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CHAPTER I

INTRODUCTION

The papers and reports that have been written on the geology and petrology of the Wichita Mountain System are relatively few in number. Most of these are preliminary and general in nature. The purpose of this study is to enlarge upon the previous work on the igneous rocks forming the eastern end of the Wichita Mountain System.

Location

The Wichita Mountain System is located in southwestern Oklahoma. It trends about N. 70° W. from Fort Sill, in Comanche County, for about sixty five miles to a point four miles northwest of Granite, in Greer County. The greatest width is across the central part where, if the outlying knobs are included, it approaches thirty miles. The eastern half of the System is divided into two main divisions. On the northeast are the Limestone Hills and on the southwest are the "Wichita Mountains". The western half of the System is composed of scattered groups of hills. The group near the town of Granite is called the Headquarters Mountain Group. To the southeast of Granite in the bend of the North Fork of the Red River is the Devils Canyon Group. The

Raggedy Mountain Group is located just west of the central portion of the System.

Parts of the Wichita Mountains have been given separate names. The eastern portion is called the Carlton Mountain Group. The southern portion is known as the Quanah Mountain Group, while the northern portion retains the name of the Wichita Mountain Group. The igneous rocks of the eastern portion to be described in this thesis outcrop in Comanche County in T. 2 N., R. 12 W.; T. 3 N., R. 12 W.; T. 2 N., R. 13 W.; T. 3 N., R. 13 W.; and the eastern portion of the T. 2 N., R. 14 W.; T. 3 N., R. 14 W. It covers an area thirteen miles long and seven miles wide.

Previous Work

The first work of note was that done by George G. Shumard[1] in 1853. The outcome of the expeditions and geological surveys which followed this early report are described in papers by T. B. Comstock and W. F. Cummins[2], R. T. Hill[3], T. Wayland Vaughan[4], and H. F. Bain[5].

[1]George G. Shumard, "Remarks on the General Geology of the Country Passed Over by the Exploring Expedition to the Sources of the Red River", U. S. 32nd Cong., 2nd Sess., Sen. Ex. Doc. 54, (1853), pp. 179-195.

[2]T. B. Comstock and W. F. Cummins, "A Preliminary Report on the Geology of the Central Mineral Region of Texas", Texas Geol. Survey, 1st. Ann. Rept. (1889), pp. 319-328.

[3]R. T. Hill, "Notes on a Reconnaissance of the Ouachita System in Indian Territory", Am. Jour. Sci. 3rd Ser. Vol. 42 (1891) pp. 122-123.

[4]T. Wayland Vaughan, "Geologic Notes on the Wichita Mountains, Oklahoma and the Arbuckle Hills, Indian Territory", Am. Geologist, Vol. 24 (1899), pp. 44-45.

[5]H. F. Bain, "Geology of the Wichita Mountains", Bull. Geol. Soc. America, Vol. 11 (1900) pp. 127-144.

These works were reviewed by J. A. Taff[6]. A general map and report of the Wichita Mountains was completed by Taff with the assistance of C. N. Gould and E. O. Ulrich in the latter part of 1901. The report was published in 1904.

Taff divided the igneous rocks into four general classes. These, in order of apparent age, are, (1) gabbro and related anorthosite, (oldest), (2) granite and related aplites, (3) granite-porphyry and associated aporhyolite, and (4) diabase dike rocks. He mentions the micropegmatitic texture of the acidic rocks. He recognized at least one lava rock, an aporhyolite, but most were classified as plutonic granites and gabbro-anorthosites. Cutting these igneous masses are quartz veins, aplites, pegmatites, and diabase dikes.

A. F. Rogers[7] published a paper in 1907 describing the aegirite-riebeckite bearing rocks in the vicinity of Granite, Oklahoma.

In 1915 C. H. Taylor[8] published a second[9] report on the igneous rocks of the Wichita Mountains. It was in this publication

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[6] J. A. Taff, "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma", U. S. Geol. Sur., Prof. Paper 31 (1904), Reprinted as Okla. Geol. Sur., Bull. 12 (1928).

[7] A. F. Rogers, "Aegirite and Riebeckite Rocks from Oklahoma", Journal of Geology, Vol. 15 (1907), pp. 283-287.

[8] C. H. Taylor, "Granite of Oklahoma", Okla. Geol. Sur., Bull. 5 (1911), Chap. 4, pp. 40-59.

[9] C. H. Taylor, "Granites of Oklahoma", Okla. Geol. Sur., Bull. 20 (1915).

that he named and described the Meers quartzite. He also divided the granitic rocks into the Headquarters, Reformatory, Cold Springs, Lugert, and Quanah granites, reading from oldest to youngest.

Samuel Weidman[10] and O. F. Evans[11] published several papers on physiographic studies of the Wichitas.

In 1930 M. G. Hoffman[12] published the results of his work in the Wichita and Quanah Mountain Groups. He subdivided and reclassified the Lugert and Quanah granities of Taylor's[13] into the Saddle Mountain, Davidson, Carlton, Lugert, and Quanah granophyres, reading from oldest to youngest.

Hoffman calls the acidic igneous rocks, granophyres, as they commonly exhibit a micropegmatitic intergrowth and, on this basis, he concluded that the granitic rocks are hypabyssal.

In 1946 K. C. Anderson[14] completed a Master's thesis in which he described the pegmatites and miarolitic cavities of the Wichita

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[10] Samuel Weidman, "Was There Pennsylvanian-Permian Glaciation in the Arbuckle and Wichita Mountains of Oklahoma"? Jour. Geol., Vol. 31, (1923), pp. 466-489.

[11] O. F. Evans, "Some Observations On Erosion and Transportation in the Wichita Mountain Area". Proc. Okla. Acad. Sci., Vol. 2 (1922), pp. 77-79.

[12] M. G. Hoffman, "Geology and Petrology of the Wichita Mountains", Okla. Geol. Sur., Bull. 52 (1930).

[13] C. H. Taylor, "Granites of Oklahoma", Okla. Geol. Sur., Bull. 20 (1915).

[14] K. C. Anderson, "The Occurrence and Origin of Pegmatites and Miarolitic Cavities in the Wichita Mountain System, Oklahoma", (Unpublished Master's Thesis, Department of Geology, University of Oklahoma, 1946).

Mountains. He did not use the term granophyres but referred to the rocks as granites, rhyolites, etc.

In 1947 B. J. Scull[15] completed a Master's thesis in which he described the igneous rocks of the Granite-Lugert area. Scull points out that the granophyric texture, on which Hoffman[16] bases his conclusion that the Lugert granite intrusion was a hypabyssal sill, is not present in the Lugert granite of his thesis area, or when so found, it appeared to be a secondary texture as a result of deuteric or hydrothermal replacement. Scull proposes that the Lugert was intruded as a laccolith or possibly a series of small laccoliths somewhat like the laccoliths of the Black Hills of South Dakota.

Field Work

The writer lived in Lawton during the period 1937 to 1939. Familiarity with the area grew as a result of many trips to the mountains. During July of 1937 and 1938 the writer was stationed at Fort Sill and again in June and July of 1947. It was during this last period that directed field work was undertaken. Many trips to the mountains were made during the school year of 1947-48.

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[15] B. J. Scull, "A Further Study of the Igneous Rocks in the Granite-Lugert Area, Oklahoma". (Unpublished Master's Thesis, Department of Geology, University of Oklahoma, 1947).

[16] Hoffman, op. cit.

Excellent topographical maps were made available by the U. S. Army. These maps made it possible to locate points easily.

A detailed study of the area was made by the use of aerial photographs. The outcrops were plotted and mapped. These contacts then were checked in the field for accuracy. The distinction between Permian and Post-Permian sediments was not made with the exception of the Pleistocene gravels. Samples were collected at regular intervals and particularly at every place where a contact was found. The dikes and joints were examined, and their strikes and dips recorded. Prospect pits and excavations were visited but these were not deep enough to aid materially in obtaining fresh samples.

Laboratory Procedure

The work in the laboratory consisted of three phases. First, the various hand specimens were studied under the binocular microscope and the macroscopic features recorded.

Second, the thin sections of the rocks were examined for microscopic features such as texture, mineral content and shape, the inclusions, order of crystallization, and the type and degree of alteration. The mineral percentages were estimated by the Rosiwal[17] method.

Third, a portion of the specimen was crushed and a gravity separation effected by bromoform of the material which passed through

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[17] A. Johannsen, Manual of Petrographic Methods, McGraw-Hill Book Co., Inc., New York, (1918), pp. 291.

a 100 mesh screen and was retained on the 200 mesh. The heavy minerals were then studied under the polarizing microscope. The same procedure as outlined by B. F. Uhl[18] in his thesis on the igneous of the Arbuckle Mountains was followed. Sufficient information for correlation of the igneous rocks of the Wichita and Arbuckle Mountains is not yet available

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[18] B. F. Uhl, "Igneous Rocks of the Arbuckle Mountains" (Unpublished Master's Thesis, Department of Geology, University of Oklahoma, 1932).

CHAPTER II

GENERAL GEOLOGY

Physiography

The igneous rocks of the Fort Sill Reservation form the extreme eastern end of the Wichita Mountain System. Taff[1] divided the mountains into seven physiographic units or groups. These groups are: Limestone Hills, Wichita Mountain Group, Quanah Mountain Group, Carlton Mountain Group, Raggedy Mountain Group, Devils Canyon Group, and the Headquarters Mountain Group.

The area of this report includes the Carlton Mountain Group, the southern portion of the Wichita Mountain Group, and the eastern portion of the Quanah Mountain Group.

Carlton Mountain Group

The physiography of this area is well described by Taff who writes as follows:

> The Carlton group consists of low mountains and peaks which lie between the east ends of the Wichita and Quana Groups and extend eastward to within a mile of Fort Sill. The topographic features of the Carlton Mountains are markedly different from those of the Wichita and Quana mountains. The Carlton Mountains consist of granite-porphyries and old rhyolites, which, unlike the granite, break into small angular boulders and fragments upon weathering, giving rounded and comparatively smooth topographic forms. The general effect is like that produced by a topographically young region

[1]Taff, op. cit., pp. 54-57.

composed of homogeneous soft rocks — mountains composed of numerous ridges and spurs separated by V-shaped valleys.

The outline of this group, as well as of its separated members, like that of all the other groups of the region, was established by marine degradation at a time when the Permian sea stood with its shores at the approximate position of the "Red Beds" and porphyry contact.

From near the center of the group an arm projects southward and ends in Signal Mountain, the highest peak, which rises about 800 feet above the plains. A single mass of hills is separated from the main group on the southwestern side by an inlet of the "Red Beds" plain which extends up the valleys of Wolf Creek and joins the broad upland valley between the Quana and the Wichita Mountains. The most noteworthy feature of the Carlton Mountains is Medicine Bluff, at the extreme east end, about a mile west of Fort Sill. Here Medicine Bluff Creek flows against the north side of the porphyry mountain, making perpendicular bluffs 100 to 400 feet high and about half a mile long.

Wichita Mountain Group

Concerning the Wichita Mountain Group, he writes:

The largest of the groups of mountains that compose the Wichita Range is the Wichita group, from which the range has received its name. It extends from near the northwest corner of the Apache Reservation northwestward about 25 miles, and consists of many rugged and irregular granite mountains, the most prominent of which are Mounts Scott and Baker, near the southeastern and northwestern ends, respectively. Mount Sheridan is about 4 miles west of Mount Scott.

The Wichita group of mountains is separated from the Quana Mountains on the south by a wide, plainlike valley, which descends with very easy grade from Military Pass, 2 miles east of Oriana, to the western end of the Carlton Mountains, where it divides, the northern arm passing down a branch of Medicine Creek between Carlton Mountains and Mount Scott, while the southern arm extends to the plains down Beaver Creek. The sources of West Cache Creek occupy the western half of the valley and flow southward through gorges near the middle of the Quana Mountains.

Quanah Mountain Group

He describes the Quanah Mountain Group, formerly spelled Quana, as follows:

The Quana group, like the Wichita, is an elongated collection of granite mountains and low peaks about 14 miles in length. Though like the Wichita group in character of rock and topographic features, the individual mountains are lower, and none of them, it is believed, rise more than 800 feet above the general level of the plain bordering the mountains upon the south. The Quana group is separated into an eastern and western part by gaps near the center, through which the three branches of West Cache Creek flow. The two westernmost and largest branches cross the mountains in narrow and deep gorges, while the other traverses an old, wide, and flat valley that originated contemporaneously with the intermontane valley which lies north of the Quana Mountains and with which it is connected. Remnants of the "Red Beds" conglomerates and red clay deposits may yet be seen in the floor of this valley.

The mountains of the eastern end rise abruptly from the broad, gently rolling plains of southwestern Oklahoma. The greatest relief of the area is 1,340 feet. Mount Scott has an elevation of 2,480 feet above sea level. The elevation of Medicine Creek at the extreme eastern end as it leaves Medicine Bluff is about 1,140 feet. Throughout this area only the upper portion of the hills rise above the talus. The highest point in the Carlton Mountain Group is Signal Mountain which is 1,752 feet above sea level and about 500 feet above the surrounding area.

The trees are largely confined to the valleys and lower talus slopes and are mainly jack oaks and cedar, however, other types occur. Vegetation has little opportunity to take root in the Carlton Mountains because the rock is intensely shattered and weathers out in small angular pieces which wash down the slopes quite readily. The rocks of the Wichita Mountain Group on the southern portion weathers into medium to small fragments and supports trees well up to the top of the hills. There are exceptions to this rule which will appear later. The Quanah

Mountains are quite barren in parts as the rock is the least fractured and weathers out in large boulders and blocks.

The topography of the eastern Wichitas has reached maturity. With the exception of a few sharp peaks the hills are rounded, the valleys well developed, and the area is adequately drained. The higher hills are composed of granites and the low smooth hills of porphyry. The slopes and foothills just north of the area described in this thesis are underlain by gabbro-anorthosite.

Elevations and heights of all key points are to be found on the map included with this work.

Drainage

Pre-Pleistocene Drainage

There are many features present today which are not a result of normal stream development but rather those of superimposed streams. The principal pre-Pleistocene streams flowed to the southwest. The drainage pattern was subjected to changes by overloaded streams depositing gravels[2] and as the gradient was lessened the then existing valleys were filled. The streams would be consequent on this topography. Later these streams were let down upon a topography to which they were unadjusted. Some of these later streams reverted to their old channels but others were able to maintain their new courses.

An example of such an unadjusted stream is West Cache Creek and its tributaries. It would have been shorter for this stream to have

[2]Hoffman, op. cit., p. 21.

followed the interior trough southeastward and joined Blue Beaver Creek north of Cross Mountain, instead it cut deep channels through the Quanah Mountains.

Cedar Creek which flows south and southeast in the Mount Roosevelt area swings east around the base of the hill, then to the northeast to join Medicine Creek. The headward erosion of this stream is normal to a southeast drainage. There are other examples in this general area but these two serve to illustrate this feature.

Present Drainage

The Wichita Mountain System is drained by Elm Fork and Salt Fork of Red River which discharge into the Red River. The tributaries are usually minor and intermittent. Comanche County is drained on the west by West Cache Creek, Cache Creek drains the central part and Beaver Creek the eastern part. The general drainage of this area is to the southeast.

The northern area is drained by Medicine Creek and its tributaries. The southern tributaries of Medicine Creek in the Wichita Mountain group head in the Lugert Granite and flow to the north. The drainage of the Carlton Mountain group is in general to the southeast, changing from the east to the southeast, and finally to the south as one moves from the northeastern portion clockwise to the southwestern part. The Quanah Mountains drain to the south and a little east of south.

Due to the fact that many of the streams are superimposed upon the present topography and that their courses are influenced by jointing, the normal radiating pattern of an uplifted area is disrupted and modified. However, the headward erosion is adjusting itself to a radial pattern but is influenced by the general southeast drainage of the entire area.

Blue Beaver Creek heads in Graham Flats. The damming of this creek has formed Lake Rush, Lake Jed Johnson, and Ketch Lake. From Ketch Lake it flows east to southeast to south to southwest and follows closely the contact between the Lugert granite and Carlton rhyolite.

The headward erosion of the present streams are producing low divides. Evidence of piracy exists. The drainage is largely controlled by the strong joints and fractures. The streams of today are small and do not possess the power to remove coarse materials. Thus, as the streams come down from the mountains into the plains, they erode and carry out the post-igneous rocks together with the fine material derived from the igneous core. In this manner the mountains are being etched in relief.

In earlier literature Medicine Creek has been referred to as Medicine Bluff Creek, or Medicinebluff Creek. The name Medicine Creek seems to prevail in the most recent literature and more so on the newest topographical maps. In this thesis it will be referred to as Medicine Creek. Little Medicine creek is a tributary of Medicine Creek. These creeks have been dammed, forming Lake Thomas and Lake Lawtonka, respectively.

Talus and Boulder Formations

The igneous rocks of the entire area are jointed, this feature being more pronounced in certain places. The Carlton rhyolite has suffered the greatest shattering, and the fracture planes are often spaced less than an inch apart. The resulting fragments of rock are weathered out and are easily washed away. The base of these hills is covered with talus, and only the highest peaks remain uncovered. The granites are less jointed and the general average of the boulders is about four feet in diameter. The Quanah granite, however, having suffered the least jointing, weathers out as enormous boulders, sometimes 100 feet long and 20 to 40 feet thick. Here the major joint planes are spaced from 20 to 100 feet apart.

The size of the boulders is dependent upon the distance between joint planes, and the latter seems to be directly proportional to the size of the crystals that make up the rock. The medium grained rocks yield great accumulations of boulders as evidenced in the Wichita Mountain Group. The boulders are rounded by exfoliation.

The gabbro-anorthosite is more susceptible to weathering than the acidic rocks and it is interesting to note that Medicine Creek flows roughly southeastward through the center of the gabbro-anorthosite outcrop for a distance of about eleven miles. The tributaries of Medicine Creek on the north flow southward over the Permian Red Beds and those to the south flow northward over the Lugert granite.

Gravels

Within this area there are several patches of gravels. They are found in road cuts, one mile east of Central Peak, one mile north of Fern Mountain, north and west of Lake Thomas, and along the southern base of the Quanah Mountains. Remnants of the gravels are quite widespread, being present throughout the intermontaine valleys. They are recognized easily by their yellowish color, roundness, and contrast to the surrounding rock. The pebbles are composed mostly of Lugert granite but fragments of Carlton rhyolite and gabbro-anorthosite also are present.

A thin section was made of a Pleistocene rhyolite pebble but it did not disclose the nature of the upper portion of the Carlton rhyolite. It is believed that a study of the gravels may reveal tuff, breccia, or glass. Aporhyolites have been reported and it was with this in mind that an analysis of a rhyolite gravel was made. The thin section shows a typical rhyolite groundmass which does not compare with the Carlton rhyolite of Signal Mountain, that is, a brecciated appearance due to a crushing and recementation while the rock was still hot. The gravel rhyolite groundmass is a homogenous aggregate of quartz and feldspar. The phenocrysts of quartz are clear but the feldspar crystals are highly altered to kaolinite and sericite. The rock is uniformly stained by limonite, which is concentrated along tiny fissures traversing the rock. Undoubtedly, a detailed study of selected pebbles from the Pleistocene gravel beds would yield desirable information on the character of the igneous rocks from higher levels which composed the igneous rocks. The Reagan sandstone should not be overlooked in this respect.

The Pleistocene gravels are composed of rounded to semi-rounded granitic or rhyolite boulders. The size averages from 6 to 10 inches with a maximum size of 3 feet. Locally they are used for building material.

Hoffman[3] states that there is a gravel ridge southwest of Buffalo Gap at an elevation of 1,780 feet, and also that the hill southwest of Eagle Mountain consists of gravels 250 feet thick at an elevation of 1,685 feet. These probably are remnants of a gravel layer in and around the mountains.

He writes:

> Undoubtedly the gravels originally were higher than they are today. How much higher it is difficult to say, but certainly they were above 1,800 feet in the south-western portion of the mountains, and above 1,700 feet in the south central area. At this rate of decline their elevation in Blue Beaver Creek west of Carlton mountain would have been something over 1,550 feet.

Fossils found in the gravels prove their age[4] is Pleistocene. The smoothness, not the roundness of the gravels indicate that this material has been water worn and that the environment under which they were formed differed from that of today. The importance of roundness may be overemphasized. A boulder may require very little transportation to become rounded. By the process of exfoliation, the boulders of the

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[3] Hoffman, op. cit. p. 18.

[4] C. N. Gould, "On the Recent Findings of Another Flint Arrow-Head in the Pleistocene Deposits at Frederick, Oklahoma", Jour. Washington Acad. Sci., Vol. 9, No. 3 (1929) pp. 66-68.

Wichita Mountains are becoming rounded in the semi-arid environment of today although the distance of transportation is only a matter of feet.

Jointing

There are four sets of major joints in this area. One set has a strike of N. 69° - 78° W. The second strikes at right angles to the first, approximating N. 12° E. The third and fourth sets, which are not as strong as the first two, cut the first and second set at about 45°. The general direction for these latter are N. 35° W. and N. 55° E. The dip of the joints vary from vertical or nearly so to 30° to 40° to the north or south. Horizontal jointing is not consistently present or evident. There are other sets of joints in this area but they are not constant and ofttimes appear radial in nature.

The closely spaced parallel joints shown in Medicine Bluff extend nearly vertical from the top of the bluff to its base, a distance of about 400 feet. The Carlton rhyolite is so intensely fractured that there are great areas in which a boulder as large as 8 to 12 inches in diameter is a rarity. The jointing in Medicine Bluff has been referred to as rude columnar jointing.

A generalized statement appears justified that the older the rock of the area the more complex the jointing. It is as if the succeeding rock emplacements have induced jointing in all the preceeding rocks. Yet, the major joint pattern related to the orogenic belt predominates.

Faulting

Movement and the amount of displacement are difficult to determine in igneous rocks except under special conditions, and many faults probably are present in this area which were not detected.

Pre-Lugert Faulting

The hypothesis of pre-Lugert faulting is based upon indirect evidence. The fault is used as an explanation of how a medium to coarse grained rock and an aphanitic porphyritic rock can occur in large bodies at or about the same elevation. This fault or possibly a series of faults is described in the section on the emplacement of the Lugert granite.

Post-Lugert Faulting

It is apparent that considerable movement has taken place along the joints. Many of the joint faces show slickensides. The movement along any one joint is probably small, an inch more or less. The total displacement has been effected along these planes and the major faults. The joints have served as planes of movement and in this way the displacement has been proportioned to many lines of movement instead of a few well defined faults.

The large north-south fault found in this area is the one located in the eastern portion of the Quanah Mountain Group. The fault zone is confined to about 300 feet in width and strikes approximately N. 12° E. and roughly parallels a direction of one of the major joint systems. The dip appears to be vertical. The horizontal displacement of the present Quanah granite outcrop is approximately 2000 feet, however, the horizontal movement is not thought to be nearly as large. The vertical displacement cannot be measured.

The sheared zone of this north-south fault forms a defile through the high group of hills of this area. The defile is located between Cross and McKinley Mountains. A water-shed divide is located approximately in the middle of the canyon; the south flowing intermittent stream is a tributary of West Cache Creek and the north flowing intermittent stream is a tributary of Blue Beaver Creek.

An aplitic rock intrudes the Quanah and Lugert granites along their contact in this immediate area. Aerial photographs indicate that this aplite body is truncated by this north-south fault but field evidence shows that the aplite occurs as a narrow band between the Lugert and Quanah granite on the west side of the fault.

If this north-south fault is extended to the north, striking approximately N. 12° E., it would roughly coincide with the high pass between Mt. Sheridan and Mt. Wall. A hypothetical continuation of the line of the fault would intersect the big fault in the Limestone Hills to the north where the Carlton rhyolite is brought up in contact with the Arbuckle Limestone. However, the extension and direction of the north-south fault may not be justified. The line may extend southward, but the surface mantle prevents its detection.

Any offsetting of the Carlton rhyolite to the west of Ketch Lake cannot be determined. Only isolated outcrops of the rhyolite protrude above the gravels. The Davidson microgranite outcrop in

Sec. 8, 17, T. 3 N., R. 13 W. is separated from the microgranite of Sec. 16, T. 3 N., R. 13 W. and its displacement, if any, cannot be measured.

Some evidence exists for the postulation of another fault in this immediate area. Blue Beaver Creek closely follows the rhyolite and granite contact downstream from Ketch Lake. As this stream leaves Ketch Lake, it makes a sharp bend to the east. It flows east for about a mile and then swings to the southeast and continues to the south. Most of its eastward course is in the rhyolite. An unnamed intermittent stream heads between Cross Mountain and Mt. Sherman and flows north to a point within 150 yards of Blue Beaver Creek where it turns sharply to the east and parallels Blue Beaver Creek, joining it where Blue Beaver Creek swings to the south. This unnamed stream follows the Carlton rhyolite and Lugert granite contact. Blue Beaver Creek follows the contact from this point on. The contact is actually covered by a Permian embayment which extends into this valley from the south. Talus and recent sediments have completed the burial of the contact.

As in the previously described north-south fault, a dike-like protrusion of the aplite is also truncated by this proposed fault. The Quanah granite also is terminated along this line. This relationship, the presence of slickensides, a high degree of fracturing, and evidence of a shear zone, indicate the existence of this fault. (This is in the same area where the amygdaloidal dikes occur). The strike of this fault approximates N. 45° W., departing from the N. 45° W. to an east-west direction as it approaches Ketch Lake from the south and east.

These two faults, together with the intricate intrusions in the Mts. McKinley-Cross-Sherman area, have made the structure very complex. The mountains which bound this area to the north and west have not been studied in detail, thus, the solution is not complete.

The Aplite-Lugert granite to the west of the former N. 12° E. fault dips to the southeast. The Lugert granite to the east of the fault remains essentially horizontal. The present contacts and outcrops could be produced by a horizontal and a rotational movement; the area to the west of the fault being the downthrown side, tipped to the south, and horizontally displaced to the north.

The fault discovered on Welsh Hill, the northeasternmost outcrop of the Lugert granite, has brought an aphanitic porphyritic rock up into contact with the Lugert granite. The porphyry resembles the Carlton rhyolite and thus is so named. The strike of this fault is approximately N. 76° W. The dip is assumed to be vertical. A low pass, heavily covered by jack oak, serves as the dividing line; on one side, there is a hornblende granite, on the other a porphyry. Striated fragments found in the float bear evidence of the movement.

Is it chance alignment that a continuance of the strike of the fault on Welsh Hill intersects the point where the gabbro-anorthosite pinches out against the granite at Lake Lawtonka, or does it by further prolongation, coincide with the fault in Mt. Sheridan? The fault in Mt. Sheridan strikes N. 76° W., has a vertical dip, and a vertical displacement of 68 feet.

Horizontal movement of an over-riding or sheet-like nature is exposed in a series of gravel pits located S. E. 1/4 of Sec. 16,

T. 3 N., R. 13 W. The pits are just above Little Medicine Creek and below the road. Slickensides abound and there is a zone of breccia which measures ten to fifteen feet in thickness. The Davidson microgranite has been highly sheared. In this same locality but to the west the Carlton rhyolite contacts the Lugert granite. The contact is separated by a gap which averages about two feet and supports a growth of grass and small oak. The vegetation resembles that of other locations where diabase dikes form shallow trench-like depressions by erosion. A diabase dike was found to line up with this gap from the west but could not be traced farther east. Direct evidence that this is a fault, as reported and photographed by Hoffman[5], was not found in the field. Rather it is interpreted as a diabase dike cutting along the Carlton-Lugert contact and later weathered to form a depression. Indirect evidence such as the absence of the chilled phase of the Lugert granite on contact with the Carlton rhyolite, the separation of these two bodies, and the presence of a diabase dike, may support Hoffman in calling this a fault.

In the west central portion of Sec. 22, T. 3 N., R. 13 W., a diabase dike intrudes the Carlton rhyolite. It measures 18 inches in thickness. Unlike most of the diabase dikes found, this dike is sinuous. The intrusion of the dike has separated the country rock in such a way that projections of one side correspond to reentrants on the other. Evidence of faulting is found in the diabase dike and the displacement, as measured by the offset of the projection and reentrants in the rhyolite, is 18 inches. The strike of the fault and the dike is

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[5] Hoffman, op. cit., p. 16.

generally N. 30° E.

If a cross-section were to be drawn through Pratt Hill, Sec. 23, 24, T. 3 N., R. 13 W., it would lend evidence of faulting which has elevated the Davidson microgranite-Carlton rhyolite contact. The microgranite sill is essentially horizontal with an upper surface contact at about 1,400 feet, except in the cliff of the north face of Pratt Hill where the contact is at 1,500 feet. The microgranite is not found to outcrop to the east of Pratt Hill. Directly above the last outcrop to the east, striated and grooved fragments are not far removed from a small V-shaped trench which forms a fairly straight line. This trench is east of the small intermittent stream where the microgranite is exposed. The microgranite is not exposed on the south side of Pratt Hill. On the western end of Pratt Hill the microgranite-rhyolite contact shifts upstream in such a way to suggest that it is essentially horizontal. It is at an elevation of 1,400 feet. A short distance to the east in the northwestern face of Pratt Hill, the contact is found 100 feet above the water line of Lake Thomas. The contact can be followed eastward at the same elevation of 1,500 feet until it is faulted out. The faults in Pratt Hill cannot be observed because the talus covers the area where they should be seen. The structure formed by these two faults has produced a small horst.

Other locations where faults probably exist were noted but sufficient evidence could not be obtained to definitely establish the fact.

Historical Geology

A resume of the Geology of the Wichita Mountains is necessary as a background for considering the igneous rocks of the Fort Sill Reservation. However, all of the rocks mentioned in this section are not found in the thesis area.

Pre-Cambrian Events

Taylor[6] was the first to name and describe the Meers quartzite. It is present as roof pendants in the gabbros in the northeastern area, also in the Lugert granite in the S. E. ¼ Sec. 34, T. 4 N., R. 14 W. The quartzite is considered the oldest rock in the Wichita Mountain System. Taylor gave the order of intrusion of the igneous rocks outcropping in the Wichita Mountain System as gabbro-anorthosite (oldest), Headquarters granite, Reformatory granite, Cold Springs granite, Lugert granite, Quanah granite, and dike rocks and quartz veins (youngest). Hoffman[7], in 1930, subdivided the Lugert and Quanah granite of Taylor into the Saddle Mountain, Davidson, Carlton, Lugert, and Quanah granophyres, reading from oldest to youngest.

The igneous rocks comprise a series of pre-Cambrian intrusions beginning with the basic and ending with the acidic. At this time the region was above sea level and subjected to erosion. The erosion continued and it was probably during the Lipalian interval that the igneous rocks were unroofed.

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[6] Taylor, op. cit., p. 32.

[7] Hoffman, op. cit., p. 48.

Paleozoic Events

Paleozoic deposition began in upper-Cambrian and continued through the Ordovician period. The first record of derived clastic sediments is a basal limestone discovered by Decker[8] which contains fragments of the Carlton rhyolite, not only in the lower part, but continues up toward the top and on into the Reagan sandstone. He dates this limestone as upper-Cambrian. No major diastrophic movements are recorded. The basal limestone and the Reagan sandstone lie unconformably on the igneous rocks in the eastern part of the mountains. The sediments indicate that the source was reduced before the close of the upper-Cambrian epoch. About seven thousand feet of Cambrian and Ordovician limestones and some Ordovician sandstone conformably overlie the basal limestone and the Reagan sandstone[9].

The following table is reproduced in part from Decker's[10] Progress Report.

Overlying the Arbuckle Group is the Simpson formation and the Viola limestone. The Simpson is exposed in a few outcrops south of Gotebo near Rainy Mountain Mission. Small outcrops of Viola limestone have been described from the same area. The Simpson formation consists of limestones, pure sandstones, and green shales, and in

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[8] C. E. Decker, "Progress Report on the Classification of the Timbered Hills and Arbuckle Groups of Rocks, Arbuckle and Wichita Mountains, Oklahoma", Okla. Geol. Sur. Circ. 22 (1939).

[9] C. E. Decker and C. A. Merritt, "Physical Characteristics of the Arbuckle Limestone", Okla. Geol. Sur., Circ. 15 (1928).

[10] C. E. Decker, "Progress Report on the Classification of the Timbered Hills and Arbuckle Groups of Rocks, Arbuckle and Wichita Mountains, Oklahoma", Okla. Geol. Sur. Circ. 22 (1939).

TABLE I

TABLE OF FORMATIONS
SHOWING AGE, DISTRIBUTION, THICKNESS AND DESCRIPTION
OF THE ASSOCIATED SEDIMENTARY ROCKS

Periods	Groups	Formations and Members	Maximum Thickness	Description
ORDOVICIAN	Arbuckle Group	West Spring Creek	250	limestone shaly
		Kindblade	956	limestone
		Cool Creek	1015	limestone shaly sandy
		Strange	80	dolomite
		McKenzie Hill McMichel Chapman Ranch	1019	limestone conglomerate
CAMBRIAN		Butterly	Wanting	dolomite conglomerate
		Signal Mountain	350	conglomerate limestone
		Royer	219	dolomite limestone
		Fort Sill	369	limestone
	Timbered Hills Group	Honey Creek	266	coarse limestone glauconitic, siliceous, ferruginous
		Cap Mountain	Wanting	semi-dolomite
		Reagan	134	conglomerate arkose sandstone
		Basal limestone	98	limestone with rhyolite fragments

places it lies unconformably on the Arbuckle Group. The Viola limestone consists of limestones and cherts, and lies conformably on the Simpson formation.

Near the close of the Ordovician period broad regional warping brought western Oklahoma above sea level. The uplift was not great and no great amount of erosion is recorded[11].

No records of the Silurian, Devonian, Mississippian, or Lower Pennsylvanian rocks are found in the Wichita area. However, oil wells drilled on the southern flank of the Anadarko Basin indicate that these rocks pinch out against the mountains.

From mid-Pennsylvanian to the close of this period and perhaps into Permian time, Oklahoma was subjected to intense diastrophism. The Ouachita, Arbuckle, and Wichita Mountains arose. Regional warping tilted the Wichita region a little south of west. During Permian time the seas were widespread but shallow[12].

Hoffman[13] writes that:

> The Wichita mountains formed an archipelago in the early Permian sea. They were being rapidly reduced while the surrounding sedimentary deposits were becoming thicker. If the late Permian deposits did not completely cover the mountains they left very little exposed. The level of the red beds today at the base of the Headquarters Mountain Group northwest of Granite, if extended southeastward, would not fall short more than 200 or 300 feet of completely covering the Wichitas.

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[11] Sidney Powers, "Age of Folding of the Oklahoma Mountains", Bull. Geol. Soc. Amer., Vol. 39, (1928).

[12] E. B. Branson, "Triassic-Jurassic 'Red Beds' of the Rocky Mountain Region", Jour. Geol. Vol. 35, No. 7 (1927) pp. 607-630.

[13] Hoffman, op. cit., p. 28.

Post-Paleozoic Events

Following the Permian, the area was subjected to erosion. The principal drainage was to the southwest. Then came the Laramide revolution. The folding of the Rocky Mountains caused regional tilting in Oklahoma, changing the general slope to the southeast which prevails today.

During Pleistocene time the gravels found in and around the mountains were deposited. This is the only deposition of importance from the Permian to the Present. Anderson[14] postulated little erosion of the igneous rocks since Permian time.

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[14] Anderson, op. cit., pp. 60-61.

CHAPTER III

THE IGNEOUS ROCKS

Field Occurrence of the Igneous Rocks

Carlton Mountain Group

The low mountains and peaks which lie between the eastern end of the Wichita and Quanah Groups is known as the Carlton Mountain Group. This latter group constitutes the southeastern extremity of the Wichita Mountain System and is dominantly igneous. Some outcrops of the Arbuckle limestone are present. In the Ft. Sill Quarry the beds are essentially horizontal. The sedimentaries on the north and the south dip away from the igneous core.

The larger portion of the igneous rock in this group is the Carlton rhyolite. Since the mountain system has been divided into physiographic groups by Taff,[1] it includes an outcrop of Lugert granite in the southwestern portion which is located in Sec. 2, 3, 10, 11, T. 2 N., R. 13 W. The Lugert granite also outcrops along the northern portion of the Carlton Group. The Davidson microgranite outcrops in the northern

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[1]Taff, op. cit., p. 54.

portion of the Carlton Group. The Davidson microgranite outcrops in the northern portion and is located in Sec. 13, 14, 23, 24, T. 3 N., R. 13 W.

Three previously unmapped outcrops of the Carlton rhyolite were found. A fault in the northern end of Welsh Hill, Sec. 13, T. 3 N., R. 12 W., has brought rhyolite up into contact with the Lugert granite. An outcrop of rhyolite occurs in Sec. 16, T. 3 N., R. 12 W. on the southeastern nose of Mt. Cummins. Another exposure was found in Sec. 10, T. 2 N., R. 13 W. on the southwestern nose of Gruber Hill.

Wichita Mountain Group

The largest of the physiographic divisions is the Wichita Mountain Group which consists of many rugged and irregular granite peaks and hills. The most prominent of these are Mount Scott, which is near the southeastern end, and Mount Baker, which is near the northwestern end. This group is elongated in a northwest-southeast direction for a distance of about twenty-five miles. The Wichita group is separated from the Quanah on the south by a wide plain-like valley which continues eastward to the western end of the Carlton group where it divides. The northern end of the valley then passes through Little Medicine Creek between the Carlton Mountains and Mount Scott while the southern arm extends to the Permian plains down Blue Beaver Creek.

Only the igneous rocks of the southeastern portion of the Wichita group are included in the area of this study. The larger portion of these igneous rocks consists of the Lugert granite. The

Carlton rhyolite outcrops in Sec. 14, 15, 16, T. 3 N., R. 13 W. The Davidson microgranite outcrops in Sec. 14, T. 3 N., R. 13 W. as a small mass south of Mount Scott and as an intermittently narrow strip in Sec. 8, 15, 16, 17, T. 3 N., R. 13 W. A newly discovered outcrop of the microgranite was located in the south central portion of Sec. 15, T. 3 N., R. 13 W. A small outcrop of gabbro-anorthosite occurs in a saddle in the northeastern hills of Central Peak located in Sec. 18, T. 3 N., R. 13 W. and again as the very eastern extremity of the Central Area outcropping in Sec. 24, T. 3 N., R. 14 W.

Quanah Mountain Group

The Quanah Mountain Group is much like the Wichita Mountain Group in that it is elongated and extends for a distance of about fourteen miles in the same general direction. The Quanah group is roughly divided into a western and an eastern part by West Cache Creek. The eastern half of the eastern part of the Quanah group is included in this study.

The outcrops of the igneous rocks in this area are unequally divided between the Quanah granite and the Lugert granite, the latter constituting the greater portion. An aplitic body has been injected along the Quanah-Lugert contact. An outcrop of the Carlton rhyolite, completely surrounded by Lugert granite, occurs at the intersection of Sec. 4, 5, 8, 9, T. 2 N., R. 13 W.

The intricate pattern of intrusion, together with considerable faulting and subsequent erosion and deposition, have complicated this area.

Field Description of the Igneous Rocks

There are eight types of igneous rocks in the Fort Sill Reservation area. They are the gabbro-anorthosite, Carlton rhyolite, Davidson microgranite, Lugert granite, Quanah granite (granophyres)[2], diabase dikes, aplite masses and dikes, and quartz dikes and veins, reading from the oldest to the youngest.

Gabbro-Anorthosite

The gabbro-anorthosite of the Central Area, Sec. 24, T. 3 N., R. 14 W., megascopically, is medium to dark gray on fresh surfaces, light gray to a rust yellow or even black on weathered surfaces, medium to coarse grained[3], and non-porphyritic. Crystals of labradorite, which constitute the major mineral of the rock, often obtain a size of 2 cm.. in length. Polysynthetic twinning is well developed, and in reflected light the labradorite displays a play of colors, especially a deep blue. The ferromagnesian minerals are present but are in a minority.

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[2]The term granophyre as a rock name will not be used in this thesis as it is believed that it overemphasizes the micropegmatitic texture at the expense of other characteristics such as phaneritic and aphanitic, porphyritic and non-porphyritic textures. The use of the field terminology aids in the delineation of the various types of rock. This is justified in the chapter on petrography.

[3]The C.I.P.W. system of classifying the grain sizes of igneous rocks is used in this thesis: less than 1 mm., fine-grained: between 1 and 5 mm., medium-grained; over 5 mm., coarse-grained. Cross, Iddings, Pirsson, and Washington, "The Texture of Igneous Rocks", Jour. Geol., Vol. 14 (1906), pp. 692-707.

The gabbro-anorthosite weathers more readily than the granites and, therefore, the hills develop a gentle slope. The color of the residual soil is medium gray with local stainings of yellow which make a contrast to the yellow rust red of the granites; a feature which aids in locating the contact even though it is covered by residual soil. The abrupt change in slope offers further evidence of the contact. The gabbro-anorthosite supports abundant vegetation whereas the granites in comparison support plant life sparingly.

No sharp and well defined contacts are present in this area. Good contacts, however, are found outside the area, for example that exposed on Mt. Sheridan, which clearly shows the Lugert Granite to be the younger. The gabbro-anorthosite takes on a pinkish hue in Sec. 23, T. 3 N., R. 14 W., and is cut by thin stringers of aplitic material which was injected at the time the granite came in. Orthoclase crystals measuring 4 mm. have been developed by injection into the gabbro-anorthosite along the contact of the northern arm of the eastern end of the Central Area.

Deuteric and hydrothermal alteration have been profoundly destructive in localized areas. The altered basic rock is so friable that entrenchments may be dug with a hammer, and masses crumble in the hand.

The last geologic study made in this area was in 1930. Quanah Parker Dam was built in 1936 and the subsequent filling has covered a large portion of the southern arm of the eastern end of the Central Area. Thus, some of the exposures formerly available for study can no longer be observed.

The gabbro-anorthosite of the Central Peak Area, Sec. 18, T. 3 N., R. 13 W. is uniformly a medium gray on fresh surface, dark brown to black on weathered surfaces, medium grained, and non-porphyritic. The mineral content is about equally divided between labradorite and the ferromagnesian minerals and magnetite. Areal variations in the mineral content and texture cannot be determined because the outcrop is small.

Here again, the susceptibility of the gabbro-anorthosite to weathering has resulted in a physiographic feature. The rock outcrops in the saddle located in the northeastern hills of Central Peak. The area is roughly elliptical in outline, the long axis being east-west; it measures about 500 feet by 200 feet.

The contact is not exposed. The outcrop area is grass covered and supports an abundance of jack oak. Exfoliation is more rapid and pronounced on the gabbro-anorthosite boulders than on the granite. Crystals of magnetite stand out in relief on the weathered surface. The depressions have the outlines of old elongated labradorite crystals and interspaces.

The gabbro-anorthosite is cut by thin stringers of aplitic material but due to the lack of exposed contacts it cannot be definitely stated that the stringers are chilled apophyses of Lugert granite.

Carlton Rhyolite

The Carlton rhyolite where fresh varies in color from a brick red to brown to a light pink, or from a light gray to dark gray. The weathered surface usually presents a buff to brown color. The rhyolite has an aphanitic to very fine grained groundmass with phenocrysts of acid feldspars and quartz which are commonly euhedral. On the weathered surface the phenocrysts of quartz remain clear and stand out while the orthoclase blends with the color of the rock. Sometimes the feldspar has become loosened and lost, or has weathered out leaving the rock with a pitted surface. The orthoclase and quartz ofttimes are intergrown pegmatitically. The rhyolite is highly jointed and weathers out as small angular fragments, leaving smooth rounded hills. The smooth contour and silhouette of the hills are features which enable recognition of the Carlton rhyolite area from a distance.

The phenocrysts make this rock type easily identified. However, there are phases of the Lugert granite which might be mistaken for the rhyolite on first examination. The Davidson microgranite resembles the rhyolite in texture and somewhat in color but the phenocrysts are absent in the microgranite. Except for the few localized phases of the Lugert granite, the Davidson microgranite is the only rock of the area which approaches the porphyritic rhyolite in appearance. If there is an increase in phenocrysts, the groundmass becomes coarser and the ratio of quartz to orthoclase decreases; the fewer the phenocrysts, the finer the groundmass. The outcrop found on the northern portion of Welsh Hill, Sec. 13, T. 3 N., R. 12 W. contains numerous phenocrysts in a fine grained groundmass. At this location the intergrowth of orthoclase and quartz is coarse enough to be seen with the naked eye. In this outcrop the phenocrysts weather in relief. The rhyolite in Sec. 29, T. 3 N., R. 13 W., just east of Ketch Lake, has a very fine grained groundmass, and, on the rock surfaces, the phenocrysts stand out.

The flow structure found in the rhyolite is caused by linear parallelism of the feldspar phenocrysts and the linear arrangement of subhedral quartz phenocrysts. Flow layers are developed by bands of the aphanitic groundmass alternating with streaks of material high in feldspar content, the latter somewhat resembling an aplite. The principal flow is in an east-west direction but local flows give a variety of readings. The significance of the flow lines and their interpretation is discussed in the emplacement of the rhyolite.

The contact of the rhyolite and the Quanah granite is obscure but the contact of the rhyolite with the Lugert granite is well defined in several places, notably in Sec. 15, 22, 23, 25, T. 3 N., R. 13 W.

Evidence of deuteric and hydrothermal alterations is found in several places. The destruction has not been as severe as in the gabbro-anorthosite. The rhyolite has reacted differently, its grain size allows it to remain a coherent mass after alteration. The rhyolite in Medicine Bluff and on Mt. Hinds show these effects very well. On the northern face of the bluff, the whole section of the altered rhyolite zone may be seen. The rock has been altered in such a way that it appears to have been bleached. This zone is white to light gray in color while the surrounding rock is a brick red. The altered rhyolite does not resist weathering as well as the surrounding rock and this factor has resulted in a concave depression with an overhanging upper portion where this altered material is actively being weathered out. The orthoclase phenocrysts have been completely changed to kaolin. This alteration zone is closely associated with the quartz and diabase dikes at the junction of M. B. #2 and M. B. #3. The zone on Mt. Hinds is also a light gray. The orthoclase phenocrysts have been highly altered, producing cavities which are lined with megascopic euhedral crystals of quartz or muscovite or both.

Diabase dikes are common in the rhyolite, while aplite dikes are rare.

Davidson Microgranite

The Davidson microgranite is medium to dark gray, or, pink to light red on fresh surfaces. It is buff to dark gray or dull red on weathered surfaces. The texture is aphanitic to very fine grained and non-porphyritic. Locally the rock has a banding and on a weathered surface this lamination stands out in relief. Megascopically, it may easily be mistaken for a metamorphosed rock. Microscopically, the banding can be determined. Field relations show the rock to be of igneous origin. An outcrop of this rock south of Mt. Scott was misnamed the Meers quartzite by Taylor[4]. It was later classified as igneous rock by Hoffman[5] with which conclusion the writer concurs.

The microgranite has been highly jointed and weathers out as small angular fragments. In Sec. 14, T. 3 N., R. 13 W., a quarry has been blasted into a small hill of the microgranite and the material is

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[4]Taylor, *op. cit.*

[5]Hoffman, *op. cit.*

used for gravel, requiring very little crushing for that purpose. It occurs at about the same elevations and topographically occupies the lower levels.

A new outcrop found in Sec. 15, T. 3 N., R. 13 W., is typical Davidson microgranite. It is in contact with the Carlton rhyolite and the Lugert granite. The color of the groundmass of the microgranite is identical with that of the Carlton rhyolite which bounds the outcrop on the west, north, and east. The only difference here is that the rhyolite carries phenocrysts of quartz and orthoclase whereas they are absent in the microgranite.

Contacts are for the most part obscure but the bluff carved in Pratt Hill by Little Medicine Creek has bared the contact between the microgranite and the rhyolite. Inclusions of the rhyolite were found in the microgranite and also veinlets of the latter cut the rhyolite. Just west of Pratt Hill the Lugert granite contacts the microgranite and the rhyolite. It is here that apophyses of the granite were found in the microgranite.

The laminations of the Davidson microgranite are flow lines which have become more evident by differential weathering. Their general strike is east-west and they have an average dip of about 50 degrees to the north. The lines are very fine and number about 30 to the inch. Crenulations and minute folds of the flow lines are comparable to a feature developed by contemporaneous deformation in shales or to plastic flowage in metamorphosed sediments.

The elongate outcrop just south and east of Mt. Roosevelt, Sec. 8, 15, 16, 17, T. 3 N., R. 13 W., was called the Davidson granophyre by Hoffman. This rock is light pink on fresh surfaces, light brown on weathered surfaces, very fine grained, and non-porphyritic. The texture of this rock differs from the microgranite. Microscopically, the red microgranite is coarser grained than the gray microgranite and resembles an aplite. Its color is nearly that of the Lugert granite and the contact is difficult to locate because the granite has a chilled border at the contact. Apophyses of the Lugert granite are found in the Davidson microgranite, therefore, the red microgranite is older. The exposure measures approximately 50 feet thick at a maximum and thins to 5 feet at the eastern end of the outcrop. The microgranite overlies the Carlton rhyolite and is highly brecciated just above the contact with the underlying rhyolite.

Lugert Granite

The Lugert granite is dominantly a pink to red color on fresh surfaces and a dull reddish brown to light gray on weathered surfaces. The grain size varies from 1 to 5 millimeters, the extreme limits for the medium grained classification. The rock exhibits a faint porphyritic appearance which is not always perceptible. The porphyritic texture is related to the quartz intergrowths. The "phenocrysts" are contrasted on weathered surfaces and is exemplified on Davidson Hill, N. E. 1/4, Sec. 19, T. 3 N., R. 13 W. However, large areas are exposed in which the porphyritic texture is not evident. Microscopically, the texture is more clearly defined. Sometimes the crystals of orthoclase or perthite weather out and the surface of the rock becomes pitted. In this case the cavity has the shape of the crystal which was dissolved.

The term Lugert granite is here used for the rocks referred to by Taylor[6] by that name. His type was taken from the vicinity of Lugert, Oklahoma. The so-called Lugert granite of this thesis area is well represented by the rock in Mt. Scott, Sec. 11, T. 3 N., R. 13 W, however, this rock contains a higher per cent of hornblende than does the same rock at other locations. If the granite of Mt. Scott is considered the type for this eastern area, then it resembles in many respects the Lugert granite of the western area, yet, there are some differences. The question arises as to the validity of correlating these two granites across the intervening distance of 35 miles which has not been studied in detail. Sufficient data are not available at this time for definite correlation.

The granite of Mt. Scott contains numerous small dark masses which are segregations of hornblende, some of which have sharp border lines while others have merely a shadowy outline. The presence of these femic concentrations may not be restricted to this one outcrop. The road cut that extends to the top of Mt. Scott has exposed fresh surfaces from the top to the bottom, allowing the dark masses to be easily noticed. These segregations may be widespread but are not noticeable on weathered surfaces. Microscopically, the segregations do not show

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[6]Taylor, <u>op. cit.</u>, p. 60.

the sharp contact seen macroscopically. The dark masses in the Lugert granite of Mt. Scott are composed of quartz, orthoclase and microperthite, and a high percent of hornblende and magnetite; the hornblende being in excess of magnetite. The average grain size of the segregation is 0.5 mm. and its mode, as taken from one thin section, approaches that of the Lugert granite if the hornblende and magnetite is disregarded.

The Lugert granite of Welch Hill in the N. W. 1/4 Sec. 24, T. 3 N., R. 12 W., takes on a light grayish green color due to the abundance of ferromagnesian minerals. Here, as in other locations, the percentages of the dark minerals vary considerably. The rock becomes normal on the western nose of this hill, and is highly granophyric.

The granite composing Mt. Cummins, Sec. 18, T. 3 N., R. 12 W. has a low content of dark minerals, orthoclase being the main mineral. The Lugert granite of the southeastern portion of the Quanah Mountain Group is rather uniform and resembles the granite of Mt. Scott. A difference is that it lacks segregations and has a tendency to become aplitic. These examples serve to illustrate the diversity found to exist in the Lugert granite. The greatest deviation is textural, but a variation in the type of feldspar and in the amount and manner of aggregation of the ferromagnesian minerals also is noted.

The Lugert granite is miarolitic but this phase is confined to one outcrop. It occurs in the outcrop located in Sec. 36, T. 3 N., R. 14 W. and Sec. 1, T. 2 N., R. 14 W. The cavities, which average eight millimeters in diameter, are lined with euhedral crystals of quartz which terminate against the wall. In many cases the quartz crystals are veneered by limonite which represents the last stage of deposition in the cavity. The granite which contains the cavities weather into boulders similar to the exposure on Mt. Scott. The rock is highly granophyric. Some of the granite mapped as Quanah also contains miarolitic cavities.

The Lugert granite has a chilled marginal phase at its contacts with the Carlton rhyolite and Quanah granite. At these contacts, the granite is aplitic and highly granophyric. This is shown in the N. W. 1/4 Sec. 9, T. 2 N., T. 13 W., where the Lugert granite grades from a chilled aplitic phase at the contact with the Carlton rhyolite to the medium grained granite across a contact zone that measures about five feet in thickness. The contact in Sec. 23, T. 3 N., R. 13 W., between the Lugert granite and the Carlton rhyolite is sharp and well defined but the contrast is not great. The chilled zone measures about two feet in thickness, but in other places, as in Sec. 24, T. 3 N., R. 13 W., the zone is quite thick. As one approaches the contact from Davidson Hill going toward Pratt Hill, the granite grades from a medium grained rock, whose crystals average 3 mm., to a fine grained rock. The crystals of this quick-cooled phase average 1 mm. and the rock becomes granophyric. Another fine grained contact phase occurs on the southeastern nose of Mt. Cummins, Sec. 16, T. 3 N., R. 12 W. Chilled phases were not found in Sec. 15, 16, T. 3 N., R. 13 W., but here the contact appears to have been forced apart some 2 to 3 feet. A weathered diabase dike 2 or 3 feet wide has been intruded between the two rocks. As previously pointed out, Hoffman postulated a fault at this location.

The absence of the chilled phase of the Lugert granite may be indirect evidence of a fault.

It may be stated generally that the Lugert granite has undergone a chilling at the contact with the older rocks of this area, notably the Davidson microgranite, the Carlton rhyolite, and the gabbro-anorthosite. In most instances where the contact could be observed between the Lugert granite and other rocks, the granite became finer-grained and the quartz content increased in the contact zone.

The textural change noted in the granite, that is, the decrease in grain size and the increase in the granophyric texture when approaching a contact, led to the discovery of two previously undescribed outcrops of the Carlton rhyolite.

Many textural variations in the Lugert granite were found during this work. The writer believes that this variation may be related to the proximity of the contact with the underlying rhyolite or gabbro-anorthosite floor.

Hydrothermal alteration in the Lugert granite is not as profound as it is on the older rocks.

Diabase and aplite dikes are common in the Lugert granite. Quartz veins are numerous and are found throughout this granite.

Quanah Granite

The Quanah granite is light tan to light pink on fresh surfaces, rust yellow to light brown on weathered surfaces, medium to coarse grained, with phases which become porphyritic. Acid feldspars and quartz are the dominant rock minerals, and the content of ferromagnesian minerals is low. Riebeckite is present, and in some specimens becomes as high as five per cent, the average being less than one per cent. The granophyric texture is present in the porphyritic phase but is of minor importance in the riebeckite variety. The greater portion of the eastern quarter of the Quanah Mountain Group is composed of Lugert granite which is medium grained but tends to be fine grained. The Quanah granite becomes medium grained but the granite of this texture forms only a small portion of the total outcrop. The contact between the Lugert and the Quanah granites is accentuated by their respective reactions to weathering. The Quanah granite weathers out as large boulders, whereas the Lugert granite, being finer grained, weathers out in smaller sizes which are removed more quickly. Thus, the Quanah granite is commonly at a higher elevation at the contact zone and serves as the source for the talus which covers the actual contact. A definite exposed contact between the Quanah granite and the Lugert granite was not found in this area.

Weathering has affected the Quanah granite differently in various outcrops and in accordance with the textural features. That portion which is equigranular becomes friable after partial disintegration and the rock minerals are easily separated. However, weathering may not be the only factor involved because in these outcrops where the rock is friable, an increase in riebeckite or ferromagnesian minerals is noted. The hydrothermal alteration resulting at the time of the introduction of the riebeckite may be the controlling factor.

The porphyritic phase is not friable like the equigranular rock nor does it contain as much ferromagnesian minerals. The phenocrysts of feldspar measure a maximum of 10 mm. but the quartz remains about the same throughout, averaging 3 mm. for all phases of the granite. Surface weathering has not penetrated the porphyritic rock as deeply as the equigranular granite.

Exfoliation has rounded the boulders, and large areas on steep hills are barren of talus where slabs have peeled off and slid down the relatively smooth slopes. The Quanah granite of this area supports a growth of small trees and shrubs whereas the Lugert granite is relatively barren. This feature is due to the differences in weathering. The topographical map which is included in this thesis is taken from a recent army map. The map shows the vegetation and this feature partially outlines the contact between the different rocks of this area.

The rock which has just been described differs somewhat from the Quanah granite as described in the literature. The Quanah granite has not been described in detail for this area. Taff[7] did not distinguish the Quanah granite and Taylor[8], who named the granite, did not indicate its presence in this area. Hoffman[9] described this granite but his description is applicable to the granites of Quanah Mountain.

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[7]Taff, op. cit.

[8]Taylor, op. cit.

[9]Hoffman, op. cit.

The variances of the porphyritic and granophyric texture, miarolitic cavities, and the grain sizes have not been mentioned. The granite resembles the Lugert granite in many ways, however, it contains medium to coarse quartz grains which are not so prevalent in the Lugert granite. The Quanah granite is the coarser grained rock.

It is, therefore, with reservations that this granite and granite-porphyry is called Quanah granite. A detailed geologic study of the adjacent area to the west will affirm or disprove the supposition that this rock is the Quanah granite.

Dikes and Veins

The diabase rock is dark, medium or dark gray, or greenish to black with a basaltic aspect. The texture of this rock is dense to very fine grained. The ophitic texture cannot be observed megascopically. It is composed chiefly of ferromagnesian minerals and basic feldspars. The dikes weather easily and often are found to influence the course of small stream tributaries or to form small trench-like channels across the country rock. Sometimes the presence of a dike is indicated by a "strip" of abundant grass or small jack oak on an otherwise barren slope. Since these dikes weather out more rapidly than the country rock, the talus generally covers the evidence of their existence. The prospect pits and road cuts have revealed many diabase dikes which otherwise would have remained unnoticed. Some of the pits and cuts show dikes which are not found to outcrop on the surface. The amygdaloidal diabase dikes are described in the chapter on petrography.

The aplite occurs as small dikes and as a large semi-dike like mass. The small dikes have a light flesh or light brown color. The texture is fine grained, even-granular, but seldom becomes felsitic. Megascopically these dikes have little or no ferromagnesian minerals, being composed mostly of feldspars and quartz. The aplite dikes are more noticeable on a barren slope since their color blends with the acidic rocks and the talus and boulders hide their presence. The aplite dikes do not weather out like the diabase nor do they appear to be as numerous.

The large aplite mass which intrudes the Lugert and Quanah granites along their contact is three and one half miles long and averages 2,500 feet in width. It is semi-dike like in form. It has a light flesh or red color on fresh surfaces and a dull reddish brown on weathered outcrops. The grain size ranges from aphanitic to fine grained. A felsitic apophyses from this mass intrudes the Quanah granite, Sec. 32, T. 3 N., R. 13 W., in the form of a dike which is twenty-five feet wide and can be traced for about 1,000 yards. In the central portion of the large aplite body and at lower levels, as exposed in valley cuts, the rock becomes fine grained and is comparable with the finer phases of the Lugert granite.

The aplite breaks into small angular fragments upon weathering which gives the topography a smooth form. Masses of the Lugert and Quanah granites are included in the aplite. The coarser grained rocks are more resistant to weathering than the aplite and occur as masses

10 to 20 feet above the general aplite slope. Trees and shrubs do not grow on the aplite, a feature which, together with its smooth surface, shows the outline of the body in aerial photographs.

The aplite contact with the Lugert granite is not so well defined as it is with the Quanah granite as phases of the aplite resemble the finer varieties of the Lugert granite.

The aplite body is partially truncated by a north-south fault, Sec. 30, T. 3 N., R. 13 W. The aplite to the west of this fault is narrow and wedges out as the Lugert granite comes into contact with the Quanah granite.

The age of the large aplite mass and that of the small aplite dikes was not determined, though both are younger than the Quanah granite. The aplite dikes cut diabase dikes but no contacts of the latter rock with the large aplite body were found.

The quartz dikes and veins are described in the chapter pertaining to petrography. With the exception of the two quartz dikes discussed, the quartz veins seldom exceed an inch in thickness. Material on the dumps of the prospect pits show that quartz dikes and veins were encountered. The strike and dip of these dikes and veins, like all the dikes of this area, coincide with the strikes of major joints.

TABLE 2

DENSITIES OF THE VARIOUS ROCK TYPES

	(1)	(2)
Gabbro-Anorthosite		2.640-3.120
Central Area	2.66*	
Central Peak Area	3.14**	
Carlton Rhyolite	2.57	
Davidson Microgranite	2.59	
Quanah Granite	2.57	2.516-2.809
Lugert Granite	2.63	2,516-2.809
Diabase Dikes		
amygdaloidal	2.65	
non-amygdaloidal	2.74	2.804-3.152
Aplite Dikes	2.56	
Jasper Dike	3.02***	

1. Igneous rocks of the eastern Wichita Mountains.
2. From the latest edition of Washington's "Chemical Analyses of Igneous Rocks" Prof. Paper 99, U. S. Geol. Survey, 1917, listing the specific gravities of rock types.

* 94 per cent labradorite
** 51 per cent labradorite, 30 per cent augite, 5 percent magnetite
*** Impregnated with magnetite and hematite

CHAPTER IV

PETROGRAPHY

The igneous rocks will be discussed in the order of their ages, the oldest being considered first. The procedure used in describing the rocks will be to quote the latest descriptions as found in the literature, and then to enlarge upon these with the information gained during this work. The rocks are named according to Johannsen's classification[1]. This classification is used for three reasons: It was used by Hoffman[2] to classify the igneous rocks of the eastern part of the Wichita Mountains, by Scull[3] to classify the igneous rocks of the Granite-Lugert area of the Wichita Mountains; the Johannsen classification is mineralogical, quantitative, and modal, all desirable qualities; and a uniform classification will facilitate correlation of the igneous rocks of the Wichita Mountain System.

The acidic igneous rocks of this area were labelled granites and rhyolites by Taff and Taylor and later relabeled granophyres by

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[1]A. Johannsen, A Descriptive Petrography of the Igneous Rocks, (Chicago University Press, 1931)

[2]Hoffman, op. cit.

[3]Scull, op. cit.

Hoffman. The meaning of the term granophyre and its origin thus requires special consideration.

The granophyric texture as observed in the igneous rocks of this area has been deuterically introduced. In Harker's[4] discussion of the granophyres in Strath (Syke) no distinction was made whether the granophyric texture was primary or secondary, however, Geikie's[5] statement".... same acid magma as that which first supplied the general body of granophyre" is interpreted that the granophyric texture was present at or before the time of emplacement. Geikie further states that "the acid rock, though styled granophyre, belongs to a granitoid variety..." If the rock has been emplaced and the granophyric texture induced by a continuation of magmatic processes, then the granophyric texture has been deuterically introduced. Sederholm[6] defines "deuteric" as metasomatic changes as those that have taken place as a result of the direct continuation of the consolidation of the magma of the rock itself. Thus, "the metasomatic changes caused by solutions given off for the same magma from which the rock itself crystallized, which percolated through the already solid (or almost solid) but still hot rock, should be called deuteric".

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[4] Alfred Harker, "Geol. Soc. London, Quart. Jour". Vol. 52 (1896).

[5] A. Geikie, The Tertiary Basalt-Plateaux of North-Western Europe", Geol. Soc. London, Quart. Jour. Vol. 52 (1895), pp. 331-402.

[6] J. J. Sederholm, "On Synantetic Minerals and Related Phenomena", Bull. de la Conn. Geol. de Finlande, No. 48, (1916), pp. 141-142.

Colony[7] states that:

> During the consolidation of plutonic rocks especially, the mineralizers operate to effect changes in some of the already formed minerals, and . . . . Frequently the end-phase products, quartz and albite, penetrate the earlier feldspars, converting earlier orthoclase into a sort of "injected perthite", ...
>
> All stages of flooding with the end-consolidation, more siliceous, aqueo-igneous concentration-product may be seen, the maximum effects producing the so-called "micropegmatites" which are essentially the consolidated "concentrates" themselves . . . . the "acid" differentiate of the more basic portions of the magma.

The deuteric alterations which are going on in an igneous body when it has almost crystallized would be more profound than in a body which has completely solidified. The passageways of the crystallized rock would be restricted and the deuterically induced granophyric texture would be limited. The interspaces of a partially crystallized body would allow greater freedom for the percolation of the mineralizers. This would result in a more or less uniform occurrence of a granophyric texture throughout the hypabyssal rock. A uniform occurrence of the granophyric texture does not occur in the Wichita Mountain System. Scull[8] notes its complete absence in various parts of the Lugert granite. It is the belief of the writer that the metasomatic changes which induced the granophyric texture in this area were of a deuteric nature. Some of the changes appear to be later than deuteric, namely those produced hydrothermally, but to distinguish between these two types of

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[7]R. J. Colony, "The Final Consolidation Phenomena in the Crystallization of Igneous Rock", <u>Jour. Geol.</u>, Vol. 31 (1923) pp. 169-178.

[8]Scull, <u>op. cit</u>., p. 41.

alteration and method of dissolution, transportation, and redeposition, is often difficult. Unless otherwise stated, the alteration and introduction of the granophyric texture will be considered deuteric. These changes will be elucidated as part of the microscopic description of the igneous rock.

In only a few instances in literature on igneous rocks did the writer find the term granophyre used as a classification name. The term is almost universally used in the sense of Rosenbusch who considered it as a textural term and said[9]:

> . . . . its characteristic is that the phenocrysts as well as the groundmass are not irregular aggregates, but are in "gesetzmassig gruppirten Aggregaten geordnet". That is, the constituents have crystallized at the same time and mutually penetrate each other. The individuals may be in feathery, acicular, or irregular intergrowths, or they may show xenomorphic boundaries and the several parts of one individual extinguish at the same time, as e.g., in micropegmatite.

The writer, therefore, does not follow Hoffman in using granophyre as a rock name but rather returns to the names of Taff[10] and Taylor[11].

Gabbro-Anorthosite

The gabbro-anorthosite that outcrops in this area is found in the north western portion in Sec. 24, T. 3 N., R. 14 W., and Sec. 19, T. 3 N., R. 13 W. The former is the very eastern extremity of the Central Area; the latter is called the Central Peak Area.

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[9] Johannsen, op. cit., p. 214.

[10] Taff, op cit.

[11] Taylor, op. cit.

Hoffman[12] describes the gabbro-anorthosite of the Central Area as follows:

> The rocks are dark gray to black and medium to coarse grained. Their textures range from hypidiomorphic-granular to parallel . . . . .
>
> . . . .
>
> Labradorite is the principal constituent. Of all the specimens examined none carried less than 91 per cent. The appearance of this mineral is the same as the labradorite in the northern area.
>
> The outstanding difference between this and the northern area is that the ferromagnesian mineral which composes most of the remainder of these rocks is hornblende instead of diallage. Only one exception was found. . . . . The hornblende in these rocks is largely altered to chlorite and pistacite. Most of it has wedge shaped outlines which conform to the interspaces between the plagioclase laths.
>
> Magnetite forms as important accessory, sometimes totaling 1½ per cent. Apatite is found in abundance as stout needles, prisms, and grains. Titanite occurs in slightly greater amount than in the northern area.

Hoffman mentions the schistosity of this central area but this textural feature is confined to the northeastern edge of the outcrop.

Of the Central Peak Area, he writes:

> The rock is dark gray, medium grained, and speckled with small, black shiny crystals of magnetite. It has an ophitic texture and is composed largely of labradorite and augite. About 14 per cent of the rock is composed of chlorite and uralitic hornblende. According to the remnant structures still present the uralite appears to have come from the pyroxene, and the chlorite from biotite. It is not now possible to determine the separate percentages of these two minerals.
>
> The mode of this rock is as follows: labradorite, 51 per cent; augite, 30 per cent; chlorite and uralite, 14 per cent; magnetite, 5 per cent. Accessory minerals are apatite, titanite, and zircon. There are abundant needles and prisms of apatite. Titanite and zircon are rare.

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[12] Hoffman, <u>op. cit.</u>, pp. 35-37.

Texture

The gabbro-anorthosite of the eastern Central Area is an even, medium to coarse-grained rock. The labradorite averages 5 mm. The hornblende ranges from 0.05 to 3.0 mm., is wedge shaped and fills the interspaces. The rock is non-porphyritic and does not show marginal chilling.

The gabbro-anorthosite of Central Peak differs from that of the Central Area in that the main ferromagnesian mineral is augite instead of hornblende. Also it has the highest ferrormagnesian content of the gabbro-anorthosite of the eastern half of the mountains. Hoffman's description is applicable. The percentages essentially agree with those found by the writer in a thin section of the rock. Apatite occurs abundantly and makes up at least 1 per cent. This rock is an even, medium-grained gabbro. The labradorite averages 2.0 mm., the augite 1.0 mm. It is non-porphyritic and does not show marginal chilling.

Minerals

Labradorite is the principal mineral of the gabbro-anorthosite of the Central Area. The euhedral crystals are well twinned according to the Carlsbad and Albite laws. The labradorite is highly fractured and these minute cracks served as passageways for altering solutions and places of deposition. Changes along the margins and along twinning planes are common. The alteration products are calcite, sericite, and kaolin. Veinlets of chlorite traverse the crystals at random.

Remnants of augite remain but hornblende is far more abundant. The relationship of the augite to hornblende indicates that hornblende and augite were probably primary minerals. Original outlines of augite, now altered to chlorite, contain an abundance of magnetite in an arrangement suggesting schiller structure. Extinction angles on the remaining augite were difficult to obtain. The hornblende is altered to chlorite. The chlorite forms a pseudomorph of hornblende on the 010 face. Biotite was not found.

Magnetite and apatite are the accessory minerals. Limonitic staining is absent.

The primary minerals of the Central Peak gabbro-anorthosite are, in order of their abundance, labradorite, augite, magnetite, and apatite. Chlorite, uralitic hornblende, calcite, and kaolin, and traces of sericite are the alteration products. The labradorite of the Central Peak, except for the size, and a higher degree of fracturing, resembles that of the Central Area.

The augite fills the interspaces. The schiller structure is more marked and the magnetite which produces this structure retains its original form. Augite is difficult to identify because of its altered state.

The magnetite content may reach 10 per cent. Besides that of the schiller structure, the magnetite occurs as grains, euhedral crystals, and elongated rods, a few of which measure 4 mm. in length. Little alteration has taken place on the magnetite.

The apatite occurs as elongated prisms and many hexagonal basal sections are observed. Other accessories are rare.

Order of Crystallization

The apatite crystallized first, followed by the magnetite. Labradorite followed the accessories. The last to crystallize were the augite and hornblende.

Classification of the Gabbro-Anorthosite

The following table shows the mineral percentages of two thin sections of the gabbro-anorthosite.

TABLE 3

MINERAL PERCENTAGE OF THE GABBRO-ANORTHOSITE

	(1)	(2)
Labradorite	94.0	51.0
Augite	1.0	30.0
Chlorite-Uralite	....	14.0
Hornblende	3.5	....
Magnetite	1.0	5.0
Accessory	tr	....

1. Eastern central area, Sec. 24, T. 3 N., R. 14 W.
2. Composition given by Hoffman, Central Peak area, (Sec. 18, R. 3 N., R. 13 W.)

The mineral percentage places this rock in Class II, Order III, Family 12, of the Johannsen classification. The rock number is 2312, and the name is gabbro.

The anorthosite is a local phase of the gabbro. If the ferromagnesian minerals in the rock from Central Area were decreased 1 per cent, the rock would become 1312, an anorthosite.

Carlton Rhyolite

Hoffman[13] has described the Carlton rhyolite as follows:

> Nearly all of the Carlton Mountains are of a porphyritic granophyre. In the NW cor. sec. 9, T. 2 N., R. 13 W., a mass is included within the Lugert granophyre. The Carlton resembles the Davidson type. The outstanding difference is that it carries phenocrysts of quartz and orthoclase or microperthite, or both. These comprise about 11 per cent of the rock. The groundmass is colored purple when fresh, and weathers to a tan.
>
> The quartz crystals are quite fresh and clear. Inclusions are not especially abundant, and those that are present are arranged in lines or streaks. Many rectangular and six sided forms are still present. The edges show some mingling with the fine grained quartz and orthoclase of the groundmass. Some of the crystals are very markedly corroded. The groundmass is richer in quartz immediately surrounding these phenocrysts than it is away from them. The feldspars are completely altered, and colored with ferric oxide. Secondary products are sericite and kaolin.
>
> The groundmass is a fine grained granophyric aggregate in which the feldspar is also altered to kaolin and sericite and stained reddish. Magnetite is distributed in grains of various sizes up to those of irregular outline 0.2 mm. in diameter. Some small grains of zircon were noted and also a few small crystals of titanite.

Texture

The Carlton rhyolite is porphyritic and consists of distinct phenocrysts of quartz, perthite, and orthoclase in a fine grained, holocrystalline groundmass which is composed essentially of the same minerals. The size of the phenocrysts remain fairly constant but the grains of the groundmass vary from 0.01 mm. to 0.05 mm.

Minerals

The primary minerals of the rhyolite are quartz, perthite-microperthite, and orthoclase. The accessory minerals are apatite,

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[13] Ibid., p. 39-40.

zircon, fluorite, magnetite, and rarely titanite. Secondary minerals and alteration products are magnetite, hematite, limonite, kaolinite, sericite, muscovite, leucoxene, chlorite, and calcite.

Phenocrysts

Phenocrysts compose an average of 17 per cent of the rock mass (11 per cent quartz, 6 per cent perthite and orthoclase). The phenocrysts are embayed and penetrated by the groundmass. The crystals are moderately to highly shattered. Along these fissures the groundmass also penetrated and branched out into the phenocryst. Some of the minute cracks are not filled; others are filled by alteration products such as sericite, kaolinite, and limonite. A secondary deposition of hematite often is found along these openings.

The quartz phenocrysts average 1.5 mm., measuring through the longest dimension. The crystals are euhedral to subhedral with the prism either absent or poorly developed. The inclusions in the quartz phenocrysts consist of penetrations of microperthite, dust of magnetite and hematite, and bubbles which are commonly oriented. In a few of the crystals, some parts go to extinction at different angles because of optical discontinuity. This reorientation may have been caused by movement in the mass which fractured the phenocryst.

The perthite and orthoclase phenocrysts average 3.1 mm. and 2.0 mm., respectively. They occur as euhedral to subhedral crystals. The perthite is altered to sericite, calcite, and kaolinite along cleavage lines. Some of the perthite crystals are intergrown granophyrically with quartz. The plagioclase twinning is still evident in some crystals and their extinction angle indicated the plagioclase to be oligoclase. A few of the crystals are twinned according to the Carlsbad law.

The phenocrysts of perthite and orthoclase are clouded by alteration. The interior portion of a few crystals are corroded. These voids are sometimes lined with quartz, also sericite, hematite, or limonite; others are completely filled with the secondary minerals. Hydrothermal action has completely altered the mass in some locations and has been especially destructive to the feldspars.

An interesting feature observed in a thin section was the physical penetration of a quartz phenocryst into a perthite crystal. The perthite remnants displaced by the quartz phenocryst were held in the new position by the groundmass which came in and filled the space created by the quartz phenocryst penetration.

Groundmass

The grains of the groundmass are composed of an intergrowth of quartz, microperthite, and orthoclase. The individual grains vary in size but average 0.02 mm. in diameter. The grains of the rhyolite groundmass become coarser in the west central portion of the Carlton rhyolite outcrop, whereas the grains of the eastern portion are finer, averaging about 0.01 mm. Phases of the Carlton rhyolite resemble very closely certain portions of the Lugert granite.

Under crossed nicols, the groundmass of the eastern Carlton rhyolite displays an aggregate polarization. The matrix appears to have been broken and shattered and recemented while the rock was still hot. This shattered condition seems to be closely associated to the flow structure. Thin sections from locations where flow structure was poorly developed or lacking show a homogeneous groundmass under crossed nicols.

The flow layers are composed of quartz, microperthite, and orthoclase. The alignment of the minute crystals in the layers do not indicate the direction of movement, that is, movement of the mass from east to west or movement from west to east.

The minerals of the groundmass are about equally divided between quartz and feldspar; microperthite being more abundant than orthoclase. The quartz of the matrix is intergrown with the feldspar. Secondary quartz is present and has been hydrothermally introduced.

Magnetite, other than the primary, has been deposited extensively along joints and fissures which served as passageways for percolating hydrothermal solutions. In some locations, as on Signal Mountain, Sec. 5, T. 2 N., R. 12 W., the magnetite and hematite content approaches 8 per cent. However, this is exceptionally high. Most of the magnetite varies between 0.02 mm. and 0.24 mm. This does not include the dust particles or the rare larger masses.

The hematite is in part derived in place from the magnetite, however, the greater portion has been deposited from hydrothermal solutions as hematite. Subsequent alterations have changed the hematite to limonite, stains of which are prevalent throughout the rock mass. Hematite dust inclusions in the feldspars give them a flesh-colored appearance.

The sericite, muscovite, kaolinite, and calcite are alteration products of the perthite and orthoclase.

The leucoxene present indicates that the magnetite is titaniferous. It occurs as opaque white grains and is scattered in small amounts throughout the thin sections. Its content is less than 1 per cent.

Zircon, apatite, and fluorite occur as accessory minerals and their combined percentage does not exceed 0.5 per cent.

Chlorite is sparingly present and apparently the rhyolite has a low content of ferromagnesian minerals. Mafic minerals are notably absent in the thin sections examined, however, a few grains of biotite were found in the heavy mineral analysis.

Order of Crystallization

The first minerals to crystallize were magnetite, zircon, and apatite. The order between the quartz, perthite, and orthoclase was not determined. The microperthite of the groundmass penetrates the phenocrysts and is therefore younger. The quartz of the groundmass penetrates all the above mentioned minerals and was the last to crystallize. Secondary quartz, magnetite, and hematite have been introduced hydrothermally and contemporaneously with the alteration products.

Classification of the Carlton Rhyolite

TABLE 4

MINERAL PERCENTAGE* OF THE CARLTON RHYOLITE

	Phenocrysts	Groundmass	Total
Quartz	11.0	30.0	41.0
Perthite	4.0	....	4.0
Microperthite	....	20.0	20.0
Orthoclase	2.0	10.0	12.0
Magnetite	0.1	1.0	1.1
Zircon	tr	0.1	0.1
Apatite	tr	tr	tr
Fluorite	tr	tr	tr
Hematite	0.5	4.0	4.5
Limonite	0.2	2.0	2.2
Sericite	1.0	5.0	6.0
Kaolinite	0.5	7.0	7.5
Muscovite	tr	1.0	1.0
Leucoxene	tr	0.5	0.5
Calcite	tr	tr	tr
Chlorite	tr	tr	tr
Total	19.3**	80.6	99.9

*Phenocrysts by Rosiwal method, others estimated
**Phenocrysts total 17 per cent; 2.3 per cent includes inclusion and alteration products for total count of the rock mass.

The norm of this rock places it in Class 1, Order 2, Family 6. The rock number is 126, a <u>leucorhyolite</u>.

Davidson Microgranite

Hoffman[14] has described the Davidson microgranite as follows:

> This rock is very fine grained to dense and varies in color from a light pink to dark gray with blackish streaks. In only a few instances does it show a tendency to become porphyritic and in these the orthoclase crystals appear larger than the rest. It is usually shattered and breaks up into small sharp angular pieces less than an inch across.
>
> Microscopically these rocks are composed of very fine grained micropegmatitic masses 0.4 to 0.6 mm wide. The feldspar is orthoclase and microperthite. Much of it has been altered to kaolin or sericite, and quartz, and it is usually stained reddish with iron oxide. Sericite is found in greater amounts than kaolin. The rock is filled with numerous small grains and shreds of secondary muscovite. Some chlorite is present which appears to be an alteration product after biotite and, to some extent, possibly hornblende. The grains are so small that the original mineral structures could not be definitely determined. Grains of magnetite are about evenly distributed. Titanite is usually present, and zircon rarely.

Texture

There are two types of which has been mapped as Davidson microgranite. One type, as in Sec. 14, T. 3 N., R. 13 W., is a medium to dark gray aphanitic rock and the other, Sec. 16, T. 3 N., R. 13 W., is a pink to light red rock which is aphanitic to very fine grained. The grain size of the red microgranite averages 0.16 mm., whereas the grains of the gray rock average 0.09 mm. The former is granophyric and flow layers are absent. The latter rock contains a higher per cent of magnetite and is highly altered.

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[14] *Ibid.*, p. 39.

Minerals

The primary minerals of the red microgranite are quartz, microperthite, orthoclase, biotite and possibly hornblende. Alteration products are kaolinite, sericite, chlorite, and limonite. Accessory minerals are apatite, zircon, magnetite, and rarely titanite.

The microperthite of the red microgranite is composed of orthoclase and a feldspar which was not determined because the state of alteration and the grain size made the extinction angle indistinct, however, the angle is low and the plagioclase is probably oligoclase. The microperthite grains average 0.1 mm. and are subhedral. The grain edges are embayed and intergrown with quartz. The microperthite of the gray rock has been completely altered to sericite and kaolinite.

The quartz grains are clear, have a wavy extinction, embayed, and contain numerous inclusion of magnetite. Minute inclusions, probably gas or water, also are present in the quartz grains which suggest passageways of hydrothermal activity. The quartz grains have been fractured and the small fissures filled with alteration products. The average grain size is 0.18 mm., however, numerous anhedral quartz grains in the intergrowth are optically continuous and measure 0.3 mm.

The orthoclase occurs as subhedral grains and has been altered slightly in the red microgranite. They are fractured but have the orthoclase cleavage. The grain size averages 0.12 mm.

The magnetite of the red rock is equidimensional, and evenly distributed, whereas in the gray rock, the magnetite content is higher and contains grains of two distinct sizes; the larger being 0.24 mm., the smaller and more numerous being 0.01 mm. in diameter. The larger sized grains appear to be primary but the smaller, in part at least, have been secondarily induced. The smaller grains are dispersed throughout the gray microgranite and also along minute fissures. Distinct from those in the fissures and in the groundmass, the smaller grains are oriented. The alignment of the magnetite grains and a slight orientation of the quartz grains produce the flow structure which has previously been mentioned. The magnetite also occurs as separate and single grains, or as clusters and fine dust.

A few remnants of biotite were found, one of which measured 0.09 mm. The biotite in part has altered to chlorite.

Zircon is present as euhedral prismatic crystals and grains. The largest crystal measured 0.12 mm. and the smaller grains average 0.02 mm. It has a strong birefringence and a high relief. Titanite is present as traces in the thin sections examined. Apatite occurs as elongate prisms averaging 0.01 mm.

Fluorite has been secondarily introduced along fissures and as fillings in a few cavities. The largest grain measures 2.6 mm. long by 1.0 mm. wide. The average size of the fluorite present is 0.01 mm. Its presence was detected also in the heavy mineral analysis. Fluorite was not found in the red microgranite slide.

Sericite, chlorite, and kaolinite occur abundantly in the gray rock. The kaolinite and sericite are alteration products of the feldspars. The chlorite, also an alteration product, was derived hydrothermally from biotite and probably hornblende. These secondary products occur as masses and stringers. Minute fissures are filled with these minerals. The microgranite is stained by oxides of iron.

Classification of the Davidson Microgranite

TABLE 5

MINERAL PERCENTAGE OF THE DAVIDSON MICROGRANITE

	(1)	(2)
Microperthite	45.0	....
Orthoclase	3.0	....
Quartz	50.0	55.0
Biotite	tr	....
Magnetite	1.0	7.0
Apatite	tr	....
Zircon	tr	tr
Titanite	tr	tr
Chlorite	0.3	8.0
Kaolinite	0.5	11.0
Sericite	0.1	17.0
Fluorite	....	1.0

1. Sec. 16, T. 3 N., R. 13 W. (red type).
2. Sec. 14, T. 3 N., R. 13 W., estimated. (gray type).

The norm of this rock places it in Class 1, Order 2, Family 6. The rock number is 126; it is named a <u>leucogranite</u> (microleucogranite). The higher mafic per cent of the gray microgranite gives the rock a number of 226 of the granite family.

<u>Lugert Granite</u>

Hoffman[15] has described the Lugert Granite as follows:

> The Lugert granophyre is salmon pink and medium grained. It is speckled with little dark gray to black spots of ferromagnesian minerals. Microscopically it has a porphyritic appearance due to the

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[15] Ibid., pp. 41-42.

unevenness of the grain. The largest crystals are orthoclase and microperthite 2mm. to 4 mm. long. They are surrounded by quartz grains of smaller size which grade into micropegmatite. Some masses of the latter are arranged radially about the feldspars. The dark minerals are hornblende, magnetite, and a small amount of biotite. These are usually grouped together.

The average mode is micropegmatite 60 per cent; microperthite, orthoclase, and sodoclase-oligoclase 26 per cent; quartz 11 per cent; and ferromagnesian minerals 3 per cent. Accessories are titanite and zircon, with an occasional grain of fluorite, and rarely a few grains of apatite.

The micropegmatite is largely microperthite-micropegmatite. Its amount is variable being usually higher near the edges of the mass and less toward the center. Some of the periphery specimens contain as much as 87 per cent micropegmatite, and in many of the interior samples it is as low as 20 per cent. The feldspar in this mixture is usually very much altered, the product being kaolin and a lesser amount of sericite. The quartz is fresh and clear, and contains only a moderate amount of inclusions.

The feldspars in the phenocrysts is very much like that intergrown with the quartz. The greater part of it is microperthite. About one-third is orthoclase and usually 1 or 2 per cent is sodaclase to sodaclase-oligoclase. The principal alteration product is kaolin. Sericite is formed only in small amounts. One thin section of a specimen from the northern edge of Gramme Flat contained a crystal of oligoclase which was surrounded by a zone of orthoclase.

The ferromagnesian mineral content seems to vary inversely with the micropegmatite. When the latter forms about 80 per cent of the rock the ferromagnesian minerals drop to 1 or 2 per cent, and when it falls to 20 per cent the ferromagnesian minerals increase to about 8 per cent. The dark minerals are hornblende and magnetite with a very small amount of biotite. The average is hornblende 2 per cent and magnetite 1 per cent. The hornblende is slightly altered to epidote and chlorite. The magnetite is titaniferous and in some cases is partially altered to leucoxene with sagenitic surface structure. Some of these black crystals are rimmed with small grains of titanite. Many small crystals of titanite and zircon are present in the rock. A few grains of apatite and fluorite occur, the latter as cavity fillings.

Texture

Microscopically, the Lugert granite shows an indistinct porphyritic texture. This appearance is accentuated by the granophyric intergrowth which has selectively penetrated the crystals of the rock mass. These intergrown crystals resemble a groundmass and those crystals which have not been penetrated by quartz stand out as phenocrysts.

The texture of the Lugert granite of Mt. Scott may be regarded as the type for this area. Differences which were noted were considered as phases.

The quartz is intergrown pegmatitically with the orthoclase and perthite. The granophyre is secondary and is especially prevalent about the periphery of the phenocrysts. In one instance a crystal of orthoclase, which originally measured 2.25 mm., has been reduced to 1.75 mm. in size by the intergrowth about the edges and that part which is intergrown blends with the so-called groundmass in the hand specimen. The old outline of the crystal can be made out by crossing the nicols and rotating the stage until the orthoclase is at extinction. The quartz of the intergrowth remains clear. Many outlines of the original crystals may be seen in this manner, thus, the granite may have been equigranular but given a porphyritic appearance by the quartz intergrowths, that is, granophyre, myrmekite, and micropegmatite.

The phenocrysts average 3.0 mm. which is equal to the grain size of the Lugert granite studied by Polk[16]. However, the Lugert granite of the western Wichita Mountains is not granophyric as it is in this area.

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[16] T. R. Polk, personal communication, preparing a Master's thesis, "A Study of the Igneous Rocks of the Devil's Canyon Group, Wichita Mountains, Oklahoma".

In the fine-grained contact phases, as in Sec. 24, T. 3 N., R. 14 W. and Sec. 24, T. 3 N., R. 13 W., the phenocrysts are actually set in a finer-grained groundmass. The intergrowth of quartz is more micropegmatitic than granophyric. The phenocrysts of this groundmass average 2.5 mm.

Minerals

The primary minerals of the Lugert granite are orthoclase, perthite, quartz, hornblende, and magnetite. Accessory minerals are titanite, zircon, apatite, and fluorite. Secondary minerals are quartz and microperthite. Alteration minerals include kaolinite, sericite, chlorite, hematite, limonite, and traces of calcite.

Orthoclase-perthite are in the form of phenocrysts and as a constituent of the groundmass. The phenocrysts average 3.0 mm. Orthoclase forms the lesser portion of the feldspars present. The anhedra of feldspar are moderately altered and their borders have been corroded by secondary quartz. They are twinned according to the Carlsbad and Albite law.

The quartz also occurs as phenocrysts and average 2.0 mm. The quartz of the groundmass is present as grains or as a constituent of the intergrowths as micropegmatite (cuneiform), myrmekite (vermicular), or granophyre (feathery, acicular).

The hornblende per cent varies considerably. In Sec. 13, T. 3 N., R. 12 W., the hornblende is at a maximum of 4.8 per cent, whereas in Sec. 1, T. 2 N., R. 14 W., it is totally absent. The hornblende of the granite of Mt. Scott occurs as elongate prisms averaging

2.0 mm. Many euhedral basal sections were noted. Inclusions of magnetite are present and the hornblende is penetrated by quartz. The interior and the border edges of the crystals have been corroded.

The magnetite occurs as irregular masses and grains. The larger sizes are 0.3 mm. in diameter. It is titaniferous and leucoxene borders many of the grains. Hematite dust is present throughout the rock mass. Limonite stains the rock and is an alteration product.

Apatite is present as elongate prisms measuring 0.1 mm. in length and as minute basal sections. A thin section of the Lugert granite outcrop, Welsh Hill, Sec. 13, T. 3 N., R. 12 W. contained an abundance of apatite. Titanite forms halos about the magnetite in the granite of Mt. Scott. It also occurs as wedge-shaped crystals, the largest observed being 0.05 mm. Zircon is present as prisms and fragments which are 0.1 mm. long. Fluorite which may be primary or secondary, is present as grains averaging 0.05 mm. in diameter.

Order of Crystallization

The magnetite crystallized first. It is found as inclusions in the hornblende as well as in the other minerals. Titanite and zircon followed and are noted as inclusions. Titanite rims the magnetite; secondary injection was not seen. The accessories were followed by the hornblende and in turn by orthoclase and perthite. Perthite and quartz are present in mutual penetration. The secondary quartz was introduced at a later time. Fluorite may be primary or secondary.

TABLE 6

MINERAL PERCENTAGE OF THE LUGERT GRANITE

	(1)	(2)	(3)	(4)
Orthoclase	. . .	54.8	. . .	. . .
Microperthite	. . .	1.3	. . .	. . .
	62.1	. . .	26.0	64.8
Albite	. . .	. . .	. . .	. . .
Oligoclase	. . .	1.3	. . .	. . .
Micropegmatite	. . .	. . .	60.0	. . .
Quartz	31.0	36.5	11.0	29.8
Hornblende	. . .	tr	. . .	3.8
	5.5	. . .	. . .	. . .
Augite	. . .	. . .	. . .	. . .
	. . .	. . .	3.0	
Biotite	none	1.1	. . .	tr
Magnetite	1.2	0.2	. . .	1.5
Hematite	much (1)	. . .	. . .	tr
Zircon	tr	. . .	tr	tr
Titanite	0.2	. . .	tr	0.05
Fluorite	none	. . .	tr	tr
Apatite	tr	. . .	tr	tr
Pyrite	none	. . .	. . .	. . .

1. Taylor, *op. cit.*, p. 21, Lugert Granite, quarry one mile northwest of Mountain Park.
2. Scull, *op. cit.*, p. 43, average Lugert Granite, Quartz Mountain, Sec. 16, 22, T. 5 N., R. 20 W.
3. Hoffman, *op. cit.*, p. 41-42, Lugert Granite average mode.
4. Sec. 14, T. 3 N., R. 13 W., Mt. Scott.

Classification of the Lugert Granite

The norm of this rock places it in Class 2, Order 2, Family 6, of the Johannsen classification. The rock number is 226, which places it in the granite family; it is named a granite. Hornblende forms the greater per cent of the ferromagnesian content. In various locations the leucocrates exceed 95 per cent which gives the rock a number of 126, a leucogranite.

The writer believes that the porphyritic appearing texture is secondary and caused by the introduction of quartz in the form of intergrowths. Therefore, the Lugert granite should not be called a granite-porphyry.

Quanah Granite

Hoffman[17] has described the Quanah Granite as follows:

> Practically all of the rock of the Quanah Range is coarse grained, many of the crystals being as much as 1 cm. in length. This rock is light pink when fresh and weathers to a buff color.
>
> In thin section the texture of the Quanah granophyre is hypidiomorphic-granular. The mineral content is nearly all quartz and alkali feldspars. The average norm is microperthite 53 per cent, orthoclase 14 per cent, quartz 32 per cent, and riebeckite and magnetite 1 per cent. The accessories are titanite, zircon, fluorite, and rarely a few small grains of apatite.
>
> Crystal outlines are rare. The quartz and feldspars have embayed margins. Coarse grained micropegmatite up to 28 per cent occurs as an interspace filling in the central and along the northern portion of the mass. The quartz is fresh and moderately clear, while the feldspars are kaolinized and slightly stained with ferric oxide.
>
> The ferromagnesian minerals content varies from almost nothing up to 2 per cent. Throughout the northern half, magnetite is found. Riebeckite is wanting or present as an accessory.

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[17] Hoffman, op. cit., pp. 42-43.

In the southern half riebeckite is the more abundant. It totaled $1\frac{1}{2}$ per cent at the southwestern edge. The hand specimen appeared to carry about 5 per cent, but the thin section showed the lesser amount. Magnetite is here a minor accessory and largely oxidized to hematite.

Two thin sections were made of the Quanah granite; one was coarse grained, the other was a granite-porphyry. The coarse grained grainte outcrop represented by one thin section was located in Sec. 12, T. 2 N., R. 14 W., and the granite-porphyry slide represents an isolated outcrop in Sec. 13, T. 2 N., R. 14 W.

Texture

The coarse grained Quanah granite is equigranular. It is composed of euhedral perthite and orthoclase anhedra and subhedral quartz. The feldspar crystals average 6 mm. in length, the quartz grains average 2.5 mm. The rock is less granophyric than micropegmatite.

The granite-porphyry has phenocrysts of perthite and orthoclase set in a granophyric matrix composed of the same minerals. The phenocrysts average 6 mm. in length; the quartz grains average 2.5 mm. There is no difference in the grain size of the coarse grained granite and the phenocrysts of the granite-porphyry. The relationship of the granite-porphyry to the coarse grained granite was not determined.

Minerals

The minerals of the Quanah granite do not differ markedly from the rocks previously described in this chapter. Riebeckite, which is a rare mineral in igneous rocks but not uncommon in the Wichita

Mountains, was noted in the Quanah granite. The primary minerals are perthite, orthoclase, quartz, and riebeckite (also secondary), magnetite, zircon, and apatite occur as accessory minerals. Alteration products are present.

The extinction angle of the plagioclase intergrowth in the orthoclase could not be determined; the feldspars are highly altered. The perthite and orthoclase crystals are embayed and corroded, and often micropegmatitically intergrown with quartz. Secondary microperthite is noted and stringers of microperthite cut the quartz grains. Secondary quartz occurs as intergrowths. No myrmekite was noted in the coarse grained granite.

Riebeckite occurs in less than 1 per cent. In the heavy mineral analysis, riebeckite is found in greater quantity than magnetite. In thin section it occurs as subhedral prisms which range in length from 0.1 to 0.5 mm. The rock which contains the higher content of riebeckite is very friable on weathered surfaces. The riebeckite was concentrated in the preparation for study by heavy mineral analysis and is described in that section.

The accessory minerals and alteration products do not differ from the rocks previously described.

Order of Crystallization

The accessory minerals crystallized first. Evidence of secondary riebeckite was noted. Orthoclase, perthite, and quartz followed the accessory minerals. Secondary microperthite and quartz was introduced at a later time.

Classification of the Quanah Granite

The norm of this rock places it in Class 1, Order 2, Family 6. The rock number is 126, a leucogranite.

TABLE 7

MINERAL PERCENTAGE OF THE QUANAH GRANITE

	(1)	(2)*	(3)
Microperthite	53.0	60.0	55.7
Orthoclase	14.0	10.0	14.8
Quartz	32.0	25.0	28.0
Riebeckite	1.0	1.0	0.05
Magnetite		0.5	0.1
Titanite	tr	tr	tr
Zircon	tr	tr	tr
Fluorite	tr	tr	tr
Apatite	rare	tr	tr
Alteration minerals		3.4	1.2

1. Hoffman, op. cit., pp. 42-43, average norm of the Quanah granite.
2. Coarse grained granite, Sec. 12, T. 2 N., R. 14 W.
3. Granite-porphyry, Sec. 13, T. 2 N., R. 14 W.

* Estimated, friable and slide badly made.

Dikes and Veins

Diabase Dikes

An amygdaloidal diabase dike occurring in Sec. 29, T. 3 N., R. 13 W. on Blue Beaver Creek below Ketch Lake has not been described previously. The writer is indebted to Merritt[18] for the information concerning the dike and access to his unpublished notes. Non-amygdaloidal dikes also occur in this same immediate locality but their relation-

[18] C. A. Merritt, personal communication.

ship to the amygdaloidal dikes was not ascertained.

There are several prospect pits in this locality. The diabase dike or dikes cannot be found except where exposed in the pits. They apparently were small dikes which intruded the granite and the rhyolite along a shear zone. The Lugert granite in this immediate area has been faulted and highly fractured. Fault gouge and slickensides are evident. The fractures or joints are closely spaced and parallel, have a high dip, and strike in a general east-west direction. The same applies to the Carlton rhyolite of this same area. Small angular inclusions of granite and rhyolite are found in the non-amygdaloidal diabase dikes and minor assimilation has taken place. The non-amygdaloidal diabase dike cutting the Carlton rhyolite at the head of Ketch Lake contains inclusions of the rhyolite and by partial assimilation now contain phenocrysts of orthoclase and quartz. The outline of the rhyolite fragments is barely discernible as the groundmass of the fragment has been changed to the same color as that of the dike.

The diabase 100 yards down stream from Ketch Lake intrudes the granite and is amygdaloidal. The amygdules contain chlorite, calcite, and a mineral which appears to be antigorite. The pit located 900 yards directly east of the one mentioned above also exposes an amygdaloidal dike but here the amygdules are larger and calcite is the main filling mineral, though chlorite and antigorite are present.

These amygdaloidal diabase dikes are of particular interest. According to Moehlman[19], amygdaloidal dikes are rare, amygdules being

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[19] R. S. Moehlman, "Amygdaloidal Dikes", Amer. Mineralogist, Vol. 21, (1935) pp. 329-331.

less common in dikes than in lava flows. The presence of the minerals which fill the amygdules suggest that higher temperatures prevailed than is ordinarily the case in the formation of amygdules. A deuteric, or late magmatic origin with high temperatures, or the proximity to an underlying large body of magma, would account for the unusually high temperatures prevalent when the vesicles were formed and the subsequent deposition of chlorite, antigorite, and calcite. The solutions were of magmatic origin. The orthoclase and quartz of the diabase were incorporated from the granite country rock.

The amygdaloidal diabase is aphanitic, light to dull green on fresh surfaces, and a dark green to black on weathered surfaces. The cavities are irregular, rounded to ellipsoidal or elongated and roughly oriented. Their sizes range from 2 mm. to 1.2 cm. They are filled with pink-white calcite which is coarsely crystalline and exhibits good cleavage and twinning, and chlorite with probable serpentine (antigorite). Some of the amygdaloids are not filled or only partly so. Fresh specimens could not be obtained and it is probable that if the amygdules were filled originally, the filling has been removed through surface weathering. Also included in the diabase are black rounded masses which are 2.0 mm. to 1.6 cm. in diameter and in places become as numerous as the cavities filled with calcite and chlorite. Microscopic examination shows these masses to be composed of essentially the same minerals as the groundmass but larger in size, the labradorite and biotite averaging 1 mm. whereas, in the groundmass they average 0.2 mm.

The diabase has a density of 2.6 to 2.7, the porosity, amygdules and vesicles, accounting for the low specific gravity.

Microscopically, the rock has a typical ophitic texture, and is a diabase. Euhedral crystals of labradorite compose the main mass. The interspaces once were filled with ferromagnesian minerals, now completely altered to chlorite and antigorite. The labradorite for the most part is altered but not sufficiently to account for the calcite in the quantity in which it appears. This would indicate that the calcite which is present in the amygdules was derived and introduced from an outside source.

The feldspar is mainly labradorite. It is poorly twinned, has an extinction in excess of 40 degrees, and occurs as euhedral crystals. Minor orthoclase is present, it came from the country rock.

The ferromagnesian minerals with the exception of biotite have been completely replaced by chlorite and antigorite. Theoretically, these two minerals may be formed from olivine, enstatite, augite, etc., by hydrothermal alteration. Not only have they replaced the ferromagnesian minerals but they line or completely fill the cavities, or, fill the remaining void after partial deposition of calcite. Identification of the chlorite with index oils showed it to be prochlorite. Antigorite was too fine grained to be positively identified. This mineral occurs as spherulites and fibrous needles lining some of the cavities.

The calcite is not restricted to the amygdules, several calcite veinlets cut the diabase and quartz and orthoclase crystals. The labradorite is slightly altered to calcite along cleavage planes and a few crystals have small embayed margins filled with calcite.

Biotite is present in an unusually large quantity for a diabase. It occurs as elongated or tabular crystals averaging 0.2 mm., however, in the bulbular masses they attain an average of 1 mm. The degree of alteration is slight but chlorite rims some of the crystals. The relatively unaltered state of the biotite is remarkable in view of the complete alteration which the other ferromagnesian minerals have undergone. This suggests that the biotite has been introduced later.

Many small grains of titaniferous magnetite occur throughout the mass. Some leucoxene is present. The sericite present is an alteration product of orthoclase. Apatite occurs as numerous elongate needles and may exceed 5 per cent of the rock.

Because of the badly altered nature of the rock, it cannot be classified in Johannsen's scheme; however, its general features clearly show it to be a diabase.

The composition of the non-amygdaloidal diabase dikes found in the Ketch Lake area do not differ greatly from the diabase dikes of the general area.

The largest mining operation observed in this area is the relic smelter and shaft located one and three tenths miles by road east of Ketch Lake. Remnants of the mined material remain strewn about the workings. The only mineral now found is calcite and some of the pieces indicate that the calcite vein or deposit was a few feet wide which is large for this area. The shaft had been sunk on a diabase dike but the nature of the calcite deposit or of the dike could not be determined because the shaft was filled with water. Prospect pits where found are plotted on the map which accompanies this thesis.

The alignment of these pits might suggest one dike in which case the amygdaloidal rock would be a special phase of the diabase.

The average mode[20] of the non-amygdaloidal diabase of the eastern Wichita area is labradorite 52 per cent, titan-augite 29 per cent, hornblende (uralitic) after augite, chlorite after biotite, magnetite 3 per cent, and accessory minerals as apatite, titanite, and zircon. The diabase dikes cutting the Lugert granite in the quarry face of Lake Thomas Dam are typical of the area of this thesis.

The contact of the non-amygdaloidal dikes with the country rock is sharp and little alteration has been induced in the surrounding rock. With the exception of the size of the composing mineral crystals, the dikes are essentially the same. Their strike roughly follows the major jointing pattern and usually the dip is vertical.

Microscopically, the ophitic texture is characteristic. The degree of alteration varies from a highly chloritized and serpentized remnant to a remarkedly fresh and little altered dike.

The labradorite is twinned according to the Carlsbad, Albite and Pericline laws. The crystals are euhedral, embayed along the periphery by alteration products of the augite, altering to calcite along twinning planes, and penetrated by chlorite and magnetite along cleavage planes. Euhedral cubes of magnetite and elongate and stout

[20]Hoffman, op. cit., p. 45.

prisms of apatite constitute the inclusions in the labradorite. Labradorite comprises more than 50 per cent of the rock.

The augite which filled the interspaces has been altered in part to chlorite. Very little of the original augite remains. The remnant outlines are heavily flecked with minute grains of magnetite which makes them semi-opaque but the unaltered portions are relatively clear. The altered portions exhibits the "Berlin Blue" of chlorite. Hornblende after augite occurs sparingly.

Some of the biotite remains unaltered. The change to chlorite is in place and retains the cleavage outlines of biotite. The zircon inclusions are surrounded by pleochroic halos.

Magnetite usually approaches 5 per cent. Hematite and limonite are generally absent. The magnetite occurs as cubes, grains, flakes, and as elongated masses which resembles a schiller structure.

Apatite occurs as elongated prisms and is usually present in considerable number. Zircon and titanite occur sparingly.

Aplite Dikes

The leucocratic dikes of this area are typical aplites. These dikes are composed of orthoclase, quartz, acid plagioclase, hornblende, biotite, and a few accessory minerals.

The petrographic analysis of the aplites is given by Hoffman[21] as follows:

> These aplite dikes are fine grained granophyres composed of micropegmatite and small grains of quartz and alkali feld-

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[21] Ibid., p. 45.

spars. About 1 to 2 per cent of biotite is usually present and a small amount of magnetite. The feldspars are kaolinized.

According to Johannsen's classification, they would be called leucogranite aplites. The rock number is 126.

Quartz Dikes and Veins

There is no definite dividing line between dikes and veins, so the writer considers both types of quartz intrusions under one heading.

Quartz dikes and veins are seen throughout the area studied and for the most part average 2mm. to 10 mm. in width.

A jasper dike cutting the Carlton rhyolite on the eastern nose of Signal Mountain has not been described previously. It is located in the artillery impact area and the rock is highly shattered (this in addition to closely spaced joints). The dike is more resistant to erosion than the rhyolite and stands out in relief for 4 or 5 inches. The strike is N. 45° E. and as far as can be ascertained, it has a vertical dip. It is not continuous but has suffered a series of displacements, which are fairly regular and constant. The dike is continuous for 10 to 15 feet. It is then displaced about 10 to 20 feet, again continuous, then displaced, and so on in like manner. At the northeastern end of the dike, it makes a sharp turn to the southeast; its strike then is N. 30° W. The total length of the dike exposed is about 100 feet.

Megascopically, the dike varies from a blood red to milky color on fresh surfaces, and is red with a yellowish tinge on weathered surfaces. It is composed of dense, crystalline quartz, contains cavities, and is cut by fine stringers of clear quartz. Disseminated magnetite appears as black, bright flakes and grains. The red color is caused by finely disseminated dust and grains of hematite. Staining by limonite and alignment of magnetite grains give the dike a banded appearance.

Microscopically, the dike is an aggregate of mosaic-like cryptocrystalline quartz. The outlines of voids and cavities which are sometimes filled are bordered by a concentration of hematite, though not all cavities are lined with hematite. In some, the cavities are lined with hemimorphic euhedral crystals of quartz which average 0.05 mm. in length, in others, they are completely filled but the quartz is very fine grained, more so than the average groundmass. The secondary introduction of quartz is shown by the later filling of the cavities and especially along cracks or minute fissures. The cavities are not oriented but there is a semi-orientation of fine lines which are interpreted to be minute passageways now filled with micrograined quartz. One such passageway is filled with hematite.

The red color is due to finely disseminated dust particles or clusters of hematite. Magnetite is present as grains and euhedral cubes. It is speckled with hematite and in most instances is completely surrounded by hematite. The limonite is present as an alteration product and stains are prevalent throughout the mass.

Chalcedony is a secondary mineral in one of the cavities. It occurs as spherulites and intermingles with the quartz.

The quartz dikes cutting the Carlton rhyolite at Medicine Bluff are a light bluish gray with clear grains of quartz in a dense quartz groundmass which gives the dikes a porphyritic-like texture. The inclusions[22] are numerous small grains of titanite, leucoxene, magnetite, biotite, and kaolinized feldspar. The present state of the accumulation of talus prevents the examination of the intersection of the quartz dike and a diabase dike, also present in Medicine Bluff.

The Signal Mountain and Medicine Bluff quartz dikes are the largest ones observed in this area. Smaller dikes or veins are found like those in Sec. 3, T. 2 N., R. 13 W. They cannot be followed more than 100 feet at the most and average 5 mm. in thickness. Some of the smaller dikes are seen which follow the jointing but split and diverge, converge, and branch off. Sometimes they can be found again a little farther on in line.

Aegirite-Riebeckite bearing Dikes

The aegirite-riebeckite bearing dikes described by Rogers[23] are not present in this area. They are found in the granites of the western part of the Wichita Mountains. These dikes are of interest scientifically as aegirite-riebeckite dikes are of rare occurrence in the world. Riebeckite occurs in the Quanah granite as an accessory and as a rock forming ferromagnesian mineral.

Pegmatites and Miarolitic Cavities

Anderson[24] wrote his thesis on the occurrence and origin of pegmatites and miarolitic cavities in the Wichita Mountain System. This

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[22] Ibid., p. 45.

[23] Rogers, op. cit.

[24] Anderson, op. cit.

is the most recent paper on the subject and should be consulted for a detailed discussion. Outcrops of pegmatite dikes were not found in the area studied. The miarolitic cavities noted do not differ from those described by Anderson.

Heavy Minerals

TABLE 8

HEAVY MINERAL ANALYSIS OF THE ROCK TYPES

	(1)	(2)	(3)	(4)	(5)
Magnetite	27.0	86.2	85.5	84.0	33.4
Hematite	2.0	8.0	4.1	3.6	3.0
Pyrite	. . .	. . .	. . .	1.0	. . .
Zircon	. . .	3.3	5.7	6.6	1.9
Fluorite	. . .	1.0	0.9	1.8	1.7
Biotite	. . .	1.5	3.8	3.0	. . .
Clinozoisite	6.0	. . .	. . .	. . .	. . .
Apatite	1.0	. . .	. . .	. . .	. . .
Rock forming	64.0	. . .	. . .	. . .	60.0*

1. Gabbro-Anorthosite, Sec. 29, T. 3 N., R. 14 W., north Quanah Parker Lake.
2. Carlton Rhyolite, Sec. 28, T. 3 N., R. 13 W., top Mt. Hinds.
3. Davidson Microgranite, Sec. 23, T. 3 N., R. 13 W., northwest flank of Pratt Hill.
4. Lugert Granite, Sec. 19, T. 3 N., R. 13 W., south flank of Mt. Scott
5. Quanah Granite, Sec. 12, T. 2 N., R. 14 W., south of Craterville.

* Riebeckite

The method used in studying the heavy minerals has already been described. A set of two slides for each rock of this area are on file in the School of Geology. The first contain the heavy minerals as they were retained on the 200 mesh after passing through the 100 mesh.

The second of the set is from the same sample but the heavy anisotropic and isotropic minerals were concentrated by removal of the magnetic minerals with a magnet. This separation was only partially complete. Electromagnets were not available.

Magnetite. The magnetite content, with the exception of the gabbro-anorthosite, is fairly constant. The Quanah granite specimen analyzed contained less magnetite than the average but was high in riebeckite. The magnetite is speckled with hematite. This is noticeably so in the Lugert granite. Limonite stains are prevalent throughout the heavy minerals. The rock forming minerals of the gabbro-anorthosite contain inclusions of magnetite, also hematite. Leucoxene fringes a few of the magnetite grains of the Lugert granite. The leucoxene can be detected better in thin section as already noted. Inclusions of magnetite in the quartz of the Davidson microgranite brought numerous grains of quartz down as heavy minerals. Those grains which come down are literally "loaded" with magnetite. Many of the crushed grains show no alteration. These are interpreted as the interiors of larger grains since the surfaces of others are altered to limonite.

Hematite. Some hematite came down as grains but mainly it occurs as specks on magnetite. Hematite dust weighed several light minerals sufficiently to increase their density which permitted their settling with the heavy minerals. The grains of hematite are rounded with a feathery edge which is often limonitic. The hematite percentages vary, being greater in the Carlton rhyolite. The Carlton rhyolite weathers to a tan or yellow color as the iron minerals alter to limonite.

Often the blood red color of hematite grades to a yellow in reflected light and the percentage of limonite cannot be calculated with any degree of accuracy.

Pyrite. The percentage of pyrite is quite variable in the specimens analyzed. It appears as grains and as small inclusions in the magnetite. It has a brass yellow color in reflected light. In one count of a microscopic field it amounted to ten per cent, though averaging one per cent for the whole slide.

Zircon. The zircon percentages were small in the thin sections but occurs quite abundantly in the heavy minerals. The greatest amount is in the Lugert granite. This is followed closely by the Davidson microgranite. The zircon of the granite and micrugranite contain inclusions of what is thought to be smaller crystals of zircon. There is no orientation of these inclusions. Gas bubbles are quite noticeable in the Davidson zircon but the bubbles also occur in the Lugert zircon. The zircons crush out as prisms terminated by pyramids.

Fluorite. Fluorite occurred in every specimen except the gabbro-anorthosite. It has the highest percentage in the Lugert granite, followed closely by the Quanah granite. The octahedral cleavage is prominent. The fluorite varies in color from colorless to purple or pale pink. The purple is not constant but rather it occurs in streaks and blotches. Inclusions consist of gas bubbles and magnetite. The gas bubbles are more numerous than the magnetite.

Biotite. The Davidson and Lugert contain by far the highest percentage of biotite. Its color varies, even in the same specimen. Alteration has almost obliterated its characteristics. Red, reddish brown, and green are the dominant colors. Most flakes are basal sections and interference figure, slight pleochroism on upturned edges, and index of refraction, make recognition possible.

Clinozoisite. This heavy mineral was found only in the gabbro-anorthosite. It is colorless to slightly dusty, of moderate relief as compared to zircon, weak birefringence, and parallel extinction. It has one good cleavage direction. The grains exhibit an abnormal blue interference color much like that of chlorite. Uhl[25] called a mineral very similar to this one, zoisite. The field relations here suggest clinozoisite rather than zoisite. A universal stage is not available and with the data obtained it cannot be distinguished from zoisite. Since zoisite is a metamorphic mineral and clinozoisite an alteration (deuteric) product, that is, an iron-free epidote, it seems more likely that the minerals is clinozoisite. Polk[26] reports clinozoisite from a gabbro outcrop located in the western Wichita Mountains.

Apatite. Apatite was only found in the gabbro-anorthosite where it occurs as prisms and grains. In all likelihood the apatite passed the 200 mesh to the pan in the other specimens screened. The heavy minerals that passed to the pan were not examined. The apatite is colorless and has imperfect cleavage. Several prismatic crystals were observed.

Riebeckite. The rock forming ferromagnesian mineral found in the Quanah granite is riebeckite. It is also noted in thin section. The rock which contains the higher percentages of riebeckite is very

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[25] Uhl, op. cit., p. 29.

[26] Polk, op. cit.

friable and difficulty is encountered in making a thin section of this rock without taking special precautions to preserve its coherence. Therefore, the riebeckite is described here since the individual grains are easily concentrated in a heavy mineral analysis.

The riebeckite is strongly pleochroic, changing from a deep blue to a light blue on rotation. It occurs as elongate prisms. The larger crystals measure 1 cm. The content varies throughout the outcrop. The riebeckite occurs in minute crystals in the thin section of a specimen taken from the outcrop in Sec. 18, T. 2 N., R. 13 W. The riebeckite in part has been hydrothermally introduced.

Alteration products. The alteration products such as chlorite, epidote, leucoxene, and limonite were present but not included in the count. Their presence and importance have been noted in the descriptions of the thin sections.

CHAPTER V

THE EMPLACEMENT AND AGE RELATIONSHIP OF THE IGNEOUS ROCKS

Introduction

The igneous rocks of the Fort Sill Reservation outcrop as hills and peaks protruding through a mantel of Permian "Red Beds" and talus. Well records show that the steep slopes of the granite hills continue for several hundred feet eastward beneath the present "Red Bed" surface.[1] Deeper wells[2] off to the flanks indicate that the slope becomes gentler farther away from the surface outcrops. An arkosic sand was encountered at 1,430 feet to 1,448 feet in Sec. 3, T. 3 N., R. 10 W. Igneous rocks also were encountered at 1,920 feet in Sec. 33, T. 3 N., R. 10 W.; at 2,030 feet in Sec. 29, T. 2 N., R. 10 W.; at 1,960 feet in Sec. 15, T. 1 S., R. 15 W.; and at 1,860 feet in Sec. 30, T. 1 S., R. 13 W., but records do not indicate which igneous rocks the drill encountered.

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[1] Taylor, op. cit., p. 31

[2] Frank Gouin, "Geology of Comanche County," Okla. Geol. Sur., Bull. No. 41-DD (1928).

Decker[3] notes that:

> . . . significant evidence that the structure of the sedimentary rocks is intimately related to the igneous masses away from which they dip as a general rule. The masses suggest strongly their local influence on minor structure. There is also evidence that the early sediments were laid down on an irregular igneous surface with peaks of the igneous rocks supplying fragments through nearly 100 feet of the basal sediments.

The overall structure of the sedimentaries as seen today in the eastern part of the system is that of two anticlines, the Fort Sill and Blue Creek Canyon, converging at about 20°. The dip of the sediments on the most southern flank is 12°, plus or minus. The beds of the northernmost flank dip away at a much greater angle. Just north of the Wichita Mountains occurs a large syncline, the Anadarko Basin, with a steep south flank and a gentle north flank. The axis of this syncline roughly parallels the axis of the mountain.[4] The strike of the principal ridges and the alignment of the igneous peaks parallel a marked zone of fracturing or major jointing.

A close similarity exists between the Wichita Mountain System and the Arbuckle Mountains and they are thought to be closely related[5].

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[3] C. E. Decker, "Progress Report on the Classification of the Timbered Hills and Arbuckle Group of Rocks, Arbuckle and Wichita Mountains, Oklahoma," Okla. Geol. Sur., Cir. No. 22 (1939).

[4] R. W. Sawyer, "Areal Geology of a Part of Southwestern Oklahoma", A. A. P. G., Vol. 8, #3 (1924) pp. 312-321.

[5] Taff, op. cit., pp. 11, 80.

In a few articles the Ouachita-Arbuckle-Wichita-Amarillo Mountain Systems are linked collectively but it is beyond the scope of this thesis to evaluate the evidence for this theory. The Wichita and the Arbuckle Mountains have approximately the same strike, namely, N. 70° W.; the strata are essentially the same in lithology and structure, either in the rocks which outcrop or in the subsurface strata adjacent to the mountains; they were uplifted at approximately the same time; and with reservations, the igneous activity was similar in nature.

It is concluded that from pre-Cambrian through Paleozoic time, and perhaps into the Mesozoic, there existed an orogenic belt through the southern region of Oklahoma. It is further concluded that the elongation of the igneous rocks is essentially parallel to the tectonic axis of this mountain range. However, the protrusion of the present-day peaks and ridges above the Permian mantel does not prove that their elongation has always been in a N. 70° W. direction. The erosion of the past, subsequent deposition, and faulting, could shift the outcrops in such a way as to disguise their true elongation. Yet, with the data available, their true elongation cannot differ greatly from that apparent today. The Wichita Mountains are located in this orogenic belt and thus at times were affected by these earth movements.

The dimensions involved in the Wichita Mountains are not great when compared to other mountain chains.

Daly[6] states that:

> In a given mountain chain, the abundance and observed sizes of batholiths tend to be directly proportioned to the intensity of the orogenic crumpling.

The orogenic crumpling may have been great, but if this is so, the evidence is covered by the Permian sediments and it can be in no way compared to the intense folding and crumpling some mountains have been subjected to. Except for the Meers quartzite, there has been no record that profound metamorphic agents have been active. Information available indicates that the area was a peneplane in early Cambrian time and later was uplifted and subsequently the Cambro-Ordovician sediments were deposited. Near the close of the Ordovician time the area was involved in a regional uplift and near the end of the Pennsylvanian period there was another and more drastic rejuvenation.

In late pre-Cambrian[7] time a magma originated probably in the form of a batholith which marks the beginning of recorded history of the igneous rocks of the Wichita Mountains. The various rock types of this area are usually considered to be differentiates of this original deep seated magma, which most petrographers believe was basic in character.

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[6] R. A. Daly, Igneous Rocks and The Depths of The Earth, McGraw-Hill Book Co., Inc., (1933) p. 117.

[7] E. S. Larsen (Harvard) reported to the Oklahoma Geological Survey that the zircon crystals of the zircon pegmatite which represents the latest igneous activity in the mountains as being 675 million years old, thus being pre-Cambrian.

As evidenced by the presence of a roof pendant of the Meers quartzite in the gabbro-anorthosite and the Lugert granite, these intrusive rocks were covered by an unknown thickness of rocks, some or all of which were sediments. That the original sandstone bed, as pointed out by Merritt[8], covered a sizeable area is evidenced by the scattered outcrops. It is not known whether these beds were tilted and there is no information on their thickness, structure, or surface relief.

Age Relationship

The majority of geologists who have done work in the Wichita Mountains place the gabbro-anorthosite as the oldest igneous rock in the mountains. The Lugert granite intrudes the basic rock and has apophyses into the gabbro-anorthosite. The former is, therefore, younger than the latter. The Lugert granite bounds the gabbro-anorthosite on all sides in this area.

The Carlton rhyolite is intruded by the Davidson microgranite. Stringers of the microgranite are found in the rhyolite. Phenocrysts of orthoclase and quartz have been incorporated into the microgranite near the contact. Inclusions of the rhyolite are found in the microgranite. The Carlton rhyolite is, therefore, older than the Davidson microgranite. The Lugert granite, on coming in contact with the Carlton rhyolite, becomes finer grained and granophyric. In various locations the granite has induced alterations in the rhyolite. Apophyses

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[8] C. A. Merritt, "Meers Quartzite," Okla. Acad. Sci., 1947.

of the granite are also found in the rhyolite[9]. The Carlton rhyolite is older than the Lugert granite.

The Davidson microgranite is intruded by the Lugert granite. Small dikes and stringers of the granite are found in the microgranite. The Lugert granite becomes finer grained and the facies border is not too well marked in certain places. Thus, the Lugert granite is younger than the Davidson microgranite.

The age relationship of the Quanah granite was not determined in this area. Taylor[10] and Hoffman[11] placed the Quanah granite as the youngest granite rock. It is likewise considered the youngest.

The large aplite mass intrudes both the Lugert and Quanah granites. It is not clear whether this body is the same age as the small aplite dikes.

The criteria listed above indicate that the igneous rocks were intruded in the following order: gabbro-anorthosite, oldest, Carlton rhyolite, Davidson microgranite, Lugert granite, and Quanah granite, youngest. Subsequently, there followed a series of diabase, aplite, and quartz dikes, which represent the latest igneous activity in the area.

Emplacement

The classification used in this thesis to define igneous bodies is the one proposed by Daly[12] which is based upon the method of

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[9] Bain, op. cit.
[10] Taylor, op. cit., p. 32.
[11] Hoffman, op. cit. p. 43.
[12] Daly, op. cit., p. 76.

intrusion, that is, injected bodies and subjacent bodies.

Gabbro-Anorthosite

The gabbro-anorthosite represents an early differentiate of the batholith. A gabbroic or closely related noritic magma served as the parent of the anorthosite. The segregation of the plagioclase is generally considered to have been due to gravity separation. The anorthosite, therefore, is a phase of the gabbro.

The small areal extent of the gabbro-anorthosite of this area does not afford sufficient data to describe its shape or form of intrusion accurately. It was intruded into the Meers sandstone. The sandstone has been metamorphosed and only a few isolated outcrops remain to indicate the nature of the pre-Cambrian roof. Whether the gabbro-anorthosite is the upper limit of the intrusion that came into place by crosscutting the country rock or an injected body from the batholith remains a debatable question. The gabbro-anorthosite bodies of the pre-Cambrian were probably laccolithic or lopolithic in origin[13]. The earth's original crusting and conditions seem to have been then specially favorable for the development of these big, monolithic basic masses which implies somewhat peculiar conditions of the post-Archean and pre-Paleozoic. Other types of outcrops are known, namely sills, dikes, veins, bands, phases, and smaller bodies, but the larger masses belong to the laccolith and lopolith classification. Therefore, it is

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[13] <u>Ibid</u>. p. 44.

probable that the mode of intrusion of the gabbro-anorthosite of the Wichita Mountains is a laccolith or a lopolith, or since sills are so frequent in this area, it may be a sill. It had an irregular roof with projections both downward and upward.

The schistose appearance found in the gabbro-anorthosite is not thought to be caused by metamorphism but rather due to a late movement in the body.

Carlton Rhyolite

Rhyolites are a textural variety of the granite clan and may be either surface flows or intrusives[14].

A granitoid texture generally implies a plutonic or hypabyssal magma chamber and a uniformly slow rate of cooling which allows the continued growth of wide-spaced crystals until complete solidification. If a crystallizing magma is moved from a deep-seated to a shallow environment, it becomes subjected to different conditions. The faster rate of cooling, aided by the escape of occluded fluxes, mineralizers, and hyperfusibles, may induce a condition of viscosity which is too great for free molecular diffusion, and crystallization is started simultaneously at many centers. The phenocrysts are thus embedded in a finely crystalline granular groundmass. Conversely, if a body which is carrying growing phenocrysts is undercooled, the rock then consists of phenocrysts set in a matrix of glass. The latter process whereby the

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[14] F. F. Grout, Petrography and Petrology, McGraw-Hill Book Co., Inc., (1932) pp. 53, 57.

phenocrysts are set in a fine grained groundmass does not require the Carlton rhyolite to be a surface or near surface rock. On the other hand, the reported aporhyolite suggests a surface flow.

The structures associated with the Carlton rhyolite indicates that its relative position with respect to the other rock types have been influenced by two anticlines.

The axis of the two anticlines, namely the Fort Sill Anticline and the Blue Creek Canyon Anticline, s trike in a general northwest-southeast direction. The northern anticline, the Blue Creek Canyon, is less than half as wide as the southern one, and the central igneous axis is exposed as a few isolated outcrops of Carlton rhyolite. The southern anticline, the Fort Sill, is the larger of the two and its axial crest parallels and coincides with the long axis of the Carlton rhyolite outcrop of this thesis area. The amount of uplift cannot be stated definitely.

The possibility that these two anticlines were remnants of two pre-Cambrian ridges does not alter the interpretation of the form in which the rhyolite was emplaced. If they are ridges, then the uplift was horst-like, otherwise, these two anticlines have influenced the outcrop as they would in sedimentary formations, that is, sills overlying each other yield topographic features similar to those formed by stratified sedimentary formations.

The previously undescribed outcrops of the rhyolite found during this work increase its known areal extent. If the supposition that the outcrops of the rhyolite are continuous in subsurface is correct, the Carlton rhyolite may have a surface and subsurface extent equal to that of the Lugert granite of the eastern half of the Wichita Mountains.

The flow lines of the Carlton rhyolite furnish some information on the emplacement of this rock. The jointing found included both primary and secondary tectonic regional types. Interpretations of the primary jointing is based upon Balk's Memoir[15] on the structural behavior of igneous rocks. The primary flow structures found in the rhyolite are those that were developed during the time of consolidation. The flow lines are produced by an alignment of the phenocrysts of orthoclase and quartz. Sufficient readings were taken to ascertain the general relationship of the flow lines to the joints. Primary flow structures include cross joints, longitudinal joints, diagonal joints, and primary flat lying joints.

Cross joints are developed perpendicular to flow lines and are formed when the outlying portions of an intrusion have begun to consolidate while the interior remains in a partly fluid state. The cross joints of the rhyolite are not well developed. When found, they are perpendicular to the flow without much deviation. Cross joints are best developed in relatively deep levels of the crust. Surface or near-surface intrusions are usually lacking in cross joints.

Longitudinal joints are steep planes that strike parallel to

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[15] R. Balk, "Structural Behavior of Igneous Rocks," Geol. Soc. of Amer., Memoir 5, July, 1937.

the trend of the flow lines. These fractures are kept closed by lateral compressive stress. This type of joint is very well developed in the rhyolite. Almost without exception, these joints are present wherever flow structure is encountered. They are easily identified by their rough, wavy, and closely spaced surfaces. Since the majority of the flow lines are in an east-west direction and the flow planes are vertical or nearly so, the longitudinal joints coincide with flow planes. This type of joint may be due to contraction of the cooling mass or by further injection into a body which is cooling.

Diagonal joints are steep planes that form angles of approximately forty-five degrees with the trend of the flow lines. The diagonal joints are well developed in the rhyolite. They do not deviate from the forty-five degree position for an east-west flow except where the flow directions change locally. If the change in direction is consistent for any distance, the diagonal joints become adapted to the new direction. In some places the jointing is so regularly spaced that hexagonal blocks are produced. These joints are caused by a lateral compressive stress which is normal to the direction of flow and in a way are to be regarded as shear planes.

Primary flat-lying joints are best developed in sheet-like intrusions. Horizontal or near-horizontal floors or roofs and low dip of flow layers facilitate their development. Their origin may be due to volumetric changes, differential load, or the attitude of the cooling surface. Exfoliation ofttimes produces pseudo-flat-lying joints. Flat-lying joints were not determined for the Carlton rhyolite.

The rhyolite underlies the Lugert granite and the rhyolite-granite contact plane is essentially horizontal. On the south, west, and north, the Carlton rhyolite dips under the Lugert granite. In other locations where the rhyolite outcrop is relatively small and completely surrounded by the granite, the dip is always away from the rhyolite.

The elongate Carlton outcrop centering in Sec. 15, T. 3 N., R. 13 W. has an upper surface that is essentially horizontal. The exposure in the small ravine carved by Little Medicine Creek shows the relationship of the Carlton-Lugert contact to be nearly a horizontal plane. Variations from the horizontal were noted as in Sec. 16, T. 3 N., R. 12 W., but the outcrop is relatively small. The nature of the lower portion of the rhyolite body is entirely unknown.

If the interpretation of the texture, the deformation resulting from the Fort Sill Anticline, the areal extent of the rhyolite, the flow structure and associated jointing, and the near horizontal contact-relationship, was made correctly, the Carlton rhyolite was emplaced in the form of a sill or a surface flow.

If an exposure of the original upper surface could be found, the form of the rhyolite and whether it surfaced or not, could be determined more accurately. If the rhyolitic texture was acquired at depth, the aporhyolitic texture as reported by Taff[16] and Taylor[17] would represent the upper quick-chilled phase. On the other hand, the

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[16]Taff, <u>op. cit.</u>, p. 64.

[17]Taylor, <u>op. cit.</u>, p. 34.

aporhyolite might represent that portion effused and open to the sky.

If the rhyolite did surface, the subsequent intrusions of the Davidson micrograníte and the Lugert granite were through horizontal planes of weakness in the rhyolite, and the injections split and lifted the upper portion of the rhyolite. These upper parts, if they existed, probably were eroded when the area was peneplaned during the Lipalian interval. The igneous outcrops along the Blue Creek Canyon Anticline are composed of Carlton rhyolite; the Lugert granite is not known to be present. The rhyolite along this anticline may represent the original upper portion which was uplifted by the Lugert granite. The Blue Creek Canyon area has not been studied in detail and information is lacking on this point.

The rhyolite was intruded or extruded in a general east-west direction. It may have been injected through the gabbro-anorthosite or along an upper surface of the basic rock. The intrusion of the Lugert granite could have split the rhyolite from the gabbro-anorthosite and raised the rhyolite. Or, it may have intruded the gabbro-anorthosite and raised the rhyolite and gabbro-anorthosite, both of which were later eroded. Perhaps some of the rhyolite has not yet been exposed. Difficulty does not arise in the emplacement of the Carlton rhyolite. The question, whether the rhyolite surfaced or not remains unanswered.

An inspection of the map which accompanies this thesis reveals that the sedimentary Arbuckle Group on the southern flank of the igneous rocks has a maximum dip of twenty-four degrees to the south and the Arbuckle limestone on the northern flank has a maximum dip of fifty-five degrees to the north. A reconstruction of the area before the Pennsylvanian-Permian uplift would lend support to the idea that the rhyolite has been arched, though the possibility of old ridges cannot be discarded. The present planes of the flow layers would retain their original orientation if the uplift was horst-like but if the uplift was by arching, the attitude of the flow planes would be affected.

The jointing related to the flow structure indicates that the rhyolite was already partly crystallized while it was being emplaced. A thin section of a specimen taken from Signal Mountain, Sec. 5, T. 2 N., R. 12 W., shows that the groundmass has been fractured after consolidation, but while it was still hot, recementation had taken place. Lateral compressive stresses were active as evidenced by the longitudinal jointing.

From all the evidence available, it appears that the Carlton rhyolite was emplaced as a sill at shallow depth. There still exists a possibility that it was a surface flow.

Davidson Microgranite

The best criterion as to the manner of emplacement of the Davidson microgranite is that it was injected along planes of weakness at a low angle to the horizontal. The plane or planes of weakness along which the microgranite was intruded was in the Carlton rhyolite. The microgranite intrudes the rhyolite and in turn is cut by the Lugert granite.

The shifting of the Davidson-Carlton contact up gradient in the intermittent streams which empty into Lake Thomas in Sec. 23, T. 3 N., R. 13 W. on the flat west of Pratt Hill indicate that the upper surface of the microgranite is near horizontal at this location. The sudden increase in elevation of the Davidson-Carlton contact on the northwestern face of Pratt Hill, Sec. 24, T. 3 N., R. 13 W., is thought to be the result of the fault in Pratt Hill which previously has been mentioned.

The Davidson-Lugert contact has approximately the same elevations at the various exposures; the Davidson microgranite underlies the Lugert granite. The Carlton rhyolite underlies the Davidson microgranite, but in Pratt Hill the microgranite intrudes the rhyolite.

The microgranite of Pratt Hill and the outcrop located in the N. W. 1/4, Sec. 14, T. 3 N., R. 13 W. probably are continuous. In tracing the microgranite outcrop from Pratt Hill in a northwesterly direction, the rock disappears under a Pleistocene gravel ridge. Undoubtedly, it extends farther to the northwest where it is found below the Lugert granite. The microgranite outcrop in the N. W. 1/4, Sec. 14, T. 3 N., R. 13 W. is separated from the Lugert granite on the southeast by Pleistocene gravels and sediments of Recent age. If the microgranite is continuous, as is here proposed, then the Davidson microgranite forms a nearly horizontal sheet and is continuous for a considerable area.

The texture of the microgranite is aphanitic, dense to very fine grained, and is indicative of a near surface emplacement or a quick-chilled body. The absence of phenocrysts might suggest that the body was relatively small or was supplied from a source in which crystallization had not progressed far enough to form crystals of a larger dimension.

As the Carlton rhyolite cooled and contracted, planes of weakness were developed in the form of joints. Subsequent movement may have produced shear zones. The Davidson microgranite is interpreted as an intrusion along one or more of such zones of weakness in the rhyolite. The rhyolite was solid before the microgranite was intruded as some inclusions of rhyolite have sharp and angular outlines.

Resistance to the magma injection by the rhyolite, or an internal resistance in the microgranite liquid caused the alignment of the very fine grains producing flow lines. The flow lines of the microgranite strike in an east-west direction which parallels the general strike of those in the rhyolite. However, the dips differ, those of the rhyolite being fifty-five degrees south while those of the microgranite are fifty degrees north.

From the criteria given above, the Davidson microgranite is considered to have been injected in the form of a sill along horizontal or near horizontal planes of weakness in the Carlton rhyolite. The thickness of the present outcrop does not exceed fifty feet. This body was injected in a solid and somewhat cooled mass and was quickly chilled.

Subsequently, the microgranite was intruded by the Lugert granite. The Davidson outcrops mapped by Hoffman[18] on Mounts Wall and

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[18]Hoffman, *op. cit.*

Tarbone may represent the upper portion of the microgranite that was split and lifted by the invading Lugert magma as it intruded through the Carlton rhyolite and Davidson microgranite. The microgranite outcrops on Mounts Wall and Tarbone occur at higher elevation than do the microgranite outcrops of this area; a difference of about 400 feet. The rhyolite is not known to outcrop at these higher locations. These outcrops of Davidson microgranite may represent erosional remnants of a once continuous sheet of microgranite which may have extended through this area.

Lugert Granite

The structural map which is included in this thesis shows the nature of the floor on which the Lugert granite was intruded. The floor is not even. The irregularities are caused by protrusions of gabbro-anorthosite, Carlton rhyolite, and Davidson microgranite.

The igneous rocks that preceded the Lugert granite were cool or cold when the latter was intruded as chilled contact phases are found, while away from this zone the granite is medium grained. The texture of the Lugert granite indicates an abyssal or hypabyssal environment. The Carlton rhyolite underlies the granite. The rhyolite is considered to be a near surface or surface emplacement and in some way an upper portion of this rock must have served as a covering for the granite. If the rhyolite acquired its texture at depth, the emplacement of the granite offers no serious difficulty. However, if the rhyolite surfaced or was emplaced near the surface, as the writer believes, the covering necessary to impart the abyssal or hypabyssal texture to the granite requires special consideration.

Three hypotheses will be presented. They will be given in the order of importance, the first being the one that agrees with most of the data found during this work.

The gabbro-anorthosite was intruded into older pre-Cambrian rocks, some of which were sedimentary rocks. The Carlton rhyolite was intruded through the gabbro-anorthosite or along an upper surface of the basic rock but in such a way as to be emplaced as a surface flow or near surface sill. It was thick and had an areal or subsurface extent of tens of square miles.

The Lugert granite was emplaced as a sill and sought out zones of weakness. In some places it intruded through the previous igneous rocks to reach sedimentaries where it spread out in a manner resembling interformational sheets at unconformities. The granite, in part, was intruded through zones of weakness in the Carlton rhyolite. It cut through and lifted the upper portion of the rhyolite which served in part as the retaining upper surface of the granite sill. The rhyolite and the overlying sediments which may or may not have been present, afforded ample cover for the granitoid texture of the Lugert granite.

The second hypothesis which postulates a pre-Lugert fault is not necessarily in opposition to the first theory presented.

The gabbro-anorthosite lies to the north of the Lugert granite.

The basic rock is medium to coarse grained which would indicate an abyssal or hypabyssal crystallization, other factors being ignored. The Carlton rhyolite lies to the south of the granite. The contact with the gabbro-anorthosite on the north of the granite and the contact with the rhyolite on the south are at or about the same elevation. Thus, before the Lugert granite came to place, the gabbro-anorthosite had been upthrown to where it laid at or about the same elevation as the Carlton rhyolite. The fault or perhaps a series of faults preceded and possibly heralded the intrusion of the Lugert granite. The eastern area of the Wichitas, for the most part at least, was still covered by pre-Cambrian sedimentary rocks.

The third hypothesis is based on the rhyolite acquiring the aphanitic porphyritic texture at depth. In this supposition the Lugert granite was injected along horizontal or near horizontal planes of weakness in and along the upper surface of the Carlton rhyolite. The mechanics of emplacement embodies much the same principles described for the Davidson microgranite, though in no way comparative in size.

There is one question which repeatedly offers an obstacle to the emplacements of the igneous rocks. That is: what was the nature of the upper portion of the rock which acted as the roof and why isn't there more evidence of its existence than the few remnants of Meers quartzite and possibly the Davidson microgranite of Mounts Wall and Tarbone. If the Lugert granite of the eastern area is one and the same granite as that in the western area, the original retaining surface of some pre-existing rock extended throughout the Wichita area. For the eastern part, with the exception of a few outcrops of Meers quartzite, the nature of the top-most igneous rocks and their roof are unknown. Perhaps sufficient credit is not given to the magnitude of pre-Cambrian erosion. The nature of this upper portion may be better understood as the intervening area between the eastern and western portion are studied in detail.

Though not conclusive, the structural map gives support to a sill-like body of the granite. Apparently the granite was intruded from the west. The Lugert granite does not outcrop east of the area included in this thesis. The igneous rocks extend eastward in subsurface.

The Lugert contact with the gabbro-anorthosite along the northern base of Mounts Scott, Wall, Sheridan, Tarbone, and Baker is approximately horizontal. The contact-line follows the contour lines without marked variances. The exception is found in the high pass between Mounts Wall and Sheridan.

As previously mentioned in the emplacement of the Carlton rhyolite, the granite-rhyolite contact approached a horizontal plane. Those dips which are not horizontal are attributed to the irregularities of the floor over which the Lugert granite passed.

In the western part of the Wichitas the Lugert granite has been interpreted as a sill by Polk[19]. The sill-relationship is also shown there. Sills are common in many of the igneous rocks of the

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[19] Polk, *op. cit.*

Wichita Mountains. The evidence gathered during this work indicates that the Lugert granite of the eastern Wichita Mountains also was emplaces as a sill.

Quanah Granite

The areal extent of the Quanah granite in this area is not sufficient to afford data to accurately describe its shape or form of intrusion.

Taylor[20] named and described the Quanah granite. He states that "the latest granite mass is represented by the Elk Mountain intrusion, probably in the form of a batholith". Hoffman[21] interpreted the Quanah granite as a sill. Anderson[22] finds evidence in the presence of the pegmatite dikes associated with the Quanah granite suggestive of its being a deep seated batholithic intrusion.

Sufficient data are not available on the mode of emplacement of the Quanah granite; the writer is unable to classify the intrusion. Taylor[23] classified the Quanah granite as a batholith; Hoffman[24] named it a sill.

Dikes and Veins

The diabase and aplite dikes, and quartz dikes and veins, are subsequent in origin to the main mass which they accompany.

An injected body will commence to cool when it comes into contact with the country rock. This cooling naturally begins adjacent to

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[20]Taylor, op. cit., p. 32.
[21]Hoffman, op. cit., p. 48.
[22]Anderson, op. cit., p. 62.
[23]Taylor, op. cit., p. 32.
[24]Hoffman, op. cit., p. 48.

the periphery. The solidification by crystallization results in contraction which breaks this outer portion into jointed masses. This reduction in volume of the outer shell upon a still molten and liquid interior, aided by the weight of this mass and the overlying country rock, forces an injection of the magma upward into these fissures and also into the country rock. The aplites commonly are found in the central mass and the diabase more frequently in the outer portion and in the country rock.

They are termed complementary dikes because together they represent the composition of the main magma with which they are associated, however, the magma has in some way become divided into two unlike sub-magmas, thus the diabase and aplite composition.

As the process of differentiation by crystallization goes on, there will be a concentration of the substances not required in the formation of the minerals at that particular stage of the crystallization. This process continually tends to produce minerals with a higher silica percentage. In the late stage the unconsolidated magma would be high in silica content and the escaping water solutions which now penetrate the already solid but still hot igneous body carry silica. This is deposited as quartz dikes and veins in pre-existing joints and fissures.

The diabase dike in the quarried face at Lake Thomas Dam is cut by an aplite stringer, and in other locations the age relationship shows the diabase to be older than the aplite. The igneous activity was culminated in the formation of the quartz dikes and veins which represent the last igneous activity in the area.

In nearly every instance the dikes and veins coincide with the major or minor joint pattern or with shear zones which are parallel to the jointing of the area.

The large dike-like body of aplite which intrudes the Quanah-Lugert contact sought out planes of weakness between the two granites.

CHAPTER VI

CONCLUSION

"The archipelago-like arrangement of the granite mountains and peaks in the plain leaves one to assume that only a small part of the igneous core of the Wichita uplift is now exposed"[1].

The igneous rocks of the Fort Sill Reservation suffered considerable erosion from the time of their uplift until they were covered by Permian sediments. With the exception of the gravel formation the Wichitas have suffered relatively little erosion and weathering since Permian time.

The order of intrusion of the igneous rocks and the evidence of their ages is summarized below; reading from oldest to youngest.

Gabbro-anorthosite (Cut by Lugert granite in this area, and by other granites in other areas)

Carlton rhyolite (Present as inclusions in Davidson micro-granite, does not contact the gabbro-anorthosite)

Davidson microgranite (Contain inclusions of rhyolite, penetrated by apophyses of the Lugert granite)

Lugert granite (Cuts Davidson microgranite, Carlton rhyolite, and gabbro-anorthosite)

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[1]Taff, op. cit., p. 85.

Quanah granite (Host to Lugert granite apophyses, contain inclusions of Lugert granite

Aplite (Intruded the Quanah and Lugert granites)

Diabase dikes (Cut Quanah granite, host to aplite stringers)

Aplite dikes (Cut diabase dikes) (This aplite may be the same age as the aplite listed above)

Quartz dikes and veins (Cut all rocks listed above)

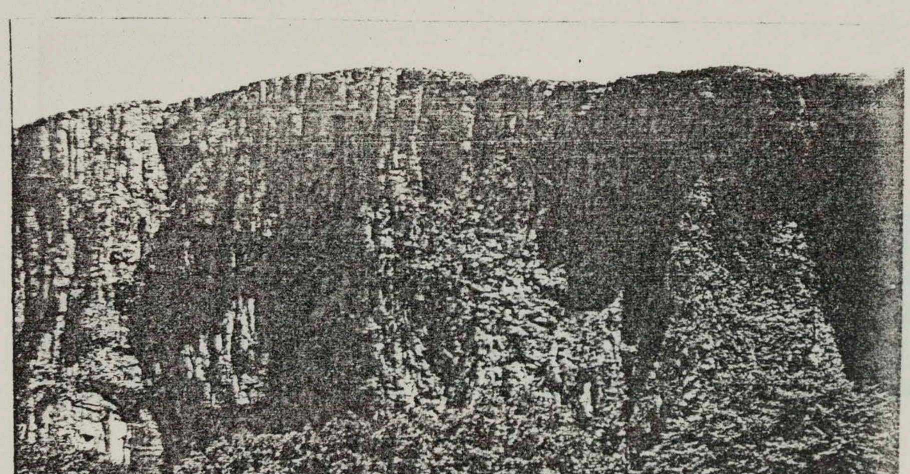
The Permian and post-Permian sediments have veiled many of the contacts. From the data obtained, the writer has concluded that the Carlton rhyolite was emplaced as a shallow sill or a surface flow. The Davidson microgranite was intruded through the Carlton rhyolite in the form of a sill. The Lugert granite intruded the Carlton rhyolite and the Davidson microgranite, also in the form of a sill. The nature of the emplacement of the gabbro-anorthosite and the Quanah granite was not determined.

The study of thin sections of the rock types and the heavy mineral analysis suggest that the various igneous rocks of the eastern Wichita Mountains are differentiates from a common magma. With the exception of the riebeckite present in the Quanah granite, the different igneous rocks of the area are composed essentially of the same minerals and the feldspar content does not vary more than ten per cent. The color differences are not marked. The outstanding distinction is texturally. The acid igneous rocks of the eastern Wichita Mountains are classified as leuco-granites, or their textural equivalents. Phases of the Lugert and Quanah granites contain ferromagnesian minerals in excess of five per cent, in which case the granites are no longer classified as leuco-granites (116), but as granites (226)

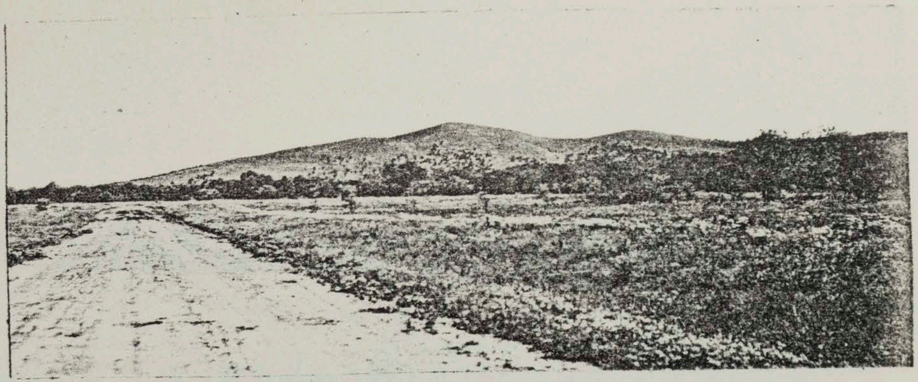
It is concluded that from pre-Cambrian through Paleozoic time, and perhaps into the Mesozoic, there existed an orogenic belt through the southern region of Oklahoma. Also that the elongation of the igneous rocks is essentially parallel to the tectonic axis of this mountain range. The Wichita Mountains are located in this belt and thus at times were affected by crustal movements.

It is pertinent, therefore, that the geology of the Wichita Mountain System be studied in detail in its entirety. A reconstruction of the past geologic activity is far from being complete and the probable answer lies in the compilation of the various detailed studies now being made. It is believed that the Wichita Mountains is the key to the subsurface geology in southwestern Oklahoma.

A. Medicine Bluff composed of Carlton rhyolite. Maximum height of cliff 400 feet, carved by Medicine Creek.



B. Close-up of Medicine Bluff showing the vertical and cross joints.

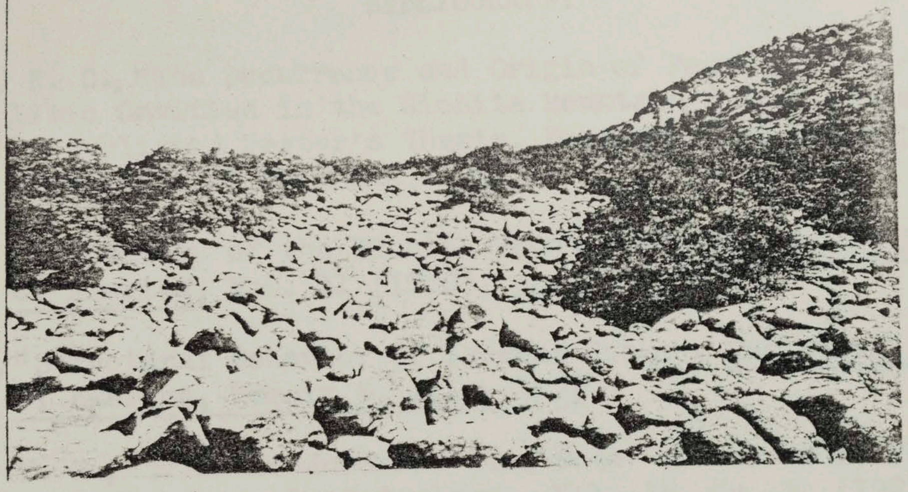


A. Northern slope of Mt. Hinds, Sec. 28, T. 3 N., R. 12 W. Example of general appearance of the Carlton rhyolite. Closely spaced jointing has broken the rhyolite into small angular fragments which give the hills a rounded and comparatively smooth topographic form.

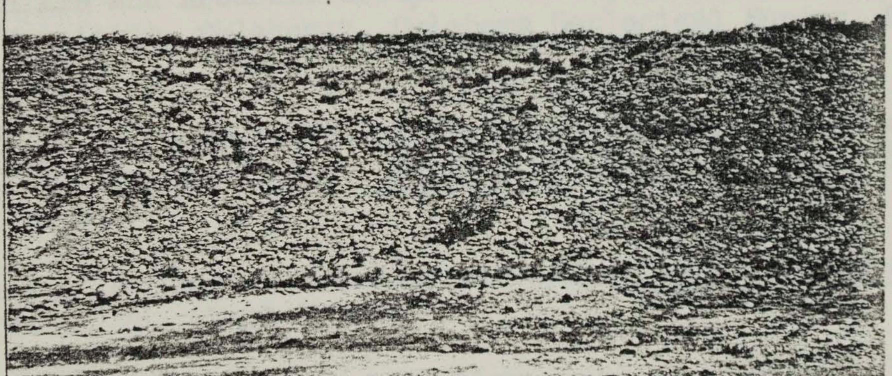
B. Contact of Lugert granite and aplite, Sec. 1, T. 2 N., R. 14 W. The aplite weathers more readily than the medium grained granite. The Lugert granite supports small jack oak whereas the aplite is generally void of vegetation.

A. Quanah granite, Sec. 12, T. 2 N., R. 14 W., isolated from main outcrop by Permian sediments. Coarse jointing produces boulders typical of Quanah Mountains.

B. Mt. Sheridan from the northeast. Lugert granite underlain by gabbro. The tree line indicates the contact.



A. Rock stream on the southern slope of Mt. Scott, Sec. 14, T. 3 N., R. 13 W. Roundness of boulders due to exfoliation.



B. Pleistocene gravel bed, Sec. 16, T. 3 N., R. 13 W., deposited on the Davidson microgranite. Pleistocene gravels are widespread through the eastern Wichita Mountains.

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