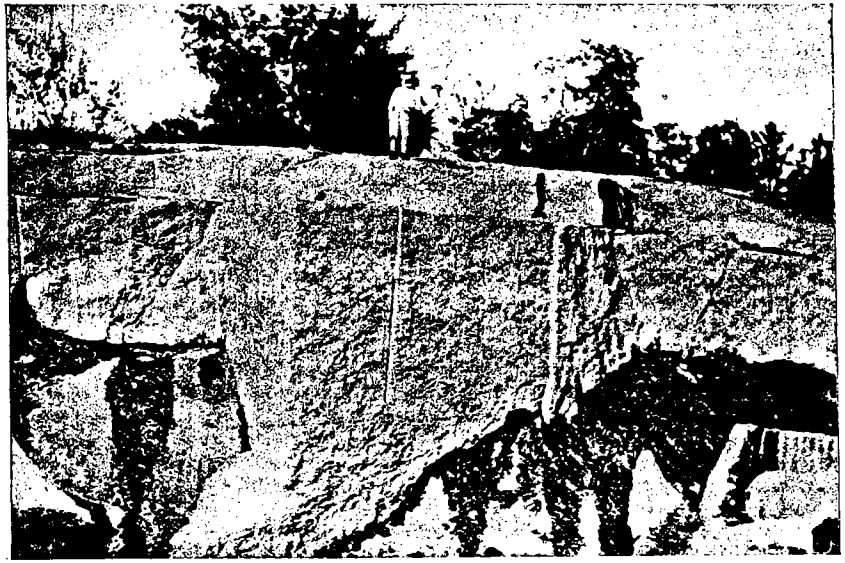
INDIVIDUAL QUARRY AREAS.

TISHOMINGO AREA.

GENERAL DESCRIPTION.

The chief available outcrops of granite in this area occur along Pennington Creek from Tishomingo to the northern borders of the granite area. (See map, Pl. XVIII.) A few good outcrops are found on the west side of Blue River. Outcrops as a rule are in the form of large, gently sloping barren surfaces, or immense boulders as along Pennington Creek. A few like exposures are found away from the streams, but they are limited in area. The greater part of the granite is now covered by residual material. No attempt has been made to open quarries where stripping is necessary. Some good exposures are found west of Blue River,

PLATE XX.



R. M. HARRIS QUARRY TWO MILES NORTH OF TISHOMINGO, SHOWING FRACTURES N THE MAIN QUARRY FACE.

northeast of Tishomingo, but with present conditions for transportation they will not be utilized.

The granite is a coarse-grained gray to pinkish-gray biotite granite. It is cut usually by two systems of fractures into rectangular blocks of large size.

Diabase and granite-aplite dikes having a general east-west strike are prevalent. Several masses of fine-grained granite, some

a few acres in extent, are found in the coarse-grained granite and are thought to be textural varieties of one original magma.

DESCRIPTION OF QUARRIES.

HARRIS QUARRY.

This quarry is situated about 2 miles north of Tishomingo. The quarry site is owned by R. M. Harris. The opening is made on the northeast side of a small ravine. The quarry face is now about 60 feet long and 18 feet high, but at the time it was visited the bottom of the opening, which is several feet below the bottom of the small ravine, was filled with boulders and water so that the lower part of the quarry face could not be seen. The quarry is terminated on the northwest by a diabase dike 14 feet thick, striking S. 50° W., and dipping 85° NW. The strongest joint system strikes S. 50° W., and at the northwest end of the quarry the joint planes dip 85° NW., while at the southeast end they dip 55° NW. Other directions of jointing are N. 55° and 30° W. The former dip 65° SW. Besides these systems of strong joints there is at the northwest end of the quarry a poorly developed fracture system dipping NW. at 15°. All of the joint systems are spaced from 6 to 25 feet apart with a usual range of from 8 to 10 feet. No place was seen where they were closer than 6 feet.

Large smooth fracture surfaces on the quarry face show that the vertical northwest-southeast plane is an easy direction of splitting. Other directions of easy plitting are parallel to the other two strong joint systems. No sheet joints are developed here.

Along the joint planes weathering has extended to the bottom of the cut, but in some of the larger masses there is unaltered granite almost at the surface. Near the surface the weathered or sap rock is usually 2 to 3 feet thick, but at the bottom of the quarry it is much thinner.

The granite here is the normal type of coarse-grained pinkish-gray biotite granite described in detail above. A few lense-shaped basic segregations were noted. Bands of fine-grained dark basic minerals 2 to 6 inches thick are occasionally shown on the quarry face. This irregularity in color and texture is sufficient to disqualify that part for any use except riprap and rubble. The waste from this source is not great. On weathering the biotite is leached of its iron and this deposited on its surface stains the granite a dirty greenish yellow.

This quarry when in operation was equipped with one 20-horsepower engine, one air compressor, one surfacer, and one derrick.

Transportation is by wagon over a hilly road 2 miles to Tishomingo as a shipping point.

Stone from this quarry has been used in the construction of the R. M. Harris bank buildings at Tishomingo, and the first story of

the government buildings at Ardmore, Guthrie, and Oklahoma City. This quarry has been idle for more than 3 years, excepting a short while during the early part of 1911, when stone was secured for the government building at Oklahoma City.

Altered surface rock from an outcrop 200 yards southwest of the Harris quarry was used in the Johnston County court house at Tishomingo. A few bright fresh blocks used in this building show their superiority over the weathered, dirty yellow stone used in the remainder of the building.

RAVIA AREA.

GENERAL DESCRIPTION.

The granite in the vicinity of Ravia outcrops in small, badly fractured masses along the small creeks east and northeast of town. The area is well wooded and has a rolling topography.

A small amount of granite has been quarried for local use but because of its fractured condition the granite will probably never be quarried on a large commercial scale. The rock is a fine-grained gray biotite granite, composed of orthoclase, microcline, albite, quartz, biotite, titanite, magnetite, and apatite, with commonly secondary epidote, sericite, and kaolin. On weathering some of the feldspars become pink. This granite has an even, granular, texture. Quartz is more abundant than in the coarse-grained variety. Numerous fractures with variable strikes cut the granite into irregular angular blocks seldom over 5 feet broad.

TROY AREA.

GENERAL DESCRIPTION.

The town of Troy is situated on an almost flat plain lying between the broken country along Rock Creek on the east and Mill Creek on the west. Along these creeks there is much timber.

There are a few outcrops of granite on the level plain but most of the granite is found near the creeks. Fractures are not so numerous as in the Ravia area. Along Mill Creek diabase dikes are abundant. Some large unfractured masses may be found on both creeks. In the area west of Troy small irregular dikes of granite or aplite are very numerous, and the chief difficulty in finding quarry sites will be in getting stone free from these dikes. They are about the same color as the inclosing rock but the texture is finer.

All of the granite west of Rock Creek is the fine-grained gray biotite granite, similar to that of the Ravia area. There is a small area of Tishomingo granite east of Rock Creek which is most easily reached from Troy.

DESCRIPTION OF QUARRIES.

CAPITOL QUARRY.

The large barren mass of Tishomingo granite outcropping about 2 miles east of Troy, known as "Ten Acre Rock" has furnished a small amount of the coarse-grained gray biotite granite for local use, and granite for the new State Capitol Building at Oklahoma City is now being quarried here. The outcrop of 5 or 6 acres stands 15 to 25 feet above its surroundings. It is cut by two systems of joints spaced 100 to 200 feet apart. At a small opening on the south side of the mass the granite appears to be fairly fresh at a depth of 2 feet beneath the surface. Segregations in the form of thin lenses of biotite are numerous. The texture is inequigranular and roughly porphyritic. The larger feldspar crystals are often 2 cms. broad. The finer quartz and feldspar are not evenly distributed but have an irregular bunch arrangement. Microscopic examination shows it to contain the same constituents as found elsewhere in the district, but albite feldspar is more abundant than is usual for the coarse-grained granite. Derricks and drills were installed during the fall of 1915, to quarry rough stone for the State Capitol Building. No finishing is done at the plant.

In secs. 19, 29, and 30, T. 2 S., R. 5 E., there are masses of slightly fractured fine-grained, gray, biotite granite which are easily accessible, and should furnish good sites for opening quarries. The rock is fine-grained gray with rarely a large crystal of pinkish feldspar. Very little of this granite has been put on the market, but in certain respects it is superior to the Tishomingo granite as a structural stone and, besides, is suitable for monumental and paving purposes.

WAPANUCKA AREA.

GENERAL DESCRIPTION.

Though Wapanucka is not situated on the granite area it is at present the logical shipping point for all the granite area east of the Blue River. This area at present has no granite quarries. There are two good reasons why this will not soon become an important granite producing area. First, the granite is so closely fractured that no good site for a quarry is likely to be found. Second, the granite outcrops are so far from shipping points as to make hauling prohibitive.

The granite is a fine-grained gray biotite granite composed of orthoclase, microcline, albite, quartz, and biotite, with accessory magnetite, titanite, and apatite.

The grain is not entirely even for there are a few widely scattered crystals of pinkish feldspar which are much larger than the remainder of the constituents.

The rock here is about the average type of Troy granite. The

composition, color, and texture indicate a granite of good quality, which should repay working on a small scale to supply local demand.

SUMMARY.

In summarizing the economic data collected in this bulletin several facts should be brought clearly to the attention of the reader The variety of granite with respect to color and texture is probably of first importance. The colors of the commercial granites of Oklahoma are: flesh-red, rose-red, reddish-brown, light-gray, pinkish-gray, and bluish-black to black. In texture they are classed as: very fine-grained, fine-grained, medium-grained, and coarse-grained, all of which are more or less even-textured. Judged on the basis of color and texture, there are at least a dozen commercial varieties of good granite to be found in the State

Tests of direct crushing strength and transverse crushing strength show that Oklahoma granites rank very favorably with other commercial granites of the United States. The tests of direct crushing strength range from 15,000 pounds per square inch up to 38,000 pounds per square inch for representative samples of the chief granites of the State. The granites having the most desirable color and texture for monumental and building stone usually have a crushing strength from 16,000 to 21,000 pounds per square inch.

Large quantities of granite of good quality are easily accessible to transportation facilities. In most cases little or no stripping is required to secure marketable stone. The spacing of vertical and horizontal joints is usually favorable to securing well-shaped blocks of stone of any size desired. There are a few varieties of granite which are so much fractured that large dimension stone cannot be secured, but monumental stone of superior quality sometimes is secured from such quarries.

Granites from Oklahoma have been put to a considerable variety of uses. The rose-red and flesh-red medium-grained granites quarried at the town of Granite have been used largely for monumental stone, rough building stone, paving blocks, riprap, and crushed stone. The brownish-red fine-grained granite quarried northwest of the town of Granite has been used chiefly for monumental stone and riprap. The gray and pinkish-gray medium-grained granite quarried at the Reformatory southeast of the town of Granite are used for monumental stone, rough and finished building stone, riprap, and crushed stone. The very fine-grained dark-gray granite quarried at Cold Springs has been used largely for monumental stone, paving blocks, riprap, and crushed stone. The bluish-black medium-grained granite quarried at Cold Springs has been used for monuemntal and rough building stone. The brownish-red and pinkish-gray fine-grained granites at Mountain Park

have been used for monumental and building stone. The coarse-grained gray granite quarried at Tishomingo and Troy has been used for large columns, and for rough and finished building stone.

The greater part of the monumental stone quarried in Oklahoma has gone to the dealers in Oklahoma, northern Texas, southern Kansas, and to Michigan City, Indiana. The granite for the new State Capitol Building at Oklahoma City is being secured two miles east of the town of Troy. The granite for the post-office building at Oklahoma City was quarried two miles north of Tishomingo. A number of other buildings in Oklahoma and adjoining states have been constructed in part of Oklahoma granite.

The lack of capital for the purchase of equipment, and a general lack of information concerning the quality of Oklahoma granite appear to be responsible for the slow development of the granite resources of Oklahoma. It is believed that this industry gives promise of becoming one of the most important in the State.

Value of granite produced in Oklahoma, 1901-1913.

Year.	Value.
1901	$12,000(e)
1902	11,970
1903	9,030
1904	32,082
1905	20,720
1906	18,847
1907	24,550
1908	23,239
1909	67,584
1910	102,566
1911	20,244
1912	14,460
1913	30,678

e. Estimated.

List of Oklahoma quarries, with brief statement of the character of the granite quarried at each.

Name of operator.	Location of quarries.	Character of Granite.			Uses.	Operating 1915.
		Class.	Color.	Texture.		
Cold Springs Granite Company	Cold Springs.	Hornblende-biotite granite or quartz monzonite.	Medium-gray.	Very fine-grained.	Monuments, building stone, crushed stone, paving blocks.	Yes.
	Cold Springs.	Augite gabbro.	Dark-gray.	Medium to coarse-grained.	Monuments, building stone.	No.
Gardner Quarry Company	Granite.	Hornblende granite.	Flesh-red.	Medium to coarse-grained.	Monuments, building stone, paving blocks.	No.
Harris Quarry Company	Tishomingo.	Biotite granite.	Light-gray, with pinkish tinge.	Coarse-grained, slightly porphyritic.	Building stone, large columns.	No.
J. M. Hazel	Mountain Park.	Hornblende granite.	Gray and red.	Fine-grained.	Monuments, building stone, paving blocks, crushed stone.	No.
C. Jecks (abandoned)	Mountain Park.	Hornblende granite.	Grayish-red.	Fine-grained.	Monuments, building stone, paving blocks	No.
Thos. L. Eggleston	Granite.	Hornblende granite.	Flesh-red.	Medium to coarse-grained.	Monuments, building stone, paving blocks.	No.

List of Oklahoma quarries, with brief statement of the character of the granite quarried at each.

Name of operator.	Location of quarries.	Character of Granite.			Uses.	Operating 1915.
		Class.	Color.	Texture.		
Oklahoma Granite Company	Granite.	Hornblende granite.	Flesh-red.	Medium coarse-grained.	Monuments, building stone, paving blocks.	No.
Oklahoma Granite and Monument Company	Cold Springs.	Hornblende-biotite granite or quartz monzonite.	Medium to dark-gray.	Very fine-grained.	Monuments, building stone, paving blocks, crushed stone.	No.
Parsons Brothers Granite Company	Mountain Park.	Hornblende granite.	Grayish-red.	Fine-grained.	Monuments, building stone, paving blocks,	No.
Roosevelt Black Granite Company	Roosevelt.	Hornblende-biotite granite.	Medium-gray to dark-gray.	Very fine-grained.	Building stone, paving blocks. crushed stone.	No.
Ruggles Quarry Company	Granite.	Hornblende granite.	Flesh-red.	Medium to coarse-grained.	Monuments, building stone, paving blocks.	No.
Southwestern Granite Company	Granite.	Hornblende granite.	Flesh-red.	Medium to coarse-grained.	Monuments, building stone, paving blocks,	No.
State Reformatory Quarry	Granite.	Hornblende granite.	Violet to pinkish-gray.	Medium-grained.	Monuments, building stone, crushed stone.	Yes.

List of Oklahoma quarries, with brief statement of the character of the granite quarried at each.

Name of operator.	Location of quarries.	Character of Granite.			Uses.	Operating 1915.
		Class.	Color.	Texture.		
New Montello Granite Company	Granite.	Hornblende-biotite granite.	Brownish-red to flesh-red.	Fine-grained.	Monuments, building stone, cobble and crushed stone.	Yes.
John M. Hazel	Cold Springs.	Gabbro.	Groy to bluish-gray.	Medium-grained.	Monuments.	Yes.
Capitol Quarry	Troy.	Biotite granite.	Gra yto pink-ish-gray.	Coarse-grained.	Building stone.	Yes.

GLOSSARY OF SCIENTIFIC AND QUARRY TERMS.

Accessory minerals in granite are original constituents of the rock, found only in small, often only in microscopic quantity.

Anticline. A term applied to granite sheets or sedimentary beds that form an arch.

Aplite. Fine-grained granite, usually occurring in dikes and containing little mica and a high percentage of silica.

Basic. A term applied to rocks in which the iron-magnesia minerals and feldspars with lime and soda predominate, such as diabase or basalts.

Boulder quarry. One in which the joints are either so close or so irregular that no very large blocks of stone can be quarried.

Channel. A narrow artificial incision across a mass of rock, which, in the case of a granite sheet, is made either by a series of continuous drill holes or by blasting a series of holes arranged in zigzag order.

Cleavage, when applied to a mineral, designates a structure consequent upon the geometrical arrangement of its molecules at the time of its crystallization.

Close-jointed. A term applied to joints that are very near together.

Crush-border. A microscopic granular structure sometimes characterizing adjacent feldspar particles in granite in consequence of their having been crushed together during or subsequent to their crystallization.

Cut-off. Quarrymen's term for the direction along which the granite must be channeled, because it will not split. Same as "hard-way."

Dike. A mass of granite, diabase, basalt, or other rock which has been erupted through a narrow fissure.

Dimension stone. A term applied to stones that are quarried of required dimensions

Dip. The inclination from the horizon, given in terms of degrees, of a sheet, joint, heading, dike, or other structural plane in a rock.

Erosion. The wearing away of portions of a rock by such natural agencies as stream or ice action.

Exfoliation. The peeling of a rock surface in sheets owing to changes of temperature or other causes.

Faulting. The slippage of a rock mass or masses along a natural fracture.

Flow structure. The parallel arrangement of the minerals in granite or other igneous rock in the direction of its flowage during its intrusion.

Grain. A quarryman's term to denote the direction of splitting only less easy than the rift, the rift being the direction of easiest splitting.

Hematite. The red iron oxide, Fe_2O_3 often widely disseminated in red granite and often formed in the weathering of the magnetite.

Igneous. A term applied to rocks that have formed by the solidification on cooling of a mass of molten rock material.

Joints. Strong, more or less continuous natural fractures cutting the granite at various angles.

Kaolin. A hydrous aluminium silicate, usually formed in the weathering of the feldspars.

LIMONITE. A hydrous iron oxide, yellowish to brown in color and formed in the weathering of minerals containing considerable amounts of iron.

MILLIMETER. The French decimal linear measure, the thousandth part of a meter, the tenth part of a centimeter. It is equivalent to nearly .04 inches.

MICROPERTHITE. An intimate intergrowth of orthoclase and albite.

OPHITIC. A rock texture in which well formed elongated crystals of feldspar are enclosed in imperfectly developed crystals of pryoxene.

PEGMATITE. A very coarse granite, found in dikes or lenses.

PLAGIOCLASE. A term applied to all the soda-lime feldspars.

POIKILITIC. A rock texture in which numerous small crystals are evenly distributed in a larger crystal.

POLARIZED LIGHT. Light which vibrates in only one plane.

POLARIZING MICROSCOPE. A microscope that polarizes the light used in the identification of minerals.

PORPHYRITIC. A rock texture in which some large crystals occur in a mass (groundmass) of finer material.

RIFT. A quarryman's term for an obscure microscopic fracturing in granite which facilitates quarrying.

SAP. A quarryman's term for the partly altered and discolored rock at the surface or along joint planes.

SCHIST. A thinly laminated, metamorphic rock which splits more or less readily along certain planes, approximately parallel.

SECONDARY MINERALS. Minerals which have formed through the alteration of original minerals.

SEDIMENTARY. A term designating those rocks which are composed of particles that have been deposited by water or wind.

SEGREGATION. In a rock, a mass of mineral matter unlike the surrounding material and which has been gathered in from adjacent material.

SERICITE. A fine, flaky form of muscovite formed in the alteration of the feldspars or other minerals.

SLICKENSIDES. The polished grooved surfaces along a fracture, the result of motion and friction.

SPECIFIC GRAVITY. The weight of a body compared with the weight of an equal volume of pure water at 4° C.

STRATIFIED. A term applied to rock consisting of beds or strata.

STRIKE. The direction at right angles to the direction of maximum inclination of a plane of bedding, dike, or joint.

STRIPPING. The removing of the sand, gravel, and disintegrated granite from the surface of the firm granite in the quarry.

WEATHERING. The decomposition of a rock owing to the action of the weather.

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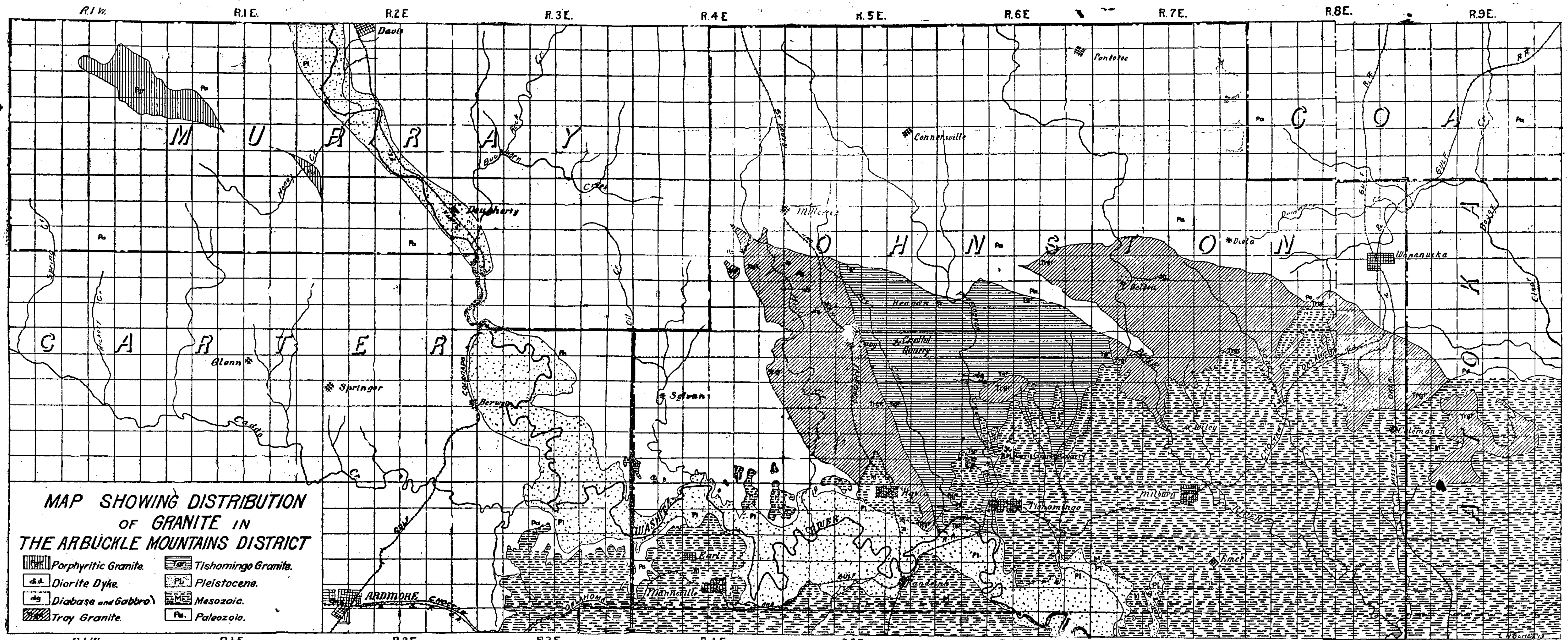
MAP SHOWING DISTRIBUTION
OF GRANITE IN
THE ARBUCKLE MOUNTAINS DISTRICT
Porphyritic Granite.
Diorite Dyke.
Diabase and Gabbro
Troy Granite.
Tishomingo Granite.
Pleistocene.
Mesozoic.
Paleozoic.
R.1 E.
R.2 E
R.3 E.
R.4 E
R.5 E.
R.6 E
R.7 E.
R.8 E.
R.9 E.
T.1 S.
T.2 S.
T.3 S.
T.4 S.
MURRAY
CARTER
JOHNSTON
COAL
Davis
Dougherty
Pontotoc
Connersville
Wapanucka
Glenn
Springer
Berwyn
Sylvan
Tishomingo
Milburn
Ardmore
Randolph
Coleman
Emet
Washita River

PLATE XVIII.

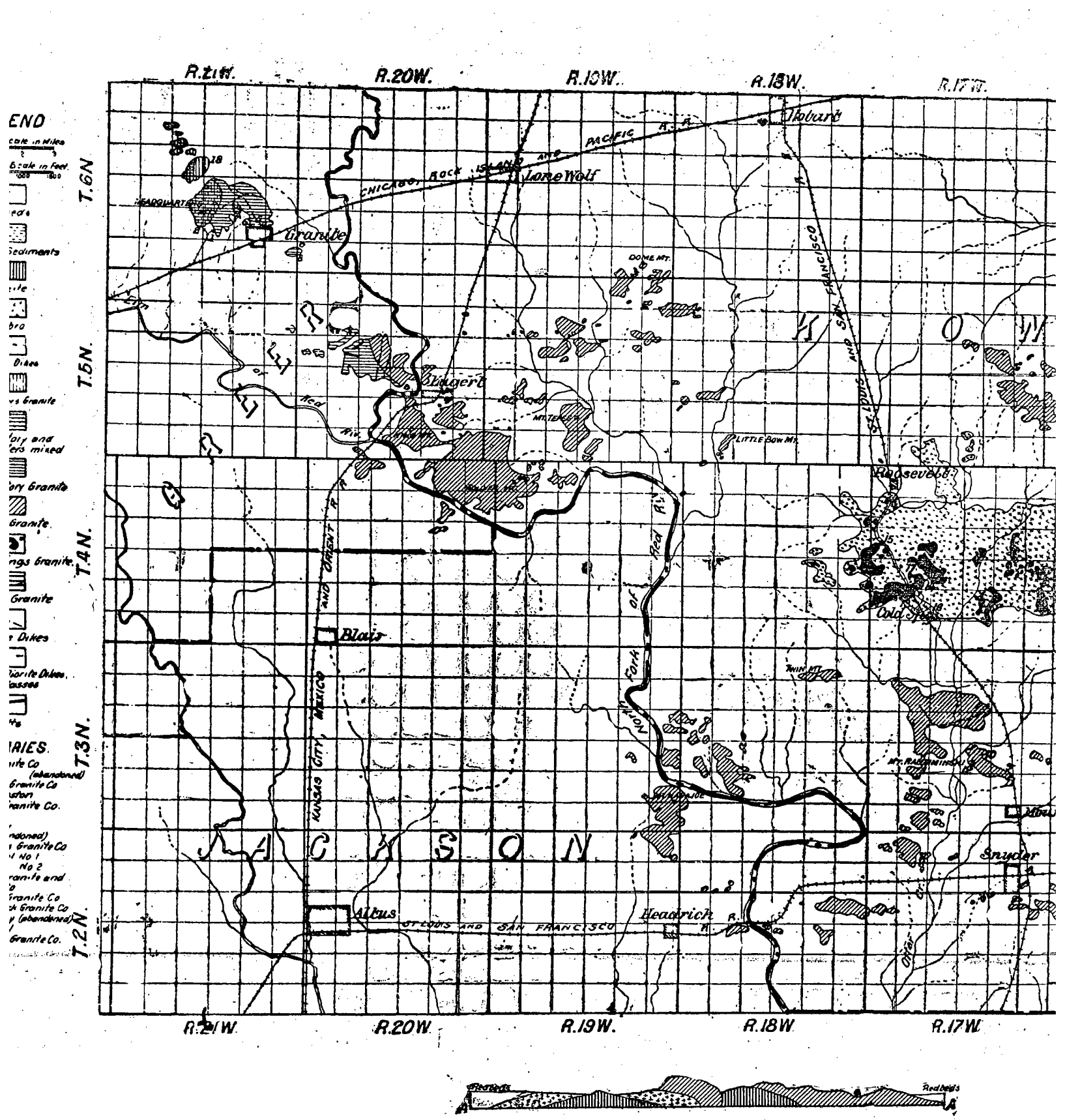
R.21W.
R.20W.
R.19W.
R.18W.
R.17W.
T.6N.
T.5N.
T.4N.
T.3N.
T.2N.
Granite
Lone Wolf
Hobart
Vigeria
Blair
Altus
Roosevelt
Cold Spring
Snyder
Headrick
JACKSON
KANSAS CITY MEXICO AND ORIENT R.
NORTH FORK of Red R.
CHICAGO, ROCK ISLAND AND PACIFIC R. R.
ST. LOUIS AND SAN FRANCISCO
DOME MT.
MT. TERRELL
LITTLE BOW MT.
TWIN MT.
MT. RADERMINOU
Redbeds
Redbeds

PLATE I.

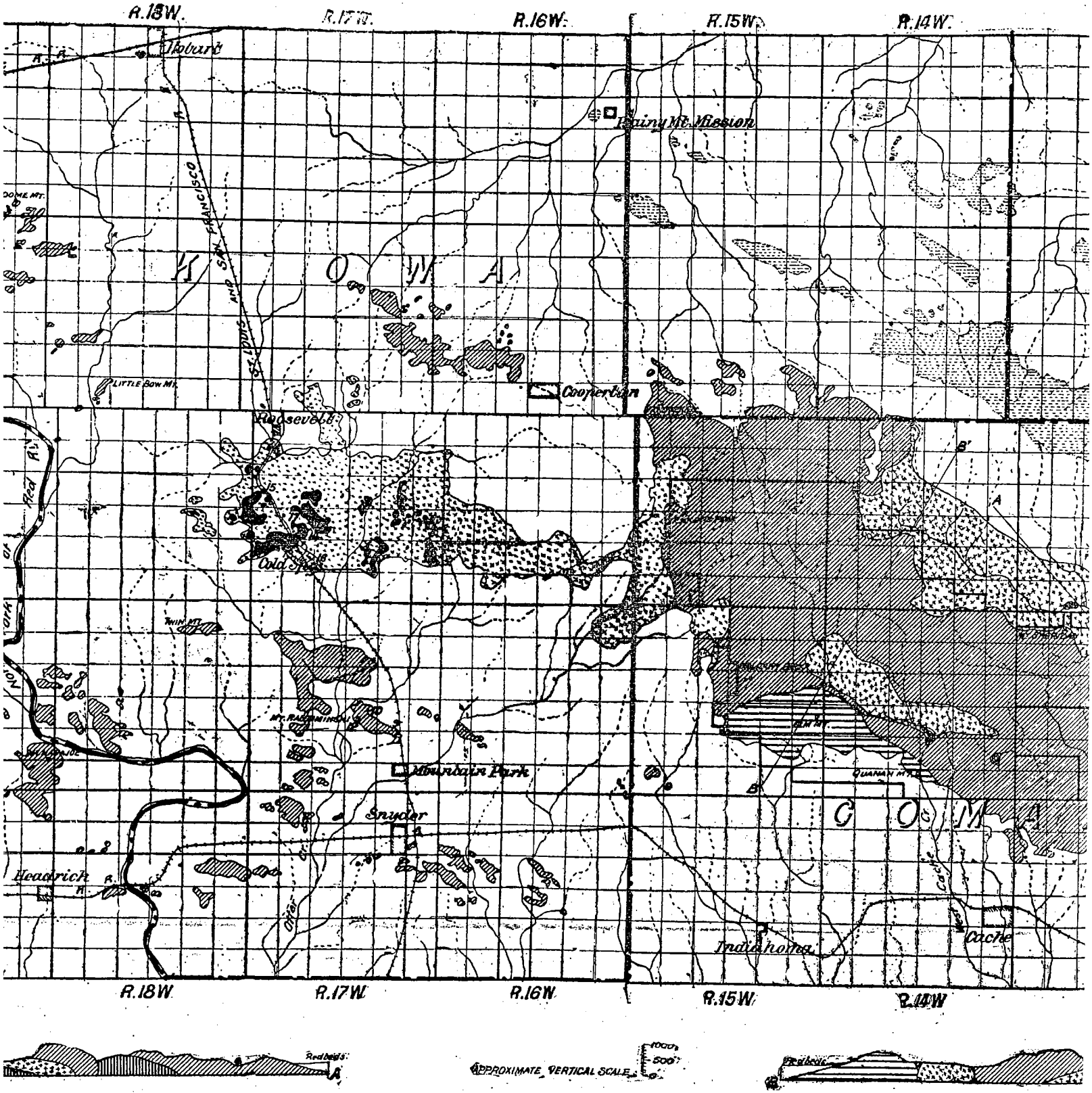
R.18W.
R.17W.
R.16W.
R.15W.
R.14W.
Okbarb
Rainy Mt. Mission
DOME MT.
OKLAHOMA
ST. LOUIS AND SAN FRANCISCO
LITTLE BOW MT.
Cooperton
Roosevelt
Red R.
Cold Spring
TWIN MT.
MT. RAINEY
Mountain Park
Snyder
Headrick
Otter Cr.
COMANCHE
QUANAH MT.
Indianola
Cache
Redbeds
APPROXIMATE VERTICAL SCALE
1000'
500'

PLATE I.