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Comparative Studies of Oklahoma and Missouri Granites with Special Attention to the Heavy Minerals of the Oklahoma Granites

Russell B. Maurer

COMPARATIVE STUDIES OF OKLAHOMA AND MISSOURI GRANITES

with

Special attention to the Heavy Minerals

of the Oklahoma Granites

By

Russell B. Maurer

A Thesis

Submitted to the Department of Geology

in Partial Fulfillment of the

Requirements for the Degree of

Bachelor of Science

Montana School of Mines

Butte, Montana

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ABSTRACT

When examined petrographically the granites of Oklahoma show a marked similarity to the granites of Southeastern Missouri. The same heavy accessory mineral suites are present in the granites of both regions and include: fluorite, zircon, apatite, titanite and epidote. This similarity was further shown by the actual correlation of the heavy mineral suites by types, these types being based on the heavy mineral distributions of the Missouri Granites.

These data, together with the relationships reported in the field, strongly suggest a common origin for the granites of these two regions.

INTRODUCTION

During the month of October, 1947 Professor Forbes Robertson of the Montana School of Mines made a rapid

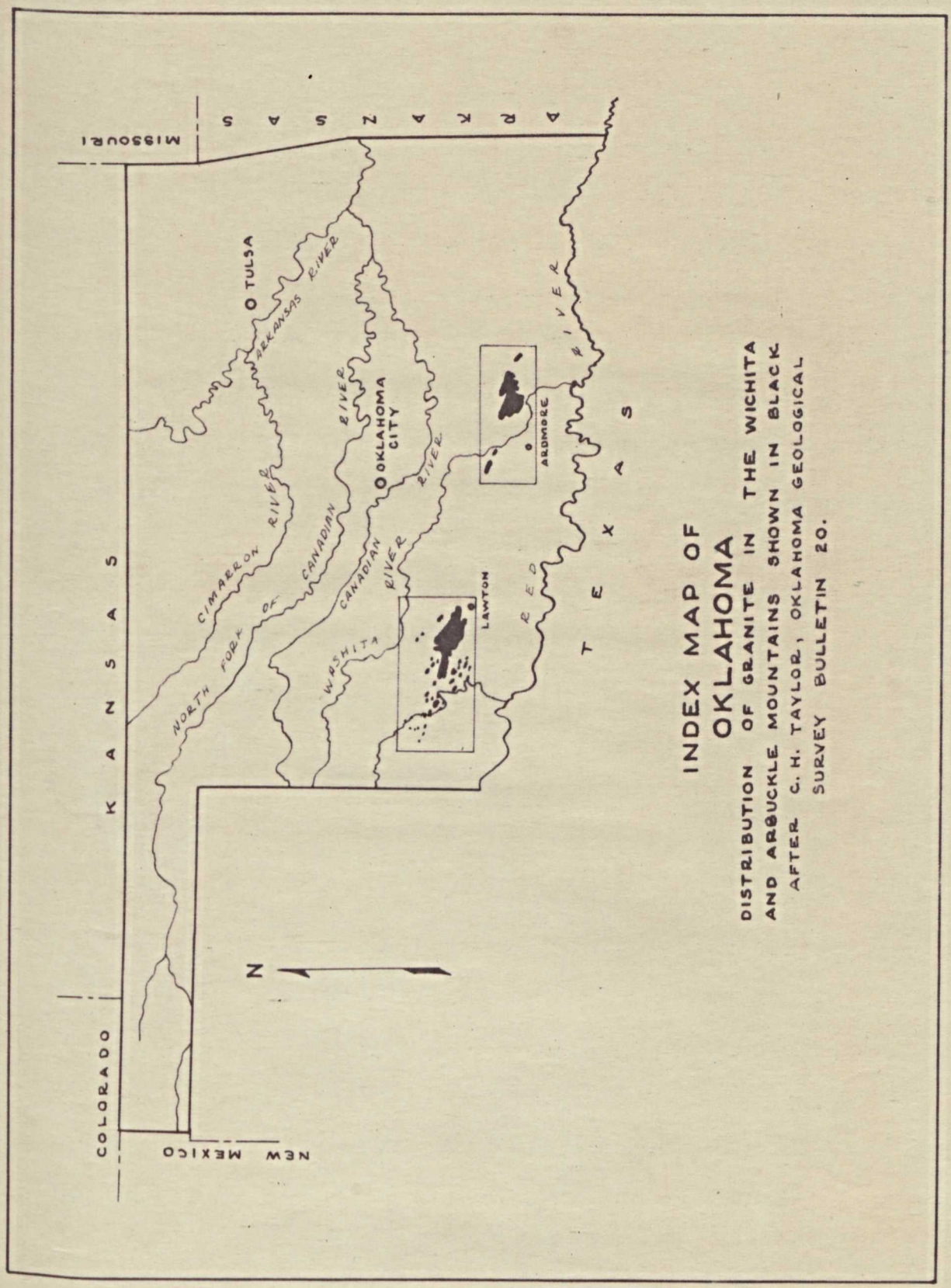
examination of the igneous rocks of the Witchita and Arbuckle Mountains of Oklahoma (Plate I). The comparison of these rocks to the pre-Cambrian granites of Missouri was the purpose of this examination. The igneous rocks of the Witchita and Arbuckle Mountains were found to be so similar in attitude, rock types, composition and age relations to those of the St. Francois Mountains of Missouri that a common origin for the two was immediately suggested.

This paper deals exclusively with the granites of the region and a comparison with similar types found in Missouri.

The heavy minerals in the Missouri granites have been described by Carl Tolman and H.L. Koch (13). The types reported by them are used as a basis for the comparison of the granites of the Wichita and Arbuckle Mountains and those of Missouri.

ACKNOWLEDGEMENTS

The writer is especially indebted to Professor Robertson for stimulating the interest of the writer in this problem and for the invaluable guidance and aid rendered during the project. Gratitude is also extended to Washington University for carrying out the heavy mineral separations and to Doctor Eugene S. Perry of the Montana School of Mines for reading and criticizing the paper.



INDEX MAP OF OKLAHOMA

DISTRIBUTION OF GRANITE IN THE WICHITA AND ARBUCKLE MOUNTAINS SHOWN IN BLACK

AFTER C. H. TAYLOR, OKLAHOMA GEOLOGICAL SURVEY BULLETIN 20.

THE PROBLEM

Because of the megascopic similarities between the pre-Cambrian granites of the St. Francois Mountains and the granites exposed in the Wichita and Arbuckle Mountains of Oklahoma, a common source of origin is suggested. This is also indicated by the close agreement in the microscopic descriptions of the granites of Missouri by Tolman and Koch and of the granites of the Wichita and Arbuckle Mountains by C.H. Taylor (12). Therefore, the primary objective of this thesis was a study of the heavy accessory mineral suites of the various granites of Oklahoma with the thought in mind that the heavy mineral assemblages might be similar to those of the Missouri granites, and this should provide an additional means of correlating the granites of the two regions. Thin sections of the Oklahoma granites were also studied so that they could be compared mineralogically with the Missouri granites.

LABORATORY PROCEDURE

Since thin sections made at the School of Mines were not satisfactory, time and temper were saved and better thin sections were obtained by having them made by a skilled technition.

The thin sections, studied with a petrographic microscope, showed microscopic textures, essential, acces-

sory and secondary minerals, and the optical properties of the various minerals were recorded where possible. The albite-anorthite ratio of the plagioclase present in each rock was determined. The approximate grain size of the minerals making up each granite was determined by a calibrated grid eyepiece. To determine the percentages of the various minerals making up each granite, seven traverses were run across each thin section with a Wentworth Traveling Stage. The percentages of the various minerals present in each granite and the albite-anorthite ratio made possible classification of the granites according to Johannsen's Quantitative Mineralogical Classification (5).

Fortunately, heavy mineral separations had been prepared on all but two of the granite samples to be studied. The heavy fraction had been further separated into highly-magnetic, magnetic and non-magnetic fractions. The weight of each constituent of the heavy fraction and the original weight of the sample were furnished with the separations. However, two heavy mineral separations were made by the writer. About 200 gram samples of the granites were crushed, pulverized and screened to a 170 -155 mesh particle size, and the crushed material was weighed and the weights recorded.

Separation of the heavy minerals was accomplished by heavy liquid, bromoform, which has a specific gravity of 2.88. The crushed and screened material was added slowly

to bromoform contained in a separatory funnel. Mineral grains with a specific gravity less than that of the bromoform were floated at the surface, while those grains with a higher specific gravity sunk to the bottom of the funnel. The heavy fraction was drawn off through the cock at the bottom of the funnel and subjected to a second separation to free any light mineral grains that might have adhered to the heavy ones. The heavy fraction was drawn from the second separatory funnel, filtered, thoroughly washed with alcohol and allowed to dry.

To recover the used bromoform the light fraction was filtered from it, and the liquid was thoroughly washed with water.

The heavy fraction obtained by this process was then weighed and the weight recorded. At this point it was desirable to further separate the heavy fraction into non-magnetic, magnetic and highly-magnetic fractions. A small horseshoe magnet was used to separate out the highly-magnetic material, but the magnetic minerals were not separated from the non-magnetic minerals because of the lack of certain desired equipment.

Microscopic slides were prepared by mounting the three heavy mineral fractions in Canada balsam for subsequent study.

The minerals comprising each fraction were determined optically, using where necessary the index, shape, color, pleochroisin, relief, extinction angle and birefringence for positive identification.

PLATE II

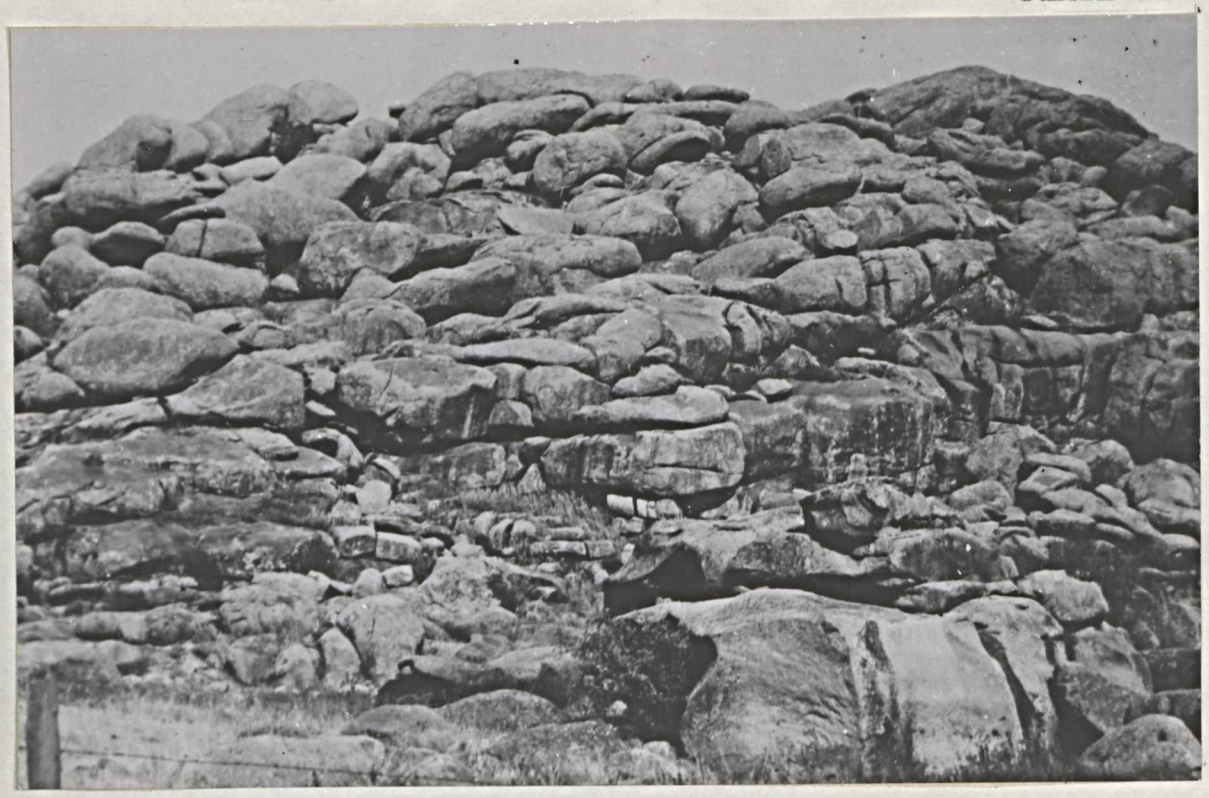
Surface Outcrops of Lugart Granite

A. Lenticular or sub-prismatic weathered blocks of Lugart Granite. Boulders at top of hill show "cracked skin" effect. NE. cor. SE¼ sec. 19, T. 5N, R. 18W, Kiowa County, Wichita Mountains, Oklahoma.

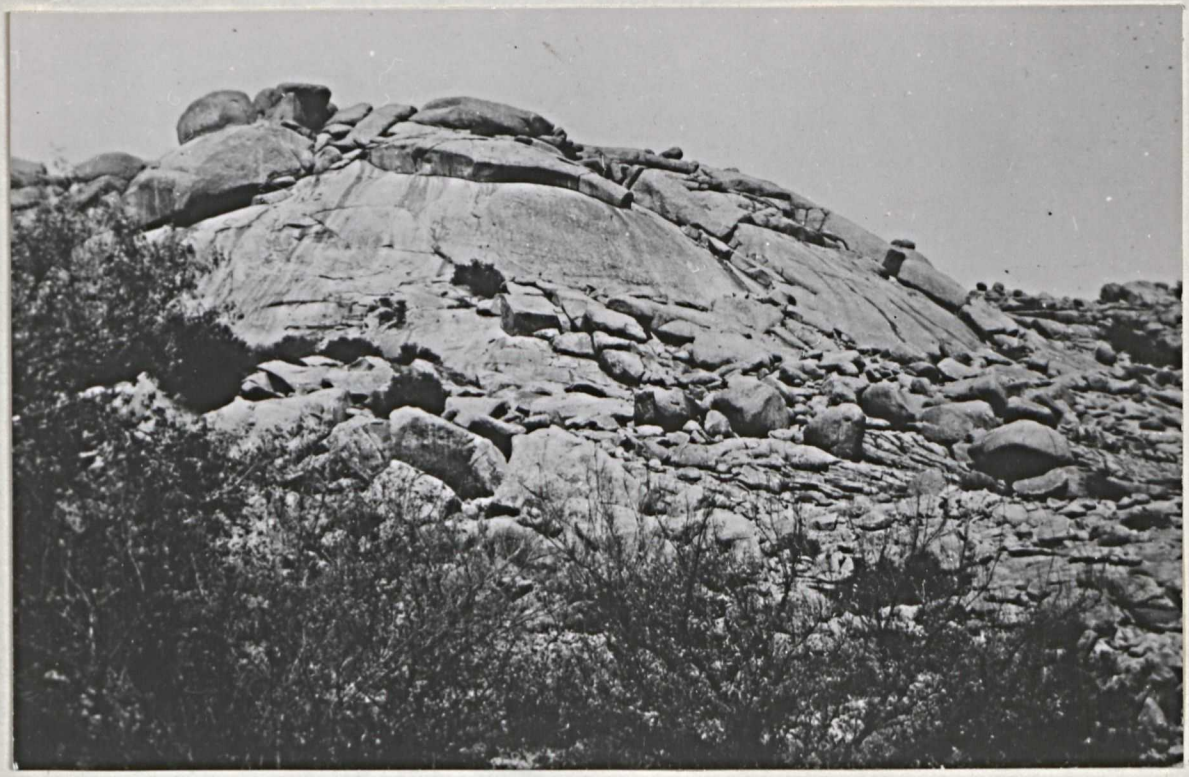
B. Exfoliation or spalling of massive granite knob about 2 miles northwest of Mountain Park, Oklahoma, Wichita Mountains.

Courtesy Forbes Robertson.

PLATE II



A.



B.

Surface Outcrop of Lugart Granite

To determine the mineral composition of the heavy mineral concentrate, a mineral particle count was made on each slide containing the non-magnetic fraction. No count was made of the highly-magnetic or magnetic fraction; however, the minerals present in these fractions were noted. Counting the grains of the non-magnetic fraction was accomplished by the use of a grid eyepiece and a Wentworth Traveling Stage. When approximately 200 mineral grains were counted on each slide, the percentages of each mineral comprising the non-magnetic fraction were calculated and plotted as histograms to clearly show the relative abundance of each constituent (Plate 9). The index figure (4), that is, the percentages of heavy minerals exceeding the specific gravity of bromoform in a given rock, was calculated for each sample.

THE GRANITES OF THE WICHITA AND ARBUCKLE MOUNTAINS

The granites of the Wichita and Arbuckle Mountains of Oklahoma have been studied, described and mapped in a general way by C.H. Taylor (12). Plates X and XI show the various granites as determined and mapped by Taylor in the Arbuckle and Wichita Mountains respectively. Since this report is limited to the description of a relatively few scattered samples taken from these two regions, the reader is referred to Taylor's paper for a more complete descrip-

tion of the granites and their occurence in these regions.

Of the approximately 175 collected samples of the igneous rocks of this region only 13 will be dealt with in this paper. Points from which the samples were taken are shown on the accompanying maps and are marked by an identifying number such as 853-21-1; "853" refers to the Missouri Geological Survey Notebook in which a brief field description and point of location is noted; "21" denotes the page in the notebook on which the data is recorded, and "1" denotes a specific sample on that page.

For comparative purposes a brief petrographic description of the Missouri granites is given in Appendix I.

Description of Accessory Minerals

The granites of the Wichita and Arbuckle Mountains are characterized by a relatively low index figure. This figure for the granites studied ranged between 2.08 and 9.41. The average of 4.71 is slightly higher than that of 3.64 for the granites of Missouri and is probably due to a slightly higher ferromagnesian mineral content of the Oklahoma granites.

Heavy accessory minerals identified in these granites include magnetite, fluorite, zircon, apatite, titanite, epidote, pyrite, leucoxene, biotite, hornblende and riebeckite.

The percentage of magnetite is not as great as that of the Missouri granites. In the granites of Oklahoma the ferromagnesian minerals are generally the predominant fraction of the heavy accessories; however, in some of the

samples the percentage of magnetite does compare favorably to that of the Missouri granites.

Fluorite is the most abundant mineral of the non-magnetic assemblages (PLATE IX). It makes up about 65 percent of the non-magnetic heavy mineral fractions of the granites of which it is the predominant non-magnetic heavy mineral. This is slightly less than the 75 to 98 percent of the Missouri granites. Grains of fluorite are mostly irregular but show perfect octahedral cleavage in some. Many grains show a violet tinge and rarely a yellow coloring, but colorless grains are the most common. Numerous randomly oriented acicular inclusions were noted in a few grains, and some of the fluorite particles showed surface stains of limonite and hematite.

Zircon is present in varying degrees in nearly all the granites studied. Generally it is more abundant than it is in the Missouri granites. Most of the zircons are of the normal variety (PLATE III, A and B), but some are brown in color, and many are iron stained. There is a large variation in size and shape. Some are stubby with their length about equal to their width, while some are long with their length approximately three times their width (PLATE III, A and B). A few zone specimens were noticed (PLATE III, C), and one zoned crystal seemed to approach the malacon variety. Numerous inclusions were present in many of the zircon crystals. Most of the zircon crystals were combinations of a first order prism (110) and pyramid (111);

however, a few ditetragonal-dipyramidal crystals were noted. None of the "cracked variety" as described by Tolman and Koch were noticed in any of the Oklahoma samples.

Apatite is present in small amounts or absent in all of the granites except the Troy Granite of the Arbuckle Mountains (853-21-1) where it is about 75 percent of the non-magnetic fraction. Many of the grains are fragments, but long hexagonal crystals with irregular ends were observed. The grains are generally quite clear, but several were noticed to contain inclusions which formed hazy blue bands running across the crystals perpendicular to the crystalographic axis.

Grains of epidote are very difficult to distinguish. The granular clusters are nearly opaque, and optical properties were practically impossible to obtain. The determination of epidote was based on its greenish color, moderate relief, granular form and its similarity in appearance to altered feldspar. Epidote, or what was thought to be epidote, is present in every granite sample in varying amounts. Rarely a clear light green grain of epidote was noticed.

Titanite is abundant in one sample from the Arbuckle Mountains (853-29-1). Grains are dark brown in color and pleochroic to lighter tans. Most of the grains are irregular to wedge shaped and display a concoidal fracture.

Other heavy accessories listed are present only to minor degrees.

For a detailed description of the heavy accessory mineral suites of each of the Oklahoma samples the reader is referred to Appendix II

Petrographic Description

Microscopically the granites of Oklahoma are also similar to those of Missouri. The same essential minerals are present and have the same percentage distributions. The essential minerals quartz, orthoclase, plagioclase, perthite and microcline make up about 95 percent of the granites. Plagioclase is present in varying degrees from one or two percent to 20 percent and falls within the albite-lower oligoclase range.

Characteristic of the Oklahoma granites is a low ferromagnesian mineral content, seldom exceeding five percent. Biotite is the principal dark mineral with small amount of hornblende being present. Riebeckite is also present.

The ordinary alteration products are present and identified as kaoline, sericite, chlorite, pennine and leucoxene. Accessory minerals include minor amounts of zircon, apatite, epidote, magnetite, fluorite and titanite.

Texturally nearly all the granites are hypautomorphic granular with excellent displays of granophyric and micropegmatitic intergrowths of quartz and orthoclase.

A detailed petrographic description and classification is given in Appendix II.

A STATISTICAL COMPARISON BETWEEN THE MISSOURI AND OKLAHOMA GRANITES

Since it is often quite difficult to look at two histograms such as those on PLATE IX and determine whether two heavy mineral suites are similar and to what degree, a statistical method of comparison was resorted to. It is recognized that the formula used may have some inherent faults and may not hold up under all conditions; but never-the-less it does furnish a means of expressing varying degrees of similarity between heavy mineral suites.

The formula used here is one proposed by Lincoln Dryden in which a "coefficient of correlation" r is calculated for the two heavy mineral suites being compared.

$$r = \frac{\Sigma(XY) - nM_x M_y}{\sqrt{(\Sigma(X^2) - nM^2_x)(\Sigma(Y^2) - nM^2_y)}}$$

Σ is the sign for the summation of that to which it is prefixed.

n is the number of pairs of percentages to be used.

M is the mean of that to which it is prefixed.

X is any percentage from sample A.

Y is the corresponding percentage from sample B.

By squaring the "coefficient of correlation" r, a figure can be obtained which expresses the similarity of the two suites as a definite percentage.

Since zero and negative values of r can be obtained,

Robertson suggests that the formula be modified to:

$$r = \frac{\Sigma(XY)}{\sqrt{(\Sigma(X^2))(\Sigma(Y^2))}}$$

In TABLE I the "coefficient of correlation" has been calculated by both formulae to show the degree of similarity in the suites being compared.

CONCLUSIONS

It has been shown that the heavy accessory minerals present in the Oklahoma granites are of the same species and have the same distribution as those of the Missouri granites. Fluorite, zircon, apatite, titanite, and epidote are the most abundant non-magnetic heavy minerals in the granites of both regions. The Tishmingo granite of the Arbuckle Mountains with its high titanite content compares favorably with the Missouri Type C. The Lugart granites of the Wichita Mountains due to their high fluorite content compare favorably with the Missouri Type A. Two samples of Lugart granite, because of their high index figure, show a similarity to Type D. Close agreement between the Reformatory granite of Oklahoma and one doubtful sample of Lugart granite and Type F is evident. Close correlation is shown between the Spavinaw granite and Type E.

This similarity between the various granites of both regions is further shown numerically in TABLE I. The degrees

TABLE I

A STATISTICAL COMPARISON OF

OKLAHOMA AND MISSOURI GRANITES

Oklahoma Granites			Missouri Granites		Dryden	Robertson
Number	Index Number	Name	Type	Index Number	r^2(%)	r^2(%)
853-21-1	4.08	Troy	-	-	No correlation	
853-29-1	6.03	Tishmingo	C	7.5	91.2	94.5
853-33-1	8.68	Lugart	D	7.5	64.7	77.5
			A	2.6	91.2	92.0
853-41-1	9.41	Lugart	D	7.5	69.5	78.9
853-45-2	2.27	Lugart	A	2.6	83.6	86.2
853-47-2-1	2.83	Lugart	B	216	71.3	73.2
			A	2.6	76.8	77.7
853-47-2-4	3.02	Lugart	A	2.6	92.6	92.1
853-57-2-2	4.54	Lugart	F	3.2	78.6	80.6
853-59-1	4.82	Reformatory	F	3.2	98.9?	78.1
853-61-1	4.00	Reformatory & Headquarters	-	-	No correlation	
853-71-3-1	2.08	Quanah	A	2.6	89.0	91.2
853-75-1	14.7	Spavinaw	E	6.4	67.4	72.4

of similarity are strikingly high, ranging from 67.4 percent to 92.6 percent with many in the 80 to 90 percent bracket.

Varietal features of the zircons were the same in the Oklahoma and Missouri granites. Most zircons were of the normal variety with numerous inclusion, and zoned specimens were also present.

When studied petrographically the similarity of the granites within the two regions is further shown.

The same essential minerals are present in about equal quantities in all the granites: quartz, orthoclase, plagioclase, perthite and microcline. Soda-rich plagioclase in small amounts is characteristic of all the granites, with most of it falling in the albite-lower oligoclase range.

The ferromagnesian mineral content of the Oklahoma granites is low, as it is in the Missouri granites and is generally restricted to biotite and small amounts of hornblende and almost always chlorite.

Texturally the granites of Oklahoma and Missouri are nearly identical; striking granophyric and micropegmatitic intergrowths of quartz and orthoclase are present in the granites of both regions.

Although the granites of Missouri were not classified by Johannsen's system, from the microcopic descriptions given by Tolman and Koch, it is evident that they would fall into the same groups as the Oklahoma granites. This is also a significant point of similarity.

On the basis of the evidence presented here and the

evidence presented in the field, there is a strong suggestion that the granites of the Wichita and Arbuckle Mountains, Spavinaw, Oklahoma and those of Southeastern Missouri are of the same origin and age relationship.

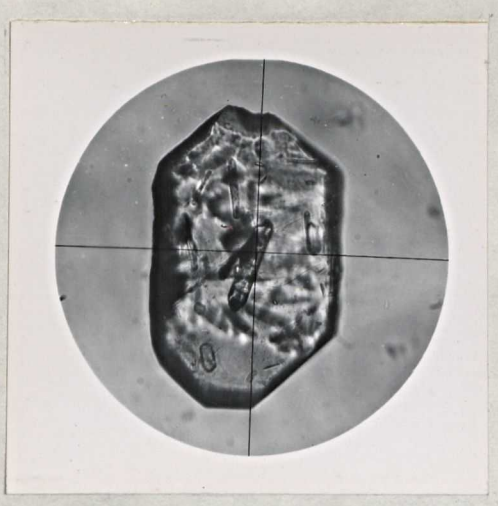
PLATE III

Zircons from the Lugart and Reformatory Granites

A. Normal zircon of the stubby variety showing numerous inclusions, Reformatory Granite, (853-59-1), x200.

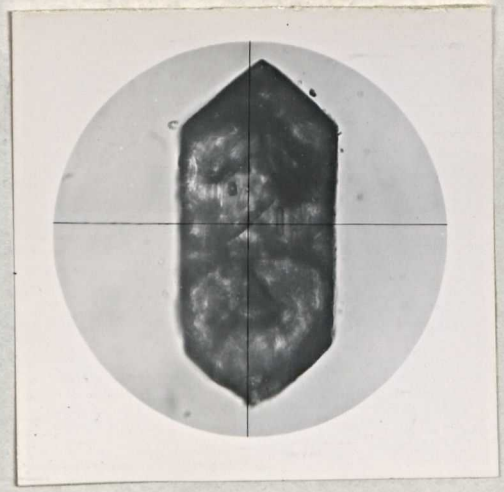
B. Normal zircon of the long clear varity from the Lugart Granite, (853-57-2-2), x200.

C. Zoned type zircon crystal from the Reformatory Granite, (853-59-1), approaching the malacon variety, x200.



A.

B.



C.

Zircons from the Lugart and Reformatory Granites

PLATE IV

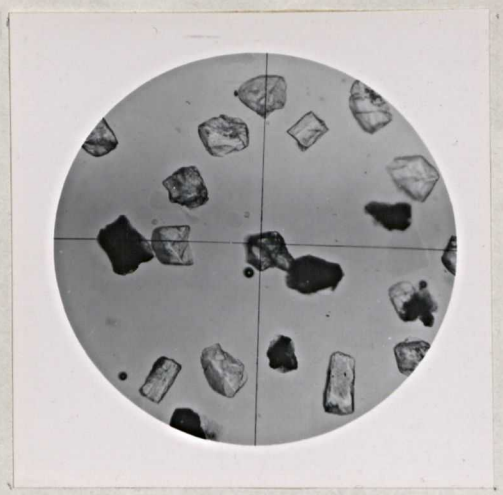
Heavy Mineral Suites of the Troy, Tishmingo, Lugart and Quanah Granites.

A. Heavy mineral assemblage from the Troy Granite, (853-21-1), Showing irregular and barrel shaped apatite grains and dark epidote grains, x15.

B. Heavy mineral assemblage from the Tishmingo Granite, (853-29-1). Medium dark abundant grains are titanite; epidote, apatite and zircon are also presetn, x15.

C. A typical heavy mineral suite from the Lugart type granite, (853-41-1), predominantly fluorite with zircon and apatite present, x15.

D. Fluorite grains showing good octahedral cleavage and zircon from Quanah Granite, (853-71-3-1), x15.



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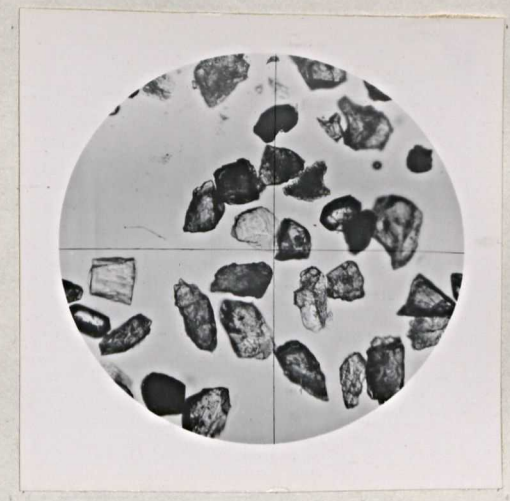
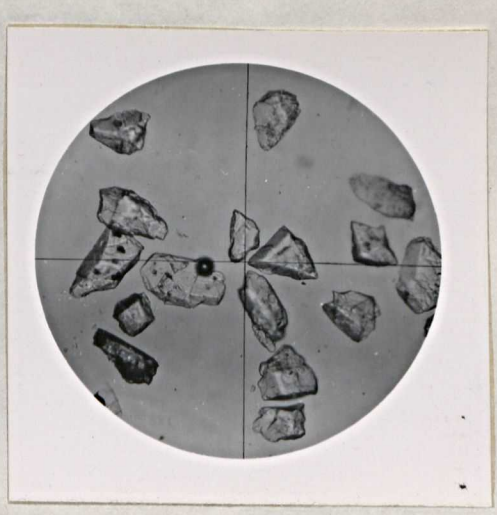


B.

C.



D.

Heavy Mineral Suites of the Troy,
Tishmingo, Lugart and Quanah Granites

PLATE V

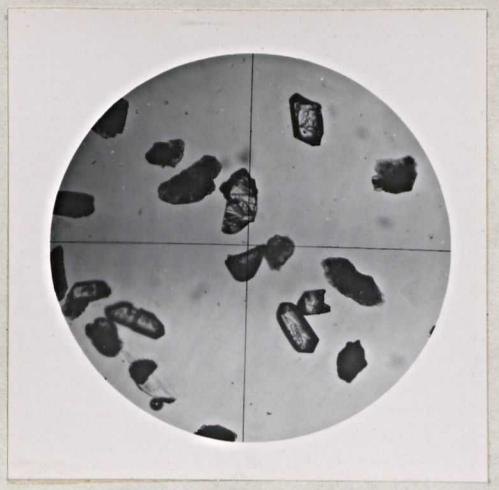
Heavy Mineral Suites of the Lugart, Reformatory and Spavinaw Granites

A. Zircon and epidote from the Lugart Granite, (853-57-2-2), x15.

B. Long, Stubby, zoned and normal zircon from the heavy mineral suite of the Reformatory Granite, (853-59-1), x15.

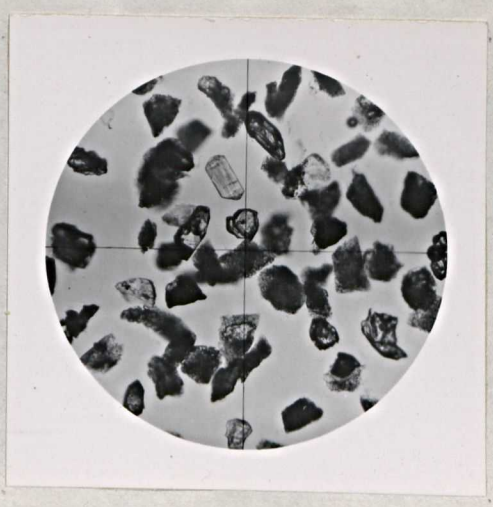
C. Heavy mineral assemblage from the Spavinaw Granite, (853-75-1), Clear barrel shaped crystal is apatite, zircon as euhedral grains while the most abundant mineral present is epidote, hazy dark grains.

PLATE V



A.

B.



C.

Heavy Mineral Suites of the Lugart,
Reformatory and Spavinaw Granites

PLATE VI

Photomicrographs of Troy, Tishmingo and Lugart Granites

A. Hypautomorphic granular texture of the Troy Granite, (853-21-1), quartz, altered orthoclase and plagioclase, x15.

B. Tishmingo Granite, (853-29-1), showing microcline, biotite altering to chlorite, magnetite, fluorite and rhombic titanite crystal, x15.

C. Microperthite and riebeckite in Lugart Granite, (853-33-1), x15.

D. Hypautomorphic granular texture, Lugart Granite, (853-41-1), x15.

A.

B.

C.

D.

Photomicrographs of Troy, Tishmingo and Lugart Granites

PLATE VII

Photomicrographs of Lugart Granite

Granophyric and micropegmatitic intergrowths of quartz and orthoclase displayed in a majority of the Lugart Granites, x15.

A. Lugart (853-45-2)

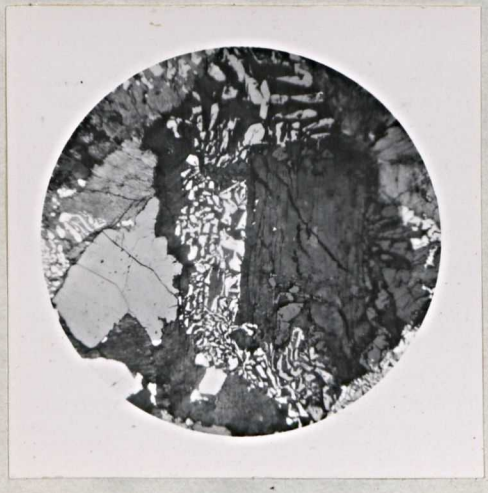
B. Lugart (853-47-2-1)

C. Lugart (853-47-2-4 Red)

D. Lugart (853-47-2-4 Green)

A.

B.



C.

D.

Photomicrographs of Lugart Granite

PLATE VIII

Photomicrographs of Reformatory, Quanah, Lugart, Reformatory and Headquarters Mixed and Spavinaw Granites

A. Microperthite, Reformatory Granite, (853-59-1), x15.

B. Microperthite, Quanah Granite, (853-71-3-1), x15.

C. Quartz, plagioclase, microperthite and chlorite from the Lugart Granite, (853-57-2-2), x15.

D. Granophyric and poikilitic textures in the Reformatory and Headquarters Mixed Granites (853-61-1), x50.

E. Micropegmatitic intergrowths of quartz and orthoclase showing false crystals of quartz, Spavinaw Granite, (853-75-1), x50.

A.

B.

C.

D.

E.

Photomicrographs of Reformatory, Quanah, Lugart Reformatory and Headquarters Mixed and Spavinaw Granites

APPENDIX I

HEAVY MINERAL AND PETROGRAPHIC DESCRIPTIONS OF THE MISSOURI GRANITES

For a detailed description of the granites of Missouri the reader is referred to Tolman and Koch's paper. However, for purposes of comparing the granites of Oklahoma to those in Missouri, a brief description of the Missouri granites will be presented here.

Description of Accessory Minerals (13)

The Missouri granites are characterized by a comparatively low index figure (4). Because of the small amounts of ferromagnesian minerals in the Missouri granites the average index figure is 3.64.

Heavy accessory minerals present in the Missouri granites include magnetite, fluorite, zircon, apatite, titanite, epidote, zoisite, rutile, cassiterite, brookite, pyrite, chalcopyrite, arsenopyrite, galena, molybdenite, garnet, leucoxene, spinel and topaz.

Magnetite is the most abundant with fluorite second. The grains of fluorite are irregularaly shaped and may show cleavage. Though most of the fluorite grains are colorless, some show blotches of purple, blue and yellow; some are iron stained, whereas inclusions are prominent in others.

Zircon is present in nearly every type granite in varying amounts. While color of the zircon is quite variable, most are of the colorless normal variety. Pronounced zoning is present in some of the crystals. Inclusions are present in a great many of the normal variety (15). A few of the malacon variety were noted.

Apatite is not abundant in any of the Missouri granites except those near the vicinity of Rosselle. Crystal fragments are the most common form, although some grains are long barrel-shaped hexagonal crystals seldom showing terminated ends. The color differs greatly, but the clear variety is the most abundant. Some of the apatite crystals show gray bands running across the crystal, due to countless dark inclusions.

Titanite occurs in abundance in the granites near Rosselle. It is easily identifiable by the wedge-shape grains and strong pleochrism.

Epidote is widely distributed and occurs in all the Missouri granites. It usually is in the form of granular masses and appears to be an alteration of feldspar.

Classification (13)

After an extensive study of 127 samples of granites Tolman and Koch were able to distinguish six types of

granites on the basis of their index numbers and the relative amounts of minerals comprising the non-magnetic heavy accessory mineral fraction. These types are designated as type A, B, C, D, E and F. The mineral distribution of each of these types is shown in PLATE IX.

Type A This granite has a low index figure, averaging 2.6. Fluorite is abundant, averaging 92.5 percent. The average amount of zircon is low, amounting to 3.6 percent. Apatite is rarely present. Small amounts of pyrite, galena, rutile, molybdenite, epidote, zoisite, garnet, spinel, titanite and leucoxene were also noticed. Nearly 60 percent of the total heavy fraction is magnetite.

Type B Granites of this type differ from Type A in that appreciable quantities of apatite are present. The percentage of zircon is slightly higher than that of Type A, while the percentage of fluorite is slightly less.

Type C The index figure for these granites is high and averages 7.5. Sixty percent of the non-magnetic accessories is titanite. Apatite averages about 16 percent. Fluorite and zircon are rarely present. Pyrite, galena, garnet, topaz, epidote and zoisite are also present in minute quantities.

Type D The index figure for these granites is also quite high and averages 7.5. Fluorite makes up 59 percent of non-magnetic heavies. Small amounts of zircon and apatite are present. Epidote averages about 32 percent. Titanite, leucoxene, galena and pyrite are present in minor amounts.

Type E The index figure is moderately high for these granites, being 6.4. The abundance of epidote is a distinguishing feature. Fluorite, zircon, apatite and titanite are present in minor amounts.

Type F The abundance of zircon, 26 to 55 percent, and low index figure, 3.2, characterize this type. Fluorite, apatite, titanite and epidote are present in about equal amounts of 12 percent. Garnet, topaz, galena, pyrite and leucoxene are also present in variable amounts.

Petrographic Descriptions (13)

Since the primary objective of Tolman and Koch's paper is the classification of the Missouri granites by the heavy mineral assemblages, a detailed petrographic description of the granites is not included in the report. Because the Oklahoma granites were microscopically studied and compared petrographically to those granites of Missouri, a brief petrographic description of the Missouri granites is included here for comparative purposes.

Type A Most of the granites show a hypautomorphic granular texture, some approaching a porphyritic fabric. The average grain size is 3 to 5mm. Microcline, albite, orthoclase and perthite constitute the feldspars present which with quartz make up 98 percent of the rock. Granopyric intergrowths of quartz and orthoclase are present. Kaolin and sericite are the alteration products of all the feldspars. Biotite is the principal ferromagnesian mineral present and shows early stages of chloritization.

The mafites average less than 3 percent of the rock. Titaniferous magnetite is evidenced by an abundance of leucoxene. Megascopically these granites are medium to coarse-grained, composed essentially of quartz and orthoclase and minor amounts of mafics.

Type B Granites of this type are similar to Type A both microscopically and megascopically.

Type C These granites also show a hypautomorphic granular texture with an average grain size between 1.5 and 2mm. Quartz, albite, orthoclase and perthite make up about 92 percent of the rocks. Hornblende is the most abundant of the mafic minerals, which include biotite, magnetite and titanite, and make up about 8 percent of the rocks. The presence of the accessory minerals, titanite and apatite is distinguishing.

Granites of this type are medium to coarse-grained in hand specimen. The feldspars are pink and gray, and there is a greater abundance of dark minerals than in the granites of Types A and B.

Type D Type D granites are also hypautomorphic granular but finer grained than the previous Types. Average grain-size is 0.3mm. Granopyric intergrowths are evident to minor degrees. Perthite is very abundant, averaging 40 percent, quartz amounts to about 35 percent and plagioclase ($Ab_{88}An_{12}$) to about 25 percent. Hornblende is the principal ferromagnesian mineral and makes up from 7 to 40 percent of the rocks. Alteration products of chlorite, epidote, sericite, kaolin, leucoxene and iron oxides are present.

Megascopically these granites are fine-grained and slightly darker than those of Type A.

Type E The grain sizes of this type range from 0.5 to 3mm. Texturally they are hypautomorphic granular and porphyritic. About 7 percent of the rock is hornblende and biotite, the remainder being albite, perthite and quartz. The feldspars are highly altered as also is the hornblende and biotite.

Mottled masses darker in color and finer in texture than the granite matrix occur in this medium to coarse-grained light-gray granite.

Type F Wide variations are shown in the granite of this type; however, a moderately coarse grain is the only characteristic feature.

APPENDIX II

HEAVY MINERAL AND PETROGRAPHIC DESCRIPTIONS OF THE OKLAHOMA GRANITES

Description of Accessory Minerals

To supplement the histograms of the Oklahoma granites, PLATE IX, a description of the heavy mineral suites of each sample will be presented. Field names used are after Taylor, and the points from which the samples were obtained are shown on PLATES X and XI. For the exact locations from which the samples were obtained the reader is referred to Missouri Geological Survey Notebook 853.

853-21-1 (Troy Granite) This granite from the Arbuckle Mountain area has an index figure of 4.08. The highly-magnetic fraction is 71 percent of the heavy accessories and is composed predominately of magnetite with some limonite and hematite. The magnetic fraction makes up about 24 percent of the heavies and is mostly biotite with minor amounts of hornblende. Some quartz grains coated with limonite and hematite are also present in this fraction. Of the non-magnetic fraction apatite is the most abundant, amounting to 75.5 percent and epidote amounting to 23.6 percent (PLATE IV, A) is the second most abundant mineral.

Traces of fluorite and zircon are also present.

The grains of apatite show some randomly oriented inclusions while some show the blue bands previously described.

Because of the high percentage of apatite, the heavy mineral assemblage of this granite does not show any similarity to the heavy mineral assemblages of the Missouri granites.

853-29-1 (Tishimingo Granite) This granite from the Arbuckle Mountains has an index figure of 6.03. Fifty-five percent of the heavy minerals are highly-magnetic, magnetite. Biotite comprises the magnetic fraction which is about 36 percent of the heavies. The non-magnetic fraction contains titanite, 67 percent; epidote, 16.1 percent; apatite, 12.3 percent; zircon, 2.4 percent and fluorite, 2.4 percent (PLATE IV, B). The mineral percentages and index number agree so closely with theType C granites of Missouri that correlation between the two is strongly suggested(PLATE IX).

853-33-1(Lugart Granite) This granite and the remaining ones to be described are from the Wichita Mountains (PLATE XI). The index figure for this specimen is 8.68. The highly-magnetic fraction contains hematite and is 21 percent of the heavies. The amphiboles riebeckite and hornblende compose the magnetic fraction which is 73 percent of the total heavies. The non-magnetic fraction is

composed of 71 percent fluorite, 24 percent zircon and 5 percent epidote. The zircons are of the short, stubby variety, and some show zoning. On the basis of mineral distribution this granite is similar to Missouri Type A; however, the high index figure suggests a similarity to Type D.

853-41-1 (Lugart Granite) This granite also has a very high index figure, 9.41. Hematite, the predominant mineral of the highly magnetic fraction, is 30 percent of the heavies. Hornblende and some epidote make up the magnetic fraction which is 60 percent of the heavies. Zircons are normal (PLATE IV, C). Of the non-magnetic fraction, 69.3 percent is fluorite, 23.4 percent is zircon and 7.4 percent is epidote. As does sample 853-33-1, this granite shows a possible correlation with Missouri Types A or D.

853-45-2 (Lugart Granite) A low index figure, 2.27, and mineral assemblage very similar to Type A point to a possible correlation between the two. Thirty-six percent of the heavies, consisting of magnetite and some epidote are highly-magnetic. Sixty percent of the heavies is hornblende. Non-magnetics are fluorite 66 percent, zircon 30 percent and epidote 4 percent. Most of the zircons are nearly opaque, stubby, length two times width, and some may be of the malacon varity.

853-47-2-1 (Lugart Granite) The index figure for this granite is 2.83. Separations of the various degrees of magnetic susceptibility were not made; therefore, no percentages for these fractions can be given. Of the non-magnetics fluorite comprised 58.5 percent, apatite 1.5 percent, zircon 6.3 percent and epidote 33.7 percent. A trace of pyrite was also noticed. The fluorite present in this sample showed a light violet color in the thicker portions of the grains. Randomly oriented inclusions were also noted in the fluorite. Because of the apatite content and the low index figure this granite correlates very closely with either Type A or B.

853-47-2-4 Red (Lugart Granite) A low index figure of 3.02 is characteristic of this granite. The highly-magnetic fraction is nearly all hematite and is 81 percent of the heavies. Hornblende and chlorite make up the magnetic fraction which is 18 percent of the total heavy accessory minerals. There is 67 percent fluorite, 20.1 percent zircon and 12.9 percent epidote in the non-magnetics. Nearly all the fluorite grains possess a bluish violet cast. Zircons are of the normal type showing some inclusions; both stubby and long ones were noted. There is a pronounced similarity between this heavy mineral suite and Type A of Missouri.

853-57-2-2 (Lugart Granite) The index figure for this specimen is 4.54. The highly-magnetic fraction is 23 percent of the heavies while the magnetic fraction is 76 percent. The non-magnetic fraction can be broken down into

zircon 59.6 percent, epidote 35.4 percent, fluorite 2.8 percent, and there are traces of apatite and tourmaline. The zircons are illustrated on PLATE V, A. Both the index figure and the mineral assemblage of this granite show close agreement with Type F.

Because the mineral distribution is so different from any of the other Lugart granites and so similar to the analysis of 853-59-1, which is a sample of the Reformatory Granite, the writer is led to believe that this sample may be Reformatory instead of Lugart granite. The close proximity of the sample to the contact between the two granites might point to a slight error in the mapping of this area.

853-59-1 (Reformatory Granite) The index figure for this granite is 4.82. The highly-magnetic fraction, consisting of magnetite and hematite, make up 40 percent of the heavy minerals. The percentage of hornblende and biotite in the heavies is 58 percent. Zircon and epidote are the primary non-magnetic heavies, amounting to 84.9 percent and 15.6 percent of this fraction respectively (PLATE V, B). This granite correlates very closely to Type F described by Tolman and Koch.

853-61-1 (Reformatory and Headquarters Granites Mixed) Two heavy mineral separations were made on this sample in an attempt to determine the non-magnetic minerals. No non-magnetic minerals were recognized in either separation; hence, it is impossible to correlate this granite with any of the Missouri types on this basis. Hornblende and biotite were the only recognizable heavy minerals. Index figure is 4.0.

853-71-3-1 (Quanah Granite) The index figure 2.08 and the percentages of non-magnetic heavy minerals would seem to place this granite in the group of Lugart Granites. Forty-eight percent of the heavies is magnetite, and 50 percent is nornblende and biotite. A typical Type A non-magnetic mineral suite is shown in the specimen (PLATE IV, D); fluorite is 71.4 percent, zircon is 24.5 percent, and epidote is 4.1 percent. Most of the zircons are normal, however, about 30 percent show distinct zoning.

853-75-1 This pre-Cambrian granite sample is from Spavinaw, Oklahoma, situated in the northeast corner of the state and approximately half way between the granites of Southeastern Missouri and those of the Wichita and Arbuckle Mountains. It serves as somewhat a connecting link between the two. An abundance of epidote probably accounts for the very high index figure of 14.7. Fifty-five percent of the heavies are highly-magnetic and are magnetite, whereas 43 percent are magnetic and are mostly hornblende with some epidote. The non-magnetic fraction is composed of 52.8 percent epidote, 32.7 percent zircon, 10.6 percent apatite, 2.4 percent fluorite and 1.4 percent titanite (PLATE V, C). Disregarding the high index figure this granite falls in Tolman's Type E.

The mineral distribution of the non-magnetic heavy

accessory mineral fractions of the discussed samples have been plotted as histograms for ease of comparison with the six Missouri types (PLATE IX).

Petrographic Descriptions

853-21-1 (Troy Granite) Texturally this granite is hypautomorphic granular (PLATE VI, A). Minerals identified and the percentage of each are: quartz 43 percent, orthoclase 35 percent, plagioclase (oligoclase, $Ab_{88}An_{12}$) 18 percent, microcline 9 percent, magnetite, biotite and chlorite 5 percent. Zircon is present in minor amounts as an accessory. The plagioclase is highly altered to kaolin and sericite making the twinning difficult to see. Leucoxene is identified around the borders of magnetite grains and in a few patches associated with biotite. Strong pleochroism was shown by the biotite, Z olive green, X light brownish green, Z>X. Most of the biotite was highly altered to chlorite. Hematite and limonite are present as stains at the boundaries of the other mineral grains. Grain sizes are: quartz, orthoclase and microcline 2 to 3mm, plagioclase 1.5mm, biotite and chlorite in elongated grains about 0.5mm wide.

By Johannsen's classification this rock is a luecogranite.

Megascopically this is a red coarse-grained granite composed of orthoclase, quartz and small amounts of chlorite.

853-29-1 (Tishmingo Granite) This granite is hypautomorphic porphyritic. Minerals identified were: quartz 16 percent, orthoclase 29 percent, plagioclase (oligoclase $Ab_{89}An_{11}$) 22 percent, microcline 22 percent and biotite, chlorite, titanite and magnetite make a total of 5 percent. Perthite and fluorite were also identified. Of the secondary alteration products kaolin, sericite, chlorite and pennine were present. Pleochroism, Z brownish green, X light brown is exhibited by biotite. Titanite occurs as euhedral crystals of acute rhombic crossections associated with the ferromagnesian minerals biotite and magnetite(PLATE VI, B). It is slightly pleochroic, Y light brown, and Z darker brown, Z>Y and displays symetrical extinction. The quartz grains are about 2mm in diameter as also is the plagioclase. Orthoclase and microcline are present as plenocrysts and are 3 to 4mm in size. Titanite crystals are about 0.3mm by 1mm.

In the hand specimen this granite is very coarse grained and porphyritic. Orthoclase occurs as the phenocrysts and are about an inch in length. Plagioclase is present to a minor degree. Quartz and biotite are major constituents.

853-33-1 (Lugart Granite) This hypautomorphic granular granite contains quartz 25 percent, orthoclase 25 percent, plagioclase (albite, $Ab_{94}An_{6}$) 11 percent, microperthite 32 percent and riebeckite 6 percent (PLATE VI, C). The feldspars are highly altered to kaolin, and the ferromangnesian minerals are all altered to chlorite except the riebeckite. Riebeckite is easily recognizable by its very strong pleochrism, X deep blue, Z olive green, and it has

parallel extinction. Very little optical data could be obtained for this amphibole although it is length fast. A few fibrous radiating grains of tremolite were identified.

Quartz, orthoclase and plagioclase have a grain size of about 1 to 2mm. The riebeckite grains are about 0.5mm wide and 1.5mm long.

Microscopically this granite is classified as a soda-clase granite.

Megascopically this specimen is medium coarse grained, containing orthoclase, quartz and hornblende. It is highly weathered and a dull pinkish orange in color.

853-41-1 (Lugart Granite) Texturally this granite is hypautomorphic granular. It is composed of quartz 23 percent, orthoclase 58 percent, plagioclase 8 percent, with hornblende, magnetite, epidote and chlorite totaling 7 percent and biotite about 2 percent. Other accessories were identified as zircon and fluorite. Alteration products are kaolin, sericite and chlorite. Hematite is present at the edges of some of the mineral grains. The plagioclase was determined as Albite ($Ab_{90}An_{10}$). Pleochroism Z green, X yellowish green and Y light brown was exhibited by the hornblende that was not altered to chlorite. Absorption for hornblende: $Z > Y > X$. Biotite is pleochroic from dark green to brownish green. Grain size for all constituents is about 1mm in diameter.

By Johannsen's classification this granite is a soda-clase-granite.

Megascopically this granite is a medium grained red granite. Orthoclase, quartz and chlorite are distinguishable.

853-45-2 (Lugart Granite) A few granophyric areas are present in this section, but the general texture is hypautomorphic porphyritic. Quartz is present as phenocrysts and makes up about 24 percent of the rock;;orthoclase is 56 percent, plagioclase (oligoclase, $Ab_{88}An_{12}$) is 1 percent, granophyric intergrowths of quartz and orthoclase are 17 percent, and biotite and magnetite are 2 percent. Microperthite, fluorite, zircon and tremolite were also noted. Kaolin, sericite, chlorite and calcite were the secondary minerals identified. Nearly all the biotite was completely altered to chlorite. Average grain size of the quartz and orthoclase is about 1mm.

Petrographically this section is a kalialaskite.

Megascopically this rock is a medium-grained, dull reddish granite. Pink feldspar and quartz are the only distinguishable minerals. There is a marked absence of dark minerals.

853-47-2-1 (Lugart Granite) Granophyric and micropegmatitic textures are excellently displayed in a section of this rock (PLATE VII, B). A hypautomorphic granular texture is also present. Minerals present in the rock are: quartz 23 percent, orthoclase 24 percent, microperthite 24 percent and hornblende 1 percent, and 27 percent of the specimen is granophyric and micropegmatitic intergrowths

of quartz and orthoclase. The grain size of the quartz and orthoclase is about 1 to 1.5mm. Quartz and orthoclase intergrowths are present in areas of about 1.5mm diameter. A single piece of plagioclase was found, and it was determined as adesine ($Ab_{62}An_{38}$).

Microscopically this rock is a kalialaskite.

In the hand specimen this granite is a deep red in color and medium-coarse grained. Quartz and orthoclase and a very minor amount of hornblende can be recognized.

853-47-2-4 Green (Lugart Granite) This granite, one side of what is thought to be a contact with 853-47-2-4 Red, is hypautomorphic granular and shows both granophyric and micropegmatitic textures (PLATE VII, C). It is composed of quartz 22 percent, orthoclase 25 percent, microperthite 16 percent and hornblende 3 percent. Intergrowths of quartz and orthoclase comprise about 24 percent of the section. Fluorite, magnetite and zircon were identified as the accessory minerals. Secondary minerals are chlorite, kaolin and calcite. One mm is the average grain size.

Petrographically the rock is classified as kalialaskite.

Megascopically the speciment is a coarse-grained green granite. An abundance of chlorite appears to account for the green color. Pink feldspar and quartz are also recognizable.

853-27-2-4 Red (Lugart Granite) This section represents the other side of the contact between these two granites. Texturally it is the same as 853-47-2-4 Green, PLATE VII D). Quartz is 16 percent of the rock, orthoclase 33 percent, microperthite 16 percent, chlorite and magnetite 4 percent. Quartz and orthoclase intergrowths are 31 percent of the specimen. Alteration products are chlorite and kaolin. Hematite is abundant interstitially and appears to account for the apparent contact of the red and green granites. Grain sizes are the same as in 853-47-2-4 Green.

This side of the contact is also a kalialaskite.

In the hand specimen this granite is identical to the previously described specimen except for the red coloring of the hematite.

853-57-2-2 (Lugart Granite) Microscopic study of this rock also suggests that it is probably Reformatory instead of Lugart. Texturally it is quite different from the other Lugart granites. It is hypautomorphic granular and porphyritic (PLATE VIII, C). Minerals present are quartz 23 percent, orthoclase 58 percent, plagioclase (Albite, $Ab_{90}An_{10}$) 15 percent, biotite and chlorite 1 percent and hornblende and magnetite 3 percent. A few zircons were noticed. Chlorite, kaolin and calcite are secondary products. Some hematite and limonite is present between the grains. Chlorite occurs in a radiating form showing parallel extinction.

The quartz and plagioclase have a grain size of about 1mm, whereas the phynocrysts of orthoclase are about twice

that size.

This granite is an alaskite by Johannsen's classification.

In the hand specimen the rock can be described as a fairly coarse grained red granite containing potash feldspar, quartz, hornblende and chlorite.

853-59-1 (Reformatory Granite) This granite is hypautomorphic granular and contains quartz 38 percent, orthoclase 57 percent, plagioclase (oligoclase $Ab_{87}An_{13}$) 1 percent, biotite 1 percent and hornblende 2 percent. Microperthite is present (PLATE VIII, A), as is fluorite, magnetite and zircon. The common alteration products kaolin and chlorite were also identified. Biotite is pleochroic Z dark brown to X light straw brown. Hornblende shows pleochroism in the following direction: X light yellow green, Y dark green, Z darker olive green, Z > Y > X.

Quartz and orthoclase grains are fairly large with an average diameter of 3 to 4mm.

Johannsen's system puts this granite in the kalialaskite group.

Megascopically this granite is very coarse grained. Pink feldspar, quartz and hornblende are identifiable in this massive red granite.

853-61-1 (Reformatory and Headquarters Mixed) A variety of textures is exhibited in this specimen. The slide is xenomorphic with granophyric intergrowths of quartz and orthoclase ranging into a poikilitic texture (PLATE VIII, D). There is 4 percent quartz, 13 percent orthoclase, 10 percent plagioclase (albite $Ab_{92}An_{8}$) and 3 percent ferromagnesian minerals. Sixty-nine percent of the section is taken up by the intergrowths described. Microperthite, zircon and sericite were also identified.

All the minerals present are within the grain sizes of 0.3 to 1mm.

Classified petrographically this rock is an alaskite.

It is a fine-grained granite, tan in color, containing orthoclase and minor amounts of quartz and hornblende in the hand sample.

853-71-3-1 (Quanah Granite) Texturally this granite is hypautomorphic granular containing 45 percent quartz, 30 percent orthoclase, 18 percent plagioclase (oligoclase $Ab_{88}An_{12}$), 1 percent microcline and 6 percent biotite and hornblende. Microperthite is also present (PLATE VIII, B). Accessory minerals are chlorite, kaolin and sericite. The mineral grains are fairly large, averaging 1.5 to 3.0mm.

Johannsen's classification places this sample in the granite group.

Megascopically this granite is coarse-grained, tan in color and contains orthoclase, quartz and altered hornblende.

853-75-1 This granite from Spavinaw, Oklahoma is similar to both the Wichita and Arbuckle granites and the Missouri granites texturally. It is hypautomorphic granular,

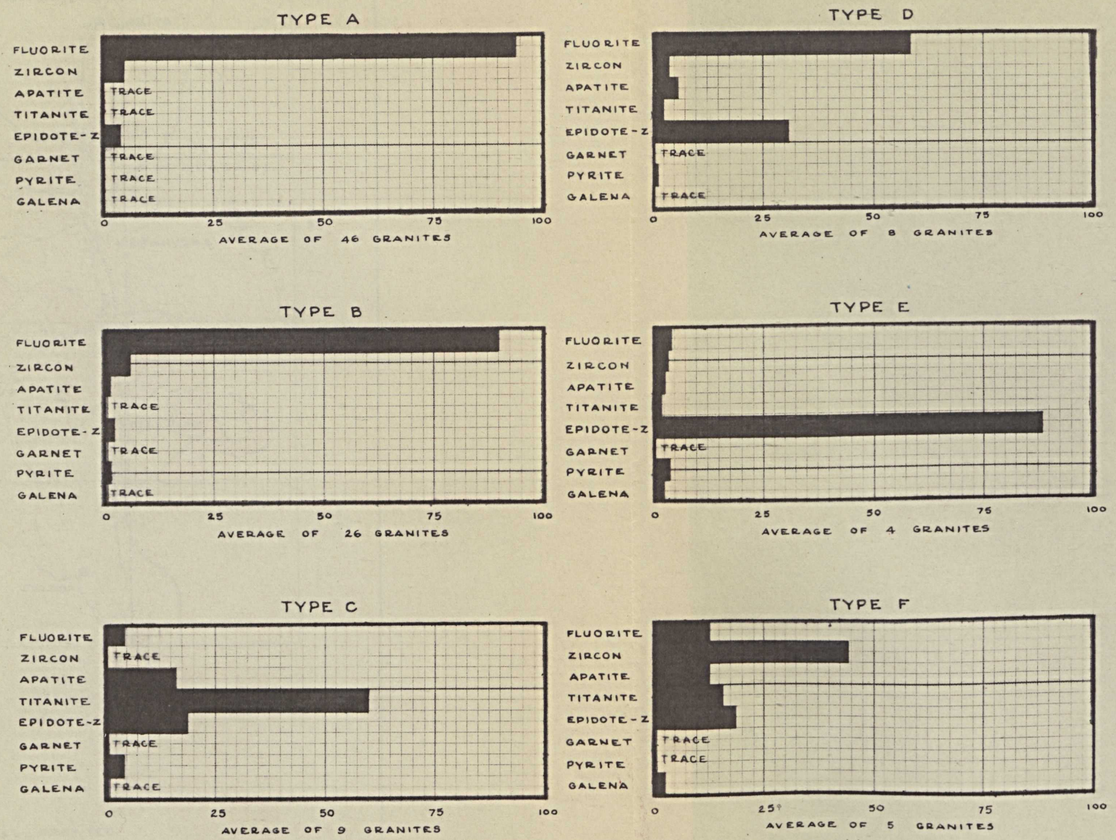
with granophyric and micropegmatitic intergrowths of quartz and orthoclase (PLATE VIII, E). Compositionally it contains 7 percent quartz, 44 percent orthoclase, 9 percent plagioclase (albite $Ab_{94}An_6$) and 8 percent chlorite and hornblende. Of the accessory minerals zircon, magnetite, apatite, and epidote are present; chlorite, sericite and pennine were noted as secondary. Pleochroism in hornblende was noted to be Y olive green, X yellow green and Z olive green; absorption $Z > Y > Z$.

The size of the mineral grains varies from 0.5 to 1.5mm.

Microscopically this granite must be called a soda-clase- granite.

An examination of the hand specimen shows the sample to be a medium-grained reddish granite, containing orthoclase, plagioclase, quartz and hornblende.

HISTOGRAMS OF SIX TYPES OF MISSOURI GRANITES DESCRIBED BY TOLMAN & KOCH *



* TOLMAN AND KOCH, "THE HEAVY ACCESSORY MINERALS OF THE GRANITES OF MISSOURI", CONTRIBUTIONS IN GEOLOGY, WASHINGTON UNIV. STUDIES - NEW SERIES SCIENCE & TECHNOLOGY -NO. 9

HISTOGRAMS OF GRANITES FROM THE WICHITA AND ARBUCKLE MOUNTAINS OKLAHOMA

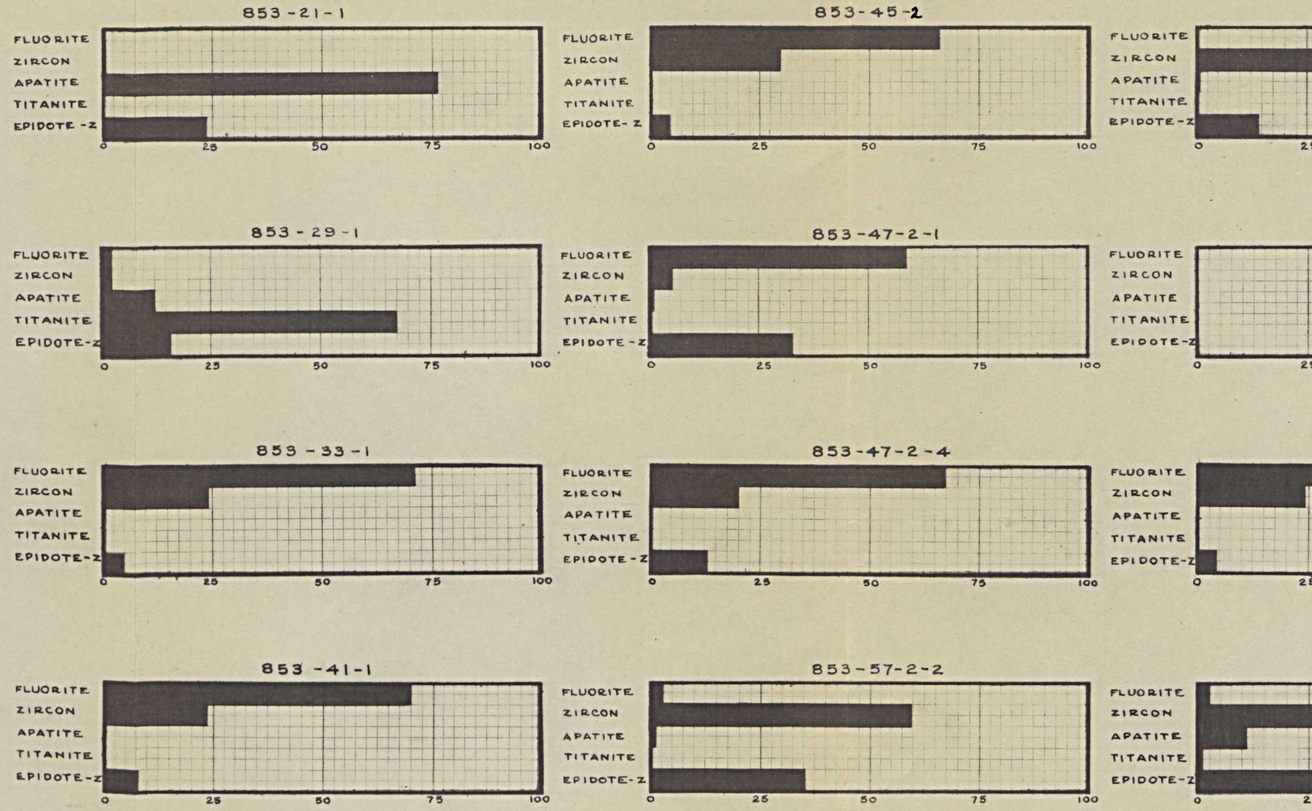
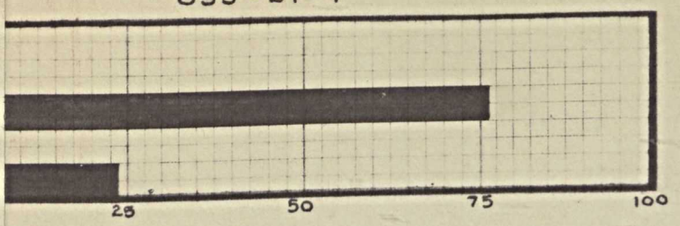


PLATE IX

HISTOGRAMS OF GRANITES FROM THE WICHITA AND ARBUCKLE MOUNTAINS OKLAHOMA

853-21-1



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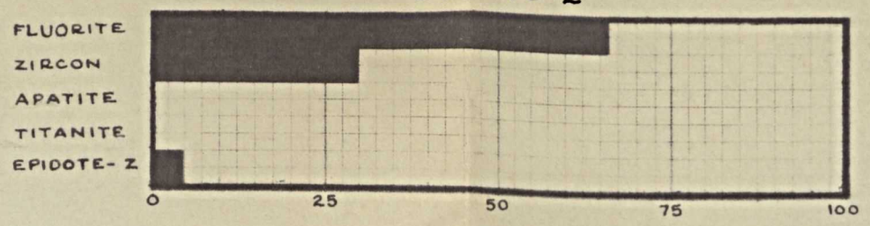

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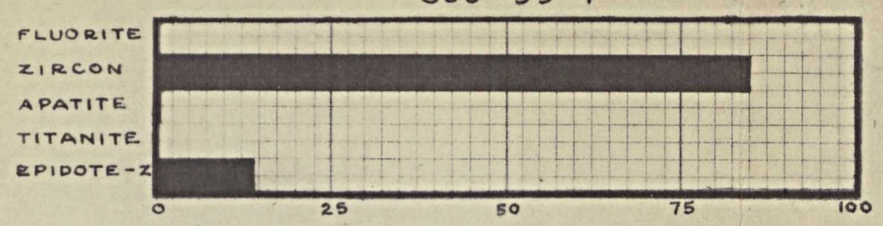

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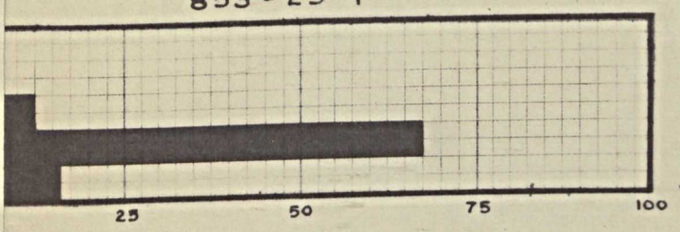

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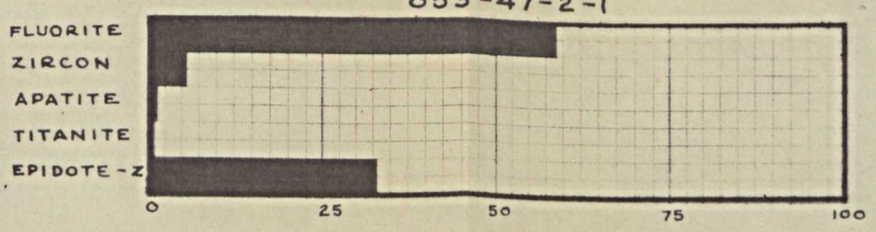

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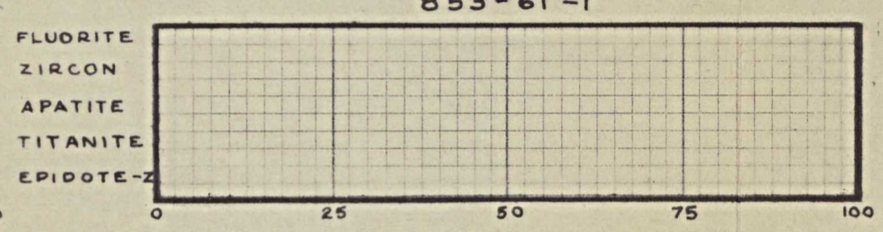

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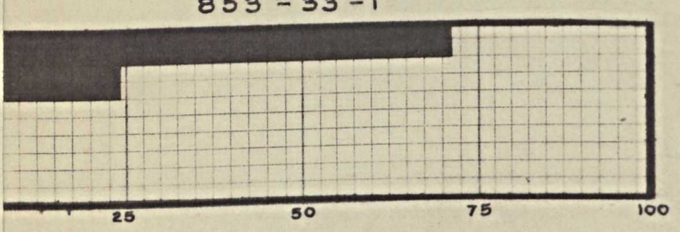

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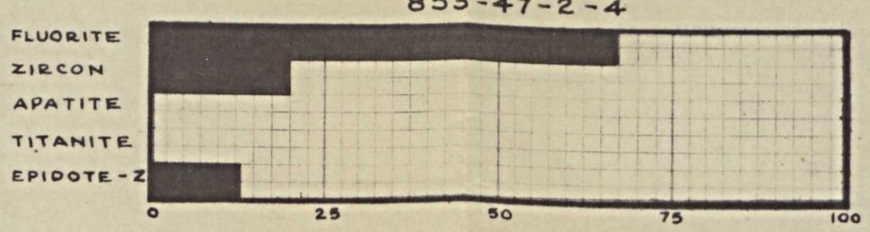

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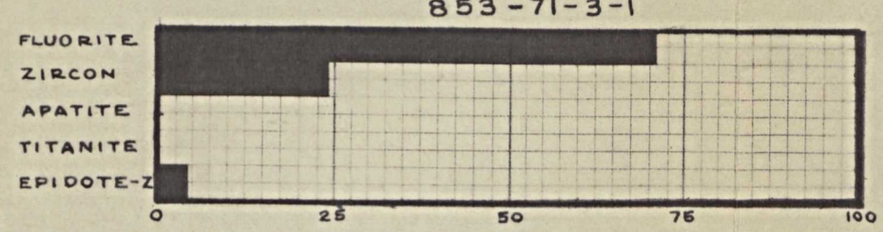

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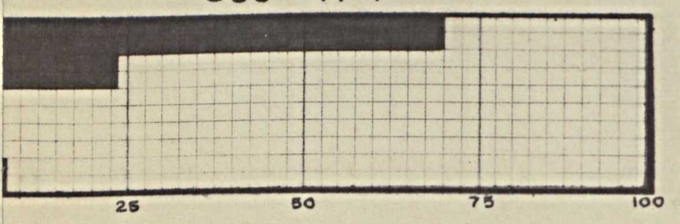

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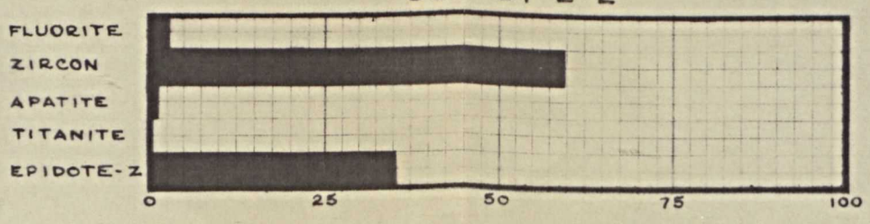

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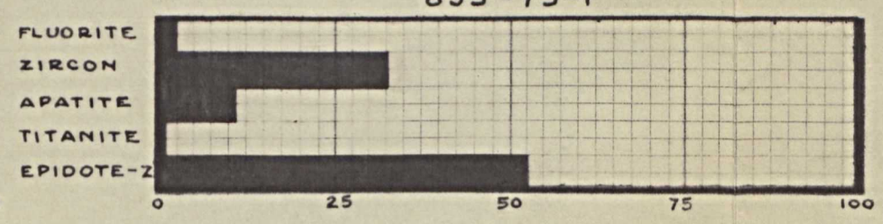
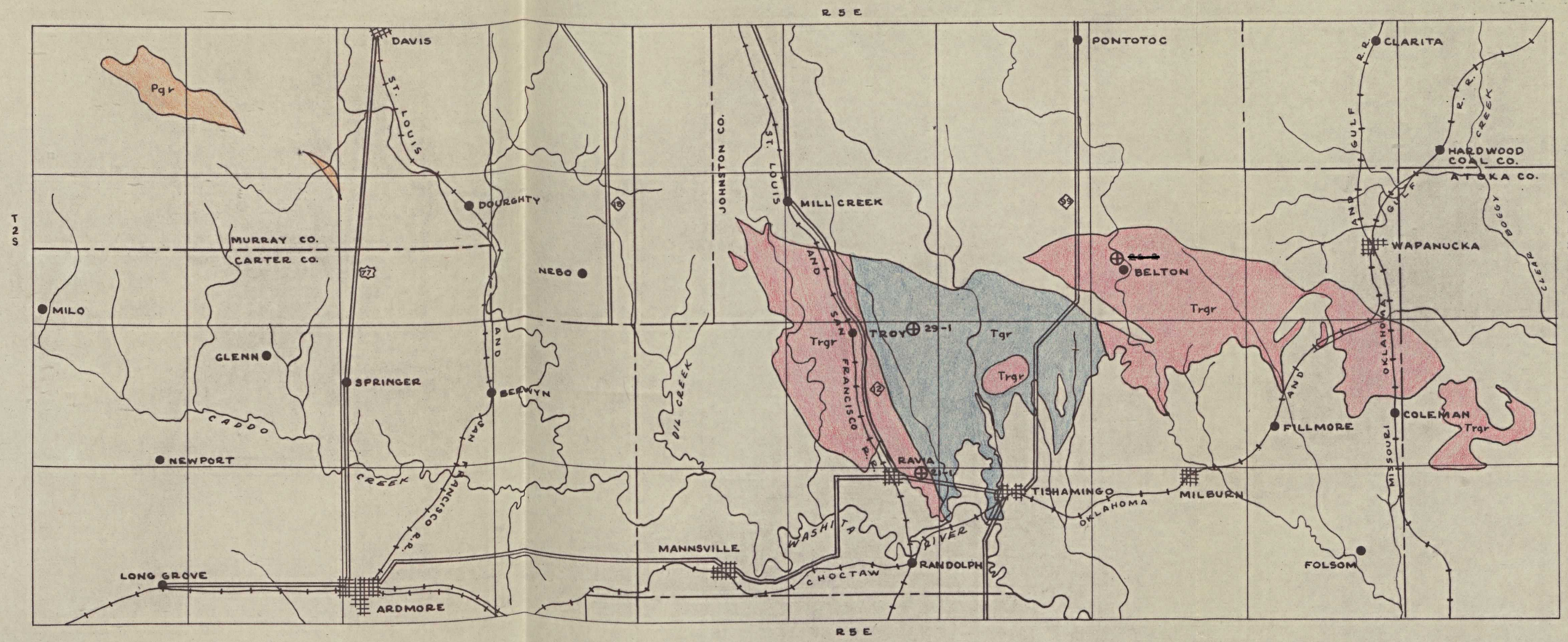




ARBUCKLE MOUNTAINS
SHOWING DISTRIBUTION OF GRANITES

SCALE IN MILES
0 5 10

N

Pgr PORPHYRITIC GRANITE

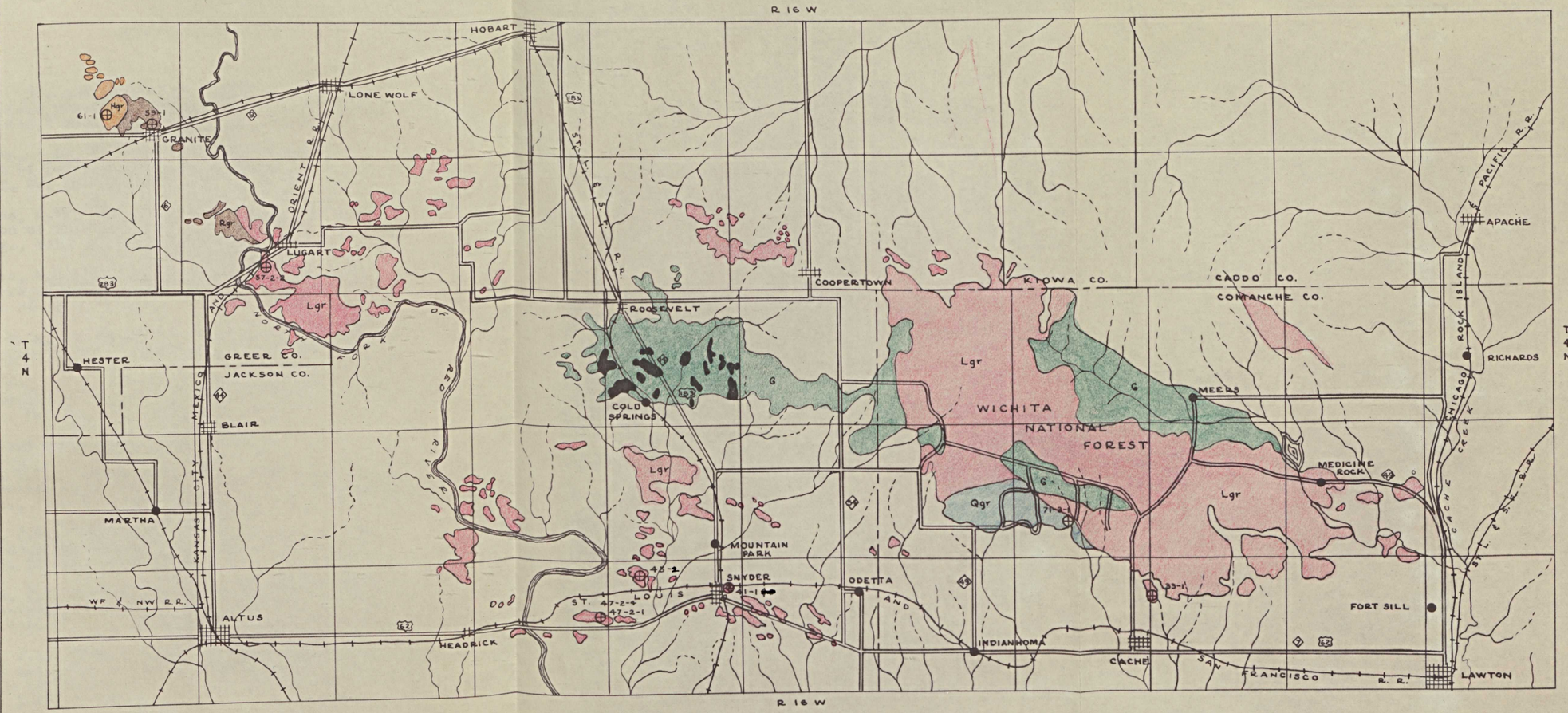
Trgr TROY GRANITE

Tgr TISHMINGO GRANITE

AFTER C. H. TAYLOR, OKLAHOMA GEOLOGICAL SURVEY BULLETIN 20.

⊕ GRANITE SAMPLES ALL PREFIXED BY 853, SAMPLE NUMBERS REFER TO MISSOURI GEOLOGICAL SURVEY NOTE BOOK, PAGE & SPECIMEN.

COLLECTED BY: FORBES ROBERTSON
OCTOBER, 1947



G GABBRO

Rgr REFORMATORY GRANITE

Lgr LUGART GRANITE

COLD SPRINGS GRANITE

Qgr QUANAH GRANITE

Hgr REFORMATORY & HEADQUARTERS GRANITE

N

⊕ GRANITE SAMPLES ALL PREFIXED BY 853, SAMPLE NUMBERS REFER TO MISSOURI GEOLOGICAL SURVEY NOTE BOOK, PAGE & SPECIMEN.

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WICHITA MOUNTAINS
SHOWING DISTRIBUTION OF GRANITES

SCALE IN MILES
0 5 10

AFTER C. H. TAYLOR, OKLAHOMA GEOLOGICAL SURVEY BULLETIN 20

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