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GEOLOGY AND PETROLOGY OF THE WICHITA MOUNTAINS

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INTRODUCTION

Intermittent periods between 1920 and 1928 were spent in a study of the sedimentary beds of central and western Oklahoma and the adjoining areas of Texas. This region surrounds the Wichita Mountains in southwestern Oklahoma. In the Fall of 1928, these mountains were visited on several occasions and each time samples of the general types of rocks were collected. During the Spring and Summer of 1929, a detailed geological survey was made. Work was limited almost entirely to the eastern divisions of the range known as the Wichita, Quanah, and Carlton Mountains.

Excellent topographic maps covered most of the area. The Army Reservation survey included the Carlton Mountains, and the map of the Forest Reserve covered most of the Quanah Mountains and more than half of the Wichita Mountains. These maps made it possible to locate easily many points so that it was not necessary to carry sight traverses more than a mile or two.

Systematic work was begun at the eastern end. Samples were collected at regular intervals usually less than one-half mile apart, and particularly at every point where a contact was found. All of these points were accurately located and detailed descriptions of each became a part of the field notes. In this manner, the areal geology was mapped from Medicine Bluff to Haystack Mountain.

The igneous rock was found to be greatly weathered and in many instances was inaccessible due to the covering of talus. In general, fresh specimens of gabbro were more easily obtained than samples of granite in a similar degree of preservation. The weathered shell exfoliated more readily from the basic than from the acidic rocks.

Where blasting had been done for road or structural work, fairly fresh samples were obtained. Some good specimens were also collected from the Hazel Quarry on the eastern slope of Mount Sheridan. The prospect pits were a disappointment. Many of them still remain, but only a few furnished good material. Most of them did not go below the weathered zone and many were dug in talus slopes.

The quarries between Cooperton, Snyder, and Granite were visited several times. Each contained very good exposures. Only a short time could be devoted to their study, but even this aided materially toward bringing out the general relationships of the various kinds of rock to the entire mass.

ACKNOWLEDGMENTS

The writer wishes to acknowledge his indebtedness to Professor Albert Johannsen, of the University of Chicago, under whose direction this work was done, for many helpful suggestions. Credit is also due to Professor Edson S. Bastin, and other members of the department of geology of the University of Chicago, for their friendly criticisms and advice.

The writer is also grateful to Dr. Chas. N. Gould, director of the Oklahoma Geological Survey, for letters of introduction to men in official capacity in the Wichita Mountains area which made it easily possible to obtain entrance into restricted areas; to Dr. C. H. Taylor, for a field conference; to Mr. Durward B. Greene, staff photographer of the Fort Worth Star-Telegram, for many excellent photographs; to Lieutenant Wm. E. Bleakley and Technical Sergeant Wm. M. Brees, of the 88th Observation Squadron, Post Field, Fort Sill, Oklahoma, for the admirable aerial views which are included in this report.

Through the kindness of General Dwight E. Aultman, Major G. M. Peek, and Major Louis H. Brereton the writer was enabled to make airplane flights over the mountains.

PREVIOUS WORK

The early expeditions and geological surveys were made by George G. Shumard[1], T. B. Comstock and W. F. Cummins[2], R. T. Hill[3], T. Wayland Vaughan[4], and H. F. Bain[5]. The work of these men has been reviewed by J. A. Taff[6]. He with the assistance of C. N. Gould and E. O. Ulrich[7] completed the first map and general report of the Wichita Mountains. The distribution and relationship of the major types of igneous and sedimentary rocks were described. The micropegmatitic character of the acidic rocks was noted. These were

1. Shumard, George G., 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, pp. 179-195, 1853.

2. Comstock, T. B. and Cummins, W. F., A preliminary report on the geology of the central mineral region of Texas: Texas Geol. Survey, 1st Ann. Rept., pp. 319-328, 1889.

3. Hill, Robert T., Notes on a reconnaissance of the Ouachita System in Indian Territory: Am. Jour. Sci. 3rd ser. vol. 42, pp. 122-123, 1891.

4. Vaughan, T. Wayland, Geologic notes on the Wichita Mountains, Oklahoma and the Arbuckle Hills, Indian Territory, with report on the igneous rocks by Dr. A. C. Spencer: Am. Geologist. vol. 21, pp. 41-45, 1899.

5. Bain, H. Foster, Geology of the Wichita Mountains: Bull. Geol. Soc. America, vol. 11, pp. 127-144, 1900.

6. Taff, Joseph A., Preliminary report on the geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma: U. S. Geol. Survey, Prof. Paper 31, pp. 51-53, 1904. (Oklahoma Geol. Survey Bull. 12)

7. Idem., pp. 53-97.

classified as granites of plutonic nature rather than hypabyssal granophyres.

In 1915 C. H. Taylor[8] published a report on the igneous rocks of the Wichita Mountains. He contributed some further details of structure and physiography and was the first to report the occurrence of quartzite near Meers. The area south of Mount Scott which he mapped as quartzite is not a metamorphosed sedimentary formation but a fine grained granophyre.

Samuel Weidman[9] and O. F. Evans[10] published several papers on physiographic studies in this region.

LOCATION

The Wichita Mountains are located in southwestern Oklahoma. Their axial direction is N 70° W, and they extend northwest from Fort Sill for a distance of 65 miles to a point 4 miles northwest of Granite. The greatest width is across the central part, and here outlying hills, which are included in the mountain group, are 28 miles apart. The entire range will be referred to as the Wichita Mountain System.

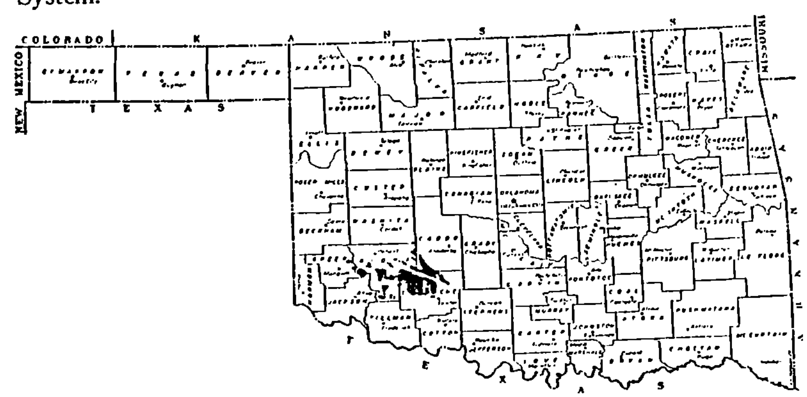

Figure 1. Map of Oklahoma showing the location of the Wichita Mountains.

The western half is composed of straggly groups of hills. The cluster near the town of Granite is called the Headquarters Mountain Group. About 10 miles southeast of Granite, in the bend of the North

8. Taylor, C. H., Granites of Oklahoma: Oklahoma Geol. Survey, Bull. 20, pp. 1-88, 1915.

9. Weidman, Samuel. Was there Pennsylvanian-Permian glaciation in the Arbuckle and Wichita Mountains of Oklahoma?: Jour. Geol. vol. 31, pp. 466-489, 1923.

10. Evans, O. F., Some observations on erosion and transportation in the Wichita Mountain area: Proc. Oklahoma Acad. Sci., vol. 2, pp. 77-79, 1922.

——————, Old beach markings in the western Wichita Mountains: Jour. Geol., vol. 37, pp. 76-82, 1929.

Fork of the Red River, is the Devils Canyon Group. Just west of the middle of the range are the Raggedy Mountains.

The eastern half is separated into two massive divisions which are elongated N. 60° W. On the northeast are the Limestone Hills, and on the southwest are the Wichita Mountains. The latter are much the larger and cover about three times the area of the former.

Even though the Wichita Mountains form a physiographic unit, parts have been given separate names. The eastern portion is called the Carlton Mountains, and the southern range of hills is called the Quanah Mountains. The term Wichita Mountains also includes the Carlton and Quanah Mountains. This is the area to be described in this paper. It extends from Fort Sill to Haystack Mountain. It is 28 miles long and from 8 to 12 miles wide, and covers approximately 250 square miles.

TOPOGRAPHY

The Wichita Mountains rise rather abruptly from the broad, gently rolling plains of southwestern Oklahoma. They form a range of hills which at the eastern end have smooth, rounded slopes, and in the central and western portions have rugged bouldery slopes.

The top of Mount Scott, at the eastern end of the Forest Reserve, is the highest point and has an elevation of 2,480 feet above sea level. The lowest point is in Medicine Bluff Creek below Medicine Bluffs and is approximately 1,140 feet above sea level. These two points, which have a vertical difference of about 1,340 feet, mark the greatest relief in the area.

Within the Forest Reserve a number of peaks approach the elevation of Mt. Scott. A few of the highest are Baker Peak, 2,405 feet, and Mount Pinchot, 2,458 feet, in the northwestern part; Mount Marcy 2,393 feet, is close to the central point; and Tarbone Mountain 2,382 feet, and Mount Lauramac 2,390 feet are in the north central portion. The average height for the central and southern hills is less than that of the northern hills, most of the highest peaks, as noted, being found in the northern area.

Throughout the central and western areas the hills are for the most part quite rugged. Their slopes are covered with talus composed to a large extent of boulders. These range in size from pieces large enough to be called a boulder up to rounded or semi-rounded masses of rock 100 feet long and 40 to 50 feet high. The largest are found in the Quanah Mountains particularly on and around Bat Cave Mountain, Mount Lincoln, and Elk Mountain. In other parts of the mountains the boulders are not usually more than 15 or 20 feet across.

Only the highest peaks rise above these talus slopes. The eastern and northeastern sides of Mount Sheridan exhibit bare rock surfaces

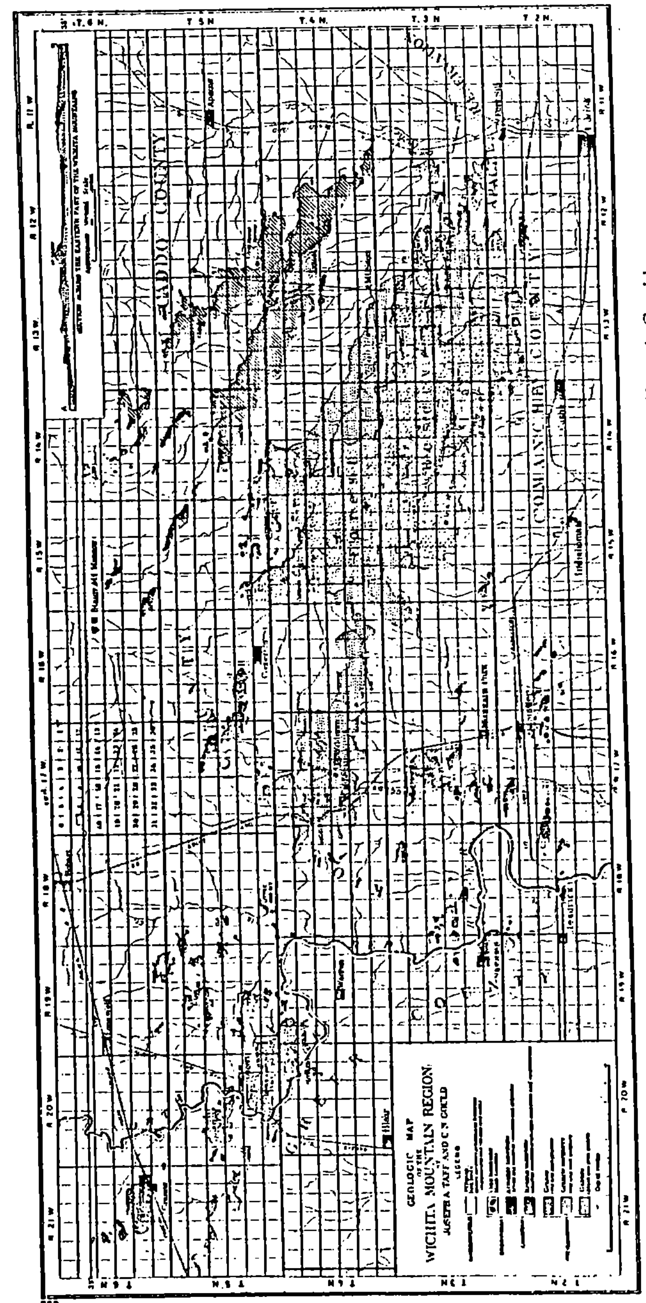

Figure 2. Geologic map of the Wichita Mountains, after Taff and Gould.

extending 300 to 400 feet down from the crest. Other well known examples of this feature are the eastern face of Tarbone Mountain and the northern slope of Mt. Scott. These walls descend in steep step-like fashion and have vertical faces sometimes as much as 60 or 70 feet high.

The southeastern group of hills, known as the Carlton Mountains, are low rounded hills with smooth slopes. The highest point is Signal Mountain which is 1,770 feet above sea level and 570 feet above the surrounding plains. In the Military Reservation, at the eastern end of the mountains, is a bluff 400 feet high at its middle point. Medicine Bluff Creek here makes a bend convex to the southwest cutting against the high rock wall. The bluff grades from nearly vertical at its upper portion to a dip of about 40° at its lower part where it merges with the talus slope along its base.

The interior of the mountains is marked by several low areas. They all radiate from a central zone much like the spokes of a wheel. The central low extends from Fern Mountain on the southwest to the foot of Mount Wall on the northeast, and from the base of Central Peak on the northwest to the porphyry hills east of Blue Beaver Creek.

Extending due south from the southwestern corner is a low area two miles long and one-half mile wide. It is the most accessible of the southern passes and is used by the road north from Cache into the mountains. From the southwestern corner west-northwesterly to Dead Man Mountain is a depression about eight miles long and from one to two miles wide. At the northwestern end is another depression also extending in a west-northwesterly direction. It is three miles long and from three-fourths to one mile wide, of which Graham Flat forms the western part. Extending northeasterly from the northwestern corner of this interior low is a trough two miles long and varying from one-half to one mile wide. This is the northern pass and is used by the road leading north to Meers. Extending eastward for about four miles is another one of these low areas. It occupies the region just south of Mounts Wall and Scott. It is rather narrow, averaging less than one-half mile wide. At the eastern side of Mount Scott it broadens very quickly and merges with the plains surrounding Lake Lawtonka. The valley of the Blue Beaver Creek is the southeastward extension of the central low region. The average width of this valley is slightly more than one-half mile. It is about five miles long and merges with the plains south of the mountains.

Excepting the region occupied by the low group of hills which form the Carlton Mountains, the valley depressions are deeper in the eastern and central portions than they are farther west. The relief in general increases from northwest to southeast. Mount Pinchot, the highest point in the western group, rises 660 feet above the valley at its southwestern base, while Mount Scott at the eastern end of the

Forest Reserve rises 1,130 feet above Lake Lawtonka. These two peaks have a difference of elevation of only 22 feet. The valley depressions fall from 1,800 feet at the foot of Mount Pinchot to 1,140 feet in Medicine Bluff Creek below Medicine Bluff.

Very few canyons and ravines still remain. The only notable ravine is the one which descends very rapidly down the northern slope between Tarbone Mountain and Mount Sheridan. Most of the canyons are found in the southern range of hills, as for example the depressions cut by West Cache and Panther creeks. By not too great a stretch of the imagination the valley of Quanah Creek across Quanah Mountain and the valley between McKinley and Cross mountains might be regarded as canyons.

Nearly all of the valleys and many of the hillsides carry a dense growth of trees. The trees are almost entirely jack oak and cedar, the former being by far more numerous than the latter. In the Carlton Mountains the woods are confined largely to the valley bottoms. The rock is intensely shattered and weathered out in small, angular pieces most of which are less than an inch across. These wash down the hillsides very readily, so vegetation has little opportunity to take root.

The slopes in the Quanah Mountains are also quite barren, but from different causes. Here the rock is the least fractured of any in the Wichitas. As a result it weathers out in enormous boulders. The only soil accumulation is found in the valleys and they are the places of abundant vegetation. The remainder of the mountains, and by far the larger part, is timbered throughout the valley areas and on most of the slopes as well. Many of the hills are completely covered by trees. The rock breaks into sizes ranging from medium to very small. Trees take hold and prosper exceedingly well as many of the slopes are covered with dense woods.

DRAINAGE

The general direction of the drainage in the Wichita Mountains is to the southeast. This also conforms to the direction of the regional drainage in southwestern Oklahoma.

The northern slopes are drained by Medicine Bluff Creek which flows in a southeasterly direction from North Mountain past Medicine Bluff. A large part of the central area is drained by Blue Beaver Creek. It heads in the western end of Graham Flat and flows southeasterly across the interior lowlands.

The west central region is drained by West Cache Creek and its tributaries. West Cache Creek heads in the northern end of the Big Buffalo Pasture and flows a little east of south across the Quanah Mountains. Panther Creek is the first tributary to the east. It heads just south of Cedar Mountain and joins West Cache in the canyon along the eastern side of Eagle Mountain. The next tributary to the east is Quanah Creek. It heads a short distance west of Central Peak and flows in a southerly direction across Quanah Mountain. Crater Creek is the last tributary to the east. Its head is north of Indian Hill. From here it flows south across the eastern end of the Quanah Mountains and joins the West Cache two miles south of the town of Cache. To the west is Rock Creek which heads in the Quanah Mountains, flows south from Bat Cave Mountain and joins the West Cache a mile southwest of the town of Cache.

The southwestern portion of the mountains is drained by Sandy Creek and Post Oak Creek. Both take a southerly course. In the northwestern group of hills the streams radiate outward. On the north they flow northward, on the northwest they flow northwestward, and so on around.

PHYSIOGRAPHY

GENERAL DESCRIPTION

The topography of the Wichita Mountains has reached maturity. A few sharp peaks and narrow valleys still remain as evidences of youth but they are minor in extent and carry little weight toward determining the age of the regional topography. In general the hills are rounded. The valleys are wide and the entire area is well drained. The few lakes found in the mountains and along its edges are all works of man.

GENERAL DISTRIBUTION OF IGNEOUS ROCKS

All of the higher hills are composed of granophyres. The lower smooth hills and ridges which form the Carlton Mountains are of porphyry. The northern slopes and foothills are underlain by gabbro as is the interior lowland from a mile west of Elm Island to Sulphur Spring.

TALUS AND BOULDER FORMATIONS

The entire area is marked by joints. Some parts of the mountains are more fractured than others. This evidence of crushing is best noted in the Carlton group. The porphyritic rock of these hills is so shattered that most of the fracture planes are less than an inch apart. This rock weathers out into small angular pieces which wash readily down the slopes and cause the smooth rounded appearance of these hills.

The medium grained granophyre, which forms most of the hills in the central, northern, and western areas is less intensely fractured than the porphyry. Local zones are shattered but throughout the major portion of it the joint planes are separated by distances of a few

inches to four or five feet. In some localities they are 10 to 20 feet apart but the general average is about four feet. The size of the boulders seems to be dependent upon the width of the joint planes. Small angular pieces are found where the rock is shattered and large rounded boulders where the joint planes are several feet apart. The rounding is produced largely by exfoliation of the isolated masses. The edges and corners more readily shell off than do the sides since they expose more surface per unit of rock, and so suffer greater temperature changes.

The least fractured rock is found in the Quanah Mountains. These hills are composed of a very coarse grained granophyre. The joint planes in a few local areas are several inches apart but throughout most of this range the distance between the joints varies from 20 to 100 feet or more. The largest boulders in the Wichita Mountains are found here. The boulders on Elk, Lincoln, and Bat Cave Mountains are typical and many of them are 100 feet long and 50 feet high.

The gabbroic rock, which is found in the low interior from Elm Island to Sulphur Spring and along the lower northern slopes, is broken and fractured to about the same extent as is the medium grained granophyre in the high northern hills. It is more susceptible to weathering than the granophyre and as a result breaks down more readily. Boulders are not found in great abundance and those that do exist are quite well rounded. The inability of this rock, as well as the granophyres, to resist erosion, is perhaps, the most important reason why it does not form any of the higher hills. It readily disintegrates to form a graywacke and gabbroic boulders are rarely found in the gravels in and around the mountains.

Generalizing it might be stated that the distance between fractures and the size of the boulders in the acidic rocks varies with the size of the crystals. The porphyry, which is intensely fractured, is composed largely of microcrystalline material. Boulders of intermediate size are found in the medium grained granophyres. The rock in the Quanah Range is the least fractured and is also the coarsest grained. Its boulders are the largest in the mountains.

BOULDER SLIDES

On many of the steeper slopes there are great accumulations of boulders in the drainage depressions. These are found particularly associated with the medium grained granophyre. The best examples can be seen on the southern side of Mount Scott and the western and northwestern sides of Mount Wall. They are composed of rounded and semi-rounded granitic masses three to six feet across.

No crushed material and very few cobblestones are found in the interstices. They are kept open by the drainage from the slopes which finds its way quite freely between and around the boulders. The rush of water through this highly porous mass sounds very much like a large stream going over steep rapids.

JOINTING

There are four sets of major joints, two of which are the stronger. Of the stronger, one runs almost parallel with the axis of the range. It varies between 69° and 78° west of north. The second set is almost at right angles to the first and its direction is about 12° east of north. The third and fourth sets cut diagonally across the first two and intersect them at angles of approximately 45°. The general directions for these are 55° east of north and 35° west of north.

There are many sets of minor joints which do not appear to approach any constancy of direction.

The dip of most of the joints is vertical or nearly so. But two fairly well defined sets were noted that had north dips of approximately 40° and 60° respectively, and two sets which dipped to the south at approximately 11° and 35° respectively.

FAULTING

Several faults were seen, but the displacement of only one could be measured. This one is the fault in Sheridan Mountain described by Taylor[11]. It is seen on the eastern slope where the crushed granite in the fault zone has been weathered out and washed away leaving a steeply dipping narrow trench from 10 to 20 feet wide. The trace of this fault cuts across Mount Sheridan and can be plainly seen from an airplane. Its general direction of N. 76° W. conforms to one of the major sets of joints. As nearly as can be determined the fault plane is vertical. The displacement is 68 feet. Granite overlies the gabbro at this point and the vertical offset of the contact can be readily determined.

Another fault was found in the bottom of Headquarters Creek, a mile west of Buffalo Lodge. The displacement could not be measured. Some excellent slickensides were observed, but not an abnormal amount of shattering. It is probable that the movement was not large, perhaps even less than in the Mount Sheridan fault. The dip was 82° S. and the direction N. 62° E.

A fault very probably exists at the CNL. SE.¼ sec. 16, T. 3 N., R. 13 W. (See Pl. VIIIa). Here the porphyry and medium grained granite are separated by a narrow trench two to four feet wide which is filled with crushed rock of both types. Scarps facing this trench appear to be weathered slickenside surfaces. The trench has vertical walls and trends N. 70° W. There was no way of determining the amount of displacement.

11. Taylor, C. H., op. cit., p. 86.

A small fault was noted on the south bank of Little Medicine Creek three-fourths mile south of Mount Scott. Some good slickenside surfaces were present, but here too the displacement could not be measured. The fault plane appeared to be vertical and was oriented N 12° E.

QUARTZ DIKES AND THEIR RELATION TO JOINTING

Throughout the mountains many quartz dikes were seen. They vary in thickness from one-sixteenth inch to three feet. In most instances their linear extent could not be traced more than 20 to 30 feet. Practically all of them are parallel to the four major joint systems. The greatest number, as well as most of the larger ones, were found to bear approximately N 72° W. The larger part of the remainder are directed approximately N 12° E. The rest are about equally divided between the other two sets of major joints.

STREAM DIRECTIONS AND THEIR RELATION TO JOINTING

Stream directions within and on the outer flanks of the mountains are controlled to a large extent by joints. Medicine Bluff Creek has many right angled turns. The small streams flowing north and south from the divide between McKinley and Cross Mountains follow a major joint line. Jointing greatly aided West Cache Creek and its tributaries to cut valleys across the Quanah Mountains.

MEDICINE BLUFF

Medicine Bluff at the eastern end of the mountains appears to be the result of stream erosion. The porphyritic rock which forms this hill is cut by strong vertical jointing as well as northwest-southeast and northeast-southwest sets of joints. Medicine Bluff Creek makes a south bend along the base of the cliff. Stream erosion prevents the accumulation of a large talus slope which would eventually protect the bluff. Due to well defined jointing the upper part of the cliff has a rude columnar structure in which the columns are approximately vertical. The columns of porphyry break off and slide down to the stream where they are broken into smaller pieces by weathering and finally carried away.

On the north side of the creek is a low hill which appears to be the northeastern remnant of the Medicine Bluff. The creek first swings to the south and then back east again, and so would have acted less on the eastern portion of the northern slope than on the western portion. The eastern remnant attests to this fact. By projection, the original Medicine Bluff Hill can be reconstructed. The development of this physiographic feature is largely the result of a superimposed stream course, aided by jointing. This problem is discussed below under pre-Pleistocene drainage.

GRAVELS

Within the mountains there are numerous isolated patches of gravels. The roads cross these gravel beds at various points, viz., one mile east of Central Peak, one mile north of Fern Mountain, from Indian Hill to the south side of Quanah Mountain, north end of Timber Hill, south of Lost Lake, one mile west of Buffalo Lodge, and southwest of Buffalo Gap. These unconsolidated clastics can also be found at a great many points surrounding the outer edge of the mountains. They can best be seen in the road cuts north and northeast of the range and in a continuous belt along the southern base of the Quanah Mountains.

The gravels are composed almost entirely of rounded and semi-rounded granitic boulders in sizes from three feet in diameter to small pebbles. The major portion of them are from six to ten inches across in which the interstices have been filled with smaller material. Gabbroic rock forms a very small part of these clastic remnants.

The gravel patches now form low hills and ridges which have smooth gentle slopes. Many of them are covered with a dense growth of jack oak. The gravel ridge southwest of Buffalo Gap reaches an elevation of 1,780 feet. This is the highest point in the mountains at which gravels were found. The hill southwest of Eagle Mountain is entirely composed of gravels. They attain a thickness of at least 250 feet and reach a height of 1,685 feet.

It is very probable that the gravels are only remnants of a layer of clastic material that once filled all of the lower areas in and around the mountains. If, by projection of the highest points of the remaining gravels the original beds were reconstructed, they would form a layer having a gentle dip to the southeast.

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 southwestern 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.

Gravels deposited at elevations similar to those described above would have been sufficient to fill all of the low and intermediate depressions in the mountains. Many of the old drainage channels would have been completely wiped out. The development of new drainage would in many instances be quite different from what it was previous to the deposition of the gravels.

South of the mountains some of these gravel beds have been traced for a number of miles. The most distant one known is located

one mile north of Frederick, Oklahoma, which is about 30 miles south of the Wichitas[12]. Here the gravels were laid down in an old river channel which was cut in the Permian red clays and shales. They are composed of the same granitic material as that found in the deposits farther north, but on the average are of much smaller size.

A large number of Pleistocene fossils have been found in the pit north of Frederick. On this basis a Pleistocene age has been assigned to it. This not only dates the gravels in the pit a mile north of Frederick, but also dates as Pleistocene the gravel remnants in and around the Wichita Mountains.

The large percentage of rounded and semi-rounded pebbles and boulders indicates that this material has been water worn to a considerable extent. The flow of water necessary to produce deposits similar to those, which most likely once existed, must have been much larger than anything known today. Since the granophyres erode very slowly the mountains could not have been much higher in Pleistocene times than they are at present. Greater drainage area and greater declivity cannot therefore reasonably be presented as an explanation. A large amount of water was necessary at the time of the formation of the gravels. Conditions today are entirely inadequate to produce deposits similar to those indicated by the present remnants. These gravels perhaps record a more humid climate than that of the present. Rock waste, which had accumulated under an earlier aridity as slope debris, was rapidly removed.

The grooving found in the granophyres in the western portion of the Wichita Mountain system has been regarded by Weidman[13] as evidence of glaciation. These grooves were first described by Taylor[14] who called them "ancient beach marks". That they are levels at which the water remained for short periods of time appears to be the correct explanation as pointed out by Evans[15]. Series of parallel grooves in places run back into reentrants in the rock as much as six feet. Some of them are lined by scalloped depressions which are clearly solution cavities.

Weidman has stated that these markings were formed during Permian time. This seems to be correct, since they are now being

12. Gould, Chas. N., On the recent finding on another flint arrow-head in the Pleistocene deposit at Frederick, Oklahoma: Jour. Washington Acad. Sci., vol. 9, no. 3, pp. 66-68, 1929.
Cook, Harold J., New trails of early man in America: Scientific American p. 114, August, 1927.
Figgins, J. D., The antiquity of man in America: Nat. Hist., vol. 27, no. 3, p. 240, 1927.
Spier, Leslie, A note on reputed ancient artifacts from Frederick, Oklahoma: Science, vol. 68, no. 1756, p. 184, 1928.
Hay, Oliver P., On the antiquity of relics of man at Frederick, Oklahoma: Science, vol. 67, no. 1739, p. 442, 1928.
Cook, Harold J., Further evidence concerning man's antiquity at Frederick, Oklahoma: Science, vol. 67, no. 1736, p. 371, 1928.
13. Weidman, Samuel, op. cit.
14. Taylor, C. H., op. cit., pp. 60-61.
15. Evans, O. F., op. cit.

exposed through the recent erosion of red Permian clays and shales. The sedimentary protection must have occurred shortly after their formation, or they would not have been preserved. The parallel markings may indicate oscillating lake or sea levels, but the general trend indicates a rising strand line.

Since these groovings are of Permian age they cannot be related to the genesis of the gravels in the mountains, which are Pleistocene.

PRE-PLEISTOCENE DRAINAGE

Many features of the present drainage in the interior of the Wichita Mountains are not the result of normal stream development. Among these, the most notable are the courses followed by West Cache Creek and several of its tributaries. These streams have cut steep walled valleys and canyons across the Quanah Mountains. They could easily have avoided this arduous task by following the interior trough southeastward, passing north of Indian Hill and joining the Blue Beaver Creek north of Cross Mountain. The present stream courses are quite evidently superimposed upon an older topography.

The headwaters of Cedar Creek appear to follow unusual courses. They first flow south-southwesterly in Mount Roosevelt, then turn sharply eastward at the southern base, finally swinging around to the northeast to join Medicine Bluff Creek. The waters in their journey practically reverse their direction. Their ravines in Mount Roosevelt appear to be the normal headward development of a southeasterly flowing stream.

Little Medicine Creek has elected a difficult course around Davidson Hill. Here it has cut a steep-walled valley between Davidson and Pratt Hills. The normal direction for this stream would have been westerly to Mount Wall and then southwesterly discharging its waters into the Blue Beaver Creek.

Southeast of Mount Sherman, Blue Beaver Creek changes from its southeasterly to a southwesterly course and avoids a low pass along the southwestern side of Carlton Mountain. From the locality north of Cross Mountain to the point at which this change of direction is made, the stream follows closely the contact between the Lugert and Carlton granophyres. On leaving the contact it assumes a more difficult course.

An inspection of field conditions indicates that the principal stream of the earlier drainage had its head approximately at the north end of Antelope Flat. From here it flowed southeasterly down the trough-like area passing north of Indian Hill to the valley of the Blue Beaver, continuing southeastward along the southwestern side of Carlton Mountain. This course follows a line less resistant to erosion than any other in the mountains. The area, from a mile west of Elm Island to Sulphur Spring is underlain by gabbroic intrusions

which are the most easily eroded of the igneous rocks. From the northern base of Cross Mountain the course bears close to the Lugert-Carlton contact. The Carlton is here intensely shattered, and afforded the easiest means for the development of an outlet.

A stream of this size had a very decided advantage over any others in or on the flanks of the mountains. It drained a much larger area, contained a greater flow of water and more rapidly cut its valley to a lower elevation. These conditions, especially that of greater declivity, greatly assisted the work of its tributaries. Normal headward erosion carried the tributaries back into Graham Flat and Mount Roosevelt on the north, and to the base of Mount Scott on the northeast. The drainage from the western group of porphyry hills flowed westerly.

If the valley depressions, which exist today in the above described drainage area, were filled, the earlier stream pattern would be reconstructed. The divides, which prevent the present streams from following their earlier courses, are all low and in several instances composed of ridges of gravel.

The earlier stream system was very probably disrupted by the deposition of the gravels. At the close of the Pleistocene this material must have filled the depressions to elevations higher than those at which they are found today. Ranging from above 1,800 feet in Buffalo Gap to perhaps a little less than 1,600 feet at Carlton Mountain these deposits were sufficient to erase most of the then existing valleys. The streams would naturally be consequent on the new topography. In some cases they followed the old courses and in many instances new directions were taken. Since the gravels were more easily eroded than the solid igneous rock the old drainage lines were largely uncovered before a completely changed system was developed. In the meantime many of the streams which followed new courses across the gravels were superimposed upon a topography for which they were not adjusted.

If these new channels contained streams large enough to maintain their new directions, and were aided by such conditions as jointing, they would not be found to revert back to their earlier courses. That this has occurred is witnessed by the fact that the Blue Beaver has lost most of its headwaters and has even developed a new valley southeast of Mount Sherman. The western waters are now carried south by the West Cache Creek and its tributaries. Crater Creek, which was probably a northward flowing tributary, now flows south through McClelland Pass. Some of the northern headwaters have been pirated by Cedar Creek, and the northeastern tributaries now flow eastward through Little Medicine Creek. Deer Creek and the West Branch Wolf Creek have captured some of the eastern tributaries.

STRATIGRAPHY

GENERAL GEOLOGY

The mountains in southwestern Oklahoma mark the axis of a regional high, which extends from the Criner Hills, at the southeastern end, across the buried Amarillo range in the Panhandle of Texas, at least as far as northeastern New Mexico. This is a distance of approximately 400 miles.

AMARILLO MOUNTAINS

The Amarillo Mountains, in the Texas Panhandle, have been briefly described by Pratt[16] and Bauer[17]. These are a buried range of hills composed of igneous rocks and extending in a northwest-southeasterly direction approximately N. 70° W. Their known extent is at least 125 miles from the southeastern corner of Wheeler County to the southwestern corner of Moore County. They probably extend much farther, continuing southeastward into Oklahoma and northwestward into New Mexico.

The highest peaks that have been reached by the drill are about 500 feet above sea level. The overlying section, which is approximately 3,000 feet thick on the crest of the range, is composed of a series of arkoses, sands, shales, clays, dolomites, and salt beds. The oldest bed in the sedimentary column is a dolomite. This has been tentatively assigned to the Cisco in the upper Pennsylvanian.[18]. The remaining section, excepting the uppermost 300 to 400 feet, is of Permian age. The upper 400 feet are Triassic, Tertiary, and Recent.

WICHITA MOUNTAIN SYSTEM

The Wichita Mountain system is composed of a range of hills of igneous rocks surrounded by sedimentary formations. The igneous rocks are pre-Cambrian, yet younger than a quartzite which they have intruded. The sedimentary section is entirely Paleozoic except for the small patches of Pleistocene and recent material found strewn about on the surface. The hills rise above the plains to a maximum of 1,100 feet, the highest point reaching an elevation of 2,480 feet above sea level. The igneous rock dips both to the northwest and southeast beneath younger formations. The highest peaks in the Amarillo district are 500 feet above sea level, whereas in the Mannsville area granitic rock has not been reached by wells drilled 1,500 feet or more below sea level.

Early Paleozoic rocks form a rim around the southeastern end of the mountains. They extend from McKenzie Hill, on the south side

16. Pratt, W. E., Oil and gas in the Texas Panhandle: Bull. Am. Assoc. Pet. Geol., vol. 7, pp. 237-249, 1923.
17. Bauer, C. Max, Oil and gas fields in the Texas Panhandle: Bull. Am. Assoc. Pet. Geol., vol. 10, pp. 733-746, 1926.
18. Pratt, W. E., op. cit. p. 242.

of the Carlton Mountains, around the eastern end, and then northwestward as far as Rainy Mountain Mission. The formations involved are the Reagan sandstone, Arbuckle limestone, Simpson formation, and the Viola limestone. They all outcrop prominently except the Simpson, which is exposed only in two small areas south of Gotebo near Rainy Mountain Mission. The sedimentaries dip away from the igneous core and form a southeasterly plunging anticline.

The best exposures of the sedimentary rocks are found in the Limestone Hills. The oldest of the series is the Reagan sandstone which rests uncomformably on the pre-Cambrian porphyry and is Upper Cambrian in age.[18a] It is described by Taff[19] as follows:

> The Reagan sandstone is the lowest Cambrian formation in the Wichita region, and it rests on the eroded uneven surface of the granite porphyry, from which most of its materials have been derived.
>
> The Reagan sandstone is approximately 300 feet thick and is composed of hard and soft sandstone, grit, conglomerate, shales, and siliceous shell limestones . . . . The conglomerate occurs invariably near the base as local beds or lentils, while the calcareous sandstone and limestone beds are without exception in the upper part of the formation.

Overlying the Reagan sandstone with apparent conformity is the Arbuckle limestone, which has an estimated thickness of at least 6,000 feet in this area. This formation is briefly described by Gould.[20]

> In the Wichita Mountains the Arbuckle limestone is exposed as rugged limestone ridges trending parallel to the main axis of the range, dipping northeast, in the northern Comanche, southwestern Caddo, and eastern Kiowa counties, and dipping south, in isolated limestone hills northwest of Lawton . . . . Fossils in the basal Arbuckle indicate Upper Cambrian age. The upper part of the limestone has been assigned to the Beekmantown (Lower Ordovician).

Three small limestone outcrops near Rainy Mountain Mission have been correlated with the Viola and Simpson found in the Arbuckle area. The Simpson formation occurs below the Viola, and above the Arbuckle limestones. It does not outcrop prominently in the Wichita region, but has been found by the drill.

The total thickness of this Cambro-Ordovician series is about 8500 feet, approximately equivalent to the corresponding section in the Arbuckle Mountains.

The Silurian, Devonian, Mississippian, and Lower Pennsylvanian periods are not represented in the Wichita area. The regional history indicates that this portion of Oklahoma lay dormant during that

18a. Decker, Chas. E., Letter dated September 23, 1930.
19. Taff, J. A., op. cit., pp. 68-69.
20. Gould, Chas. N., Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey Bull. 35, p. 13, 1925.

time. Evidence of orogenic movements is not known. Nothing but regional warping, and gradual rising and sinking of the lands, and basins of the epeiric seas, are indicated.

The next youngest sediments resting on the Ordovician beds are of Upper Pennsylvanian age. These do not outcrop around the mountains and are only known from well-log data. They thicken very rapidly to the eastward. North of the Criner Hills exposures of these beds total more than 7,000 feet in thickness[21].

Beds of Permian age overlap all of the older rocks, concealing most of them. They are gently dipping to flat-lying and fill the troughs and depressions in and around the hills and ridges of older rocks. Some of the peaks of igneous rock are completely surrounded by Permian strata.

Overlying the Permian are patches of gravels, sands and clays of Pleistocene age and younger.

ANADARKO BASIN

North of the Limestone Hills is the Anadarko Basin. This depression occupies the greater part of western Oklahoma and its axis runs northwest-southeast. It was first named and described by Gould[22]. Later Greene[23] published a structure map of this area, drawn on the base of the Enid formation, which illustrates its general character. Northward into the trough the Permian beds thicken very rapidly. Near Canute, 25 miles from the nearest granite outcrop, these beds were found in drilling to measure over 4,500 feet[24].

RED RIVER SYNCLINE

The Red River syncline is located south of the Wichita Mountains. The sediments which fill this basin are composed largely of Permian beds. A section 4,700 feet thick was found to rest on Ordovician limestone. It is entirely Permian, except a small amount of surface material, and the lower part, which was found to be Upper Pennsylvanian.[25]

ARBUCKLE MOUNTAINS

To the eastward the next major geologic feature is the Arbuckle Mountain uplift.[26] Its structure is anticlinal, and the general axis of

21. Tomlinson, C. W., The Pennsylvanian system in the Ardmore Basin: Oklahoma Geol. Survey, Bull. 46, 1929.
22. Gould, Chas. N., A new classification of the Permian red beds of southwestern Oklahoma: Bull. Am. Assoc. Pet. Geol., vol. 8, pp. 322-341, 1924.
23. Greene, Frank C., Subsurface stratigraphy of Western Oklahoma: Oklahoma Geol. Survey, Bull. 40, vol. 1, pp. 41-49, 1928.
24. Powers, Sidney, Age of folding of the Oklahoma Mountains; Bull. Geol. Soc. America, vol. 39, p. 1,057, 1928.
25. Idem. p. 1,059.
26. Taff, J. A., op. cit., and U. S. Geol. Survey Geol. Atlas, Tishomingo folio (No. 98), 1903.

the folding is approximately N. 65° W. The oldest rocks exposed are of igneous origin. The sedimentary section is much thicker here than in the Wichita Mountains. Each period in the Paleozoic era is represented by one or more formations, and the section varies in thickness from 22,000 to 32,000 feet, depending upon where it is measured. Post-Paleozoic beds are of minor importance.

OUACHITA MOUNTAINS

Eastward from the Arbuckle Mountains the Paleozoic sediments thicken rapidly. Their total amount is not known, but the Carboniferous section alone measures over 23,000 feet. Pre-Cambrian rocks are not exposed, and the only igneous rocks known are a few sills and dikes which have been intruded into Paleozoic beds. The mountains have been formed by intense crumpling, folding and thrust faulting. The thrust originated southeast of the mountains. Great blocks and masses of sediments were sheared and thrust northwestward.[27]

STRUCTURE

The Wichita-Arbuckle-Ouachita Mountain systems are all anticlinal. The greatest thickness of sediments is found in or adjoining these uplifts; away from the line of these folds the sediments thin rapidly both northward and southward. This feature indicates that the folding has occurred in or very close to the geosynclinal axes of deposition.

The outstanding features are as follows:

1. The vary marked unconformities at the base of the upper Cambrian and at the base of the upper Pennsylvanian.

2. The igneous core of the Amarillo Mountains is covered by a thin section of upper Pennsylvanian, which in turn is overlain by a thick series of Permian beds.

3. The Proterozoic rocks of the Wichita Mountains are unconformably overlain by Cambrian and Ordovician sediments. These are followed by upper Pennsylvanian beds, which are overlapped by the Permian series.

4. The sedimentary series is much thicker in the Arbuckle Mountains than in the Wichita Mountains. Beds of each Paleozoic period are represented, with breaks indicated by unconformities during the Lipalian interval, and in late middle or early upper Pennsylvanian.

5. The Ouachita Mountains contain the greatest thickness of sediments known in Oklahoma. The pre-Cambrian unconformity has not been found, but the Pennsylvania break is known.

27. Honess, C. W., Geology of the southern Ouachita Mountains of Oklahoma: Oklahoma Geol. Survey, Bull. 32, 1923.

HISTORICAL GEOLOGY

PROTEROZOIC ERA

At the northern base of Mount Sheridan along Medicine Bluff Creek, and one-quarter mile southwest of the old Meers townsite, is an outcrop of quartzite which has been intruded by grabbroic rock. This exposure of quartzite was first described by Taylor[28]. It can be seen over an area about a quarter mile in width.

An exposure of quartzite, not previously described, was found at the top of the hill in the SW¼ SE¼ sec. 34, T. 4 N., R. 14 W. The outcrop is small, being only 200 feet long by 50 feet wide. Near the top of the hill is an old prospect pit 6 feet deep where fair samples of this rock were obtained. The quartzite is here intruded by the Lugert granophyre. These exposures of metamorphosed sedimentary rock will be referred to in this paper under the name of Meers quartzite.

The area south of Mount Scott, which Taylor marked quartzite, was found to be not a quartzite, but a fine grained granophyre, which is described in the chapter on petrology.

The igneous rocks comprise a series of intrusions beginning with the basic and ending with the acidic. They are closely related in age. In many instances the grain size is not much smaller along the contacts than in the interior of the masses, indicating that one instrusion followed the other before the preceding had cooled. Coincident with the igneous activity there occurred some folding and uplift. This is shown by the presence of "porphyry pebbles and included basic rocks"[29] in the lower portion of the Reagan. If erosion had not taken place with at least some moderate degree of rapidity, weathering would have disintegrated these pebbles.

The time of this series of events is regarded as Proterozoic, conforming to the widespread vulcanism which happened at the close of the Algonkian. Upper Cambrian beds now are found resting unconformably on these earlier rocks, indicating that any uplift must have been reduced by the end of middle Cambrian. The Lipalian interval, along with the lower and middle Cambrian intervals, would have been sufficient time for the accomplishment of these changes.

PALEOZOIC ERA

CAMBRIAN AND ORDOVICIAN PERIODS

In the Wichita area deposition began in the upper Cambrian and continued through Ordovician times. No momentous diastrophic movements are recorded. From the Reagan sandstone to the Viola limestone the beds rest upon one another with apparent conformity.

28. Taylor, C. H., op. cit., p. 32.
29. Taff, J. A., op. cit., p. 69.

The Reagan conglomerate grades upward through sandstone into limy strata. These are overlain by a great series of limestones 7,000 or more feet thick[30] broken only in the upper part by a sandy horizon, the Simpson formation. The character of the sediments indicates that adjacent uplands were reduced before the close of the upper Cambrian epoch. The succeeding history is one of widespread, quiet seas. They may have been shallow seas, but certainly were not bordered by high land areas.

Formations of these periods are known to extend westward as far as Rainy Mountain Mission. Several outcrops in this locality have been correlated with the Viola limestone. The greatest westward extension of the Cambrian and Ordovician seas can only be inferred. Well records indicate that these early Paleozoic formations thin rapidly westward, and in western Oklahoma and the adjoining Texas Panhandle area, they have not knowingly been logged. It seems reasonable to suppose from the change in the character of the sediments, that the Ordovician seas were more widespread than the Cambrian, and that beds of the latter were overlapped to the westward by the former. Ordovician beds, very much thinner than those known in central Oklahoma, were probably laid down in the western and southwestern portions of the State, but most likely did not extend very far into the Texas Panhandle.

SILURIAN, DEVONIAN, MISSISSIPPIAN AND LOWER PENNSYLVANIAN PERIODS

Toward the close of the Ordovician period broad regional warping brought western Oklahoma above sea-level. Deposits of Silurian, Devonian, Mississippian, and lower Pennsylvanian time are absent from this area. There is nothing to indicate that they were deposited and eroded. Since the area over which they are absent is so large, it is more reasonable to assume that they were never laid down. On the other hand, the amount of uplift was not great. No large amount of erosion is recorded. In the Arbuckle region, where sedimentation continued throughout the Paleozoic, the break at the base of the Silurian is represented principally in the fossil sequence.

East of the Wichita area sedimentation is recorded in all of the periods of the Paleozic era. The deposits thicken eastward. The largest amount of sediments is now found in the Ouachita Mountains.

LATE PALEOZOIC EVENTS

Beginning in mid-Pennsylvanian time and continuing to the end of this period and possibly into the Permian, Oklahoma was in the throes of a gigantic diastrophism. The Ouachita, Arbuckle, and Wichita mountains arose. The orogeny began at the eastern end in the Oua-

30. Decker, Chas. E., and Merritt, C. A., Physical characteristics of the Arbuckle limestone: Oklahoma Geol. Survey, Circ. 15, 1928.

chitas and continued westward. The Amarillo Mountains most likely folded as the westward extension of the Wichita System.

Coincident with this tremendous mountain folding, most of Oklahoma, especially the middle and western parts, was tilted a little south of westward. This regional warping, along with the mountain building, initiated a westward dipping trough which later became enclosed to form the Anadarko basin. The upper Pennsylvanian and lower Permian seas encroached from the southwest and retreated in the direction from which they came.

From upper Pennsylvanian through Permian, the seas were shallow as indicated by the cross-bedding, ripple marks and lensing of the beds. Some of these formations may even have been delta or river deposits.[31]

During Permian time the seas were rather widespread, but shallow. Their deposits are now found over a large area, and their shallowness is shown by the marked changes in sedimentation which resulted in slight to negligible unconformities. At times the basins were enclosed and salts and gypsum were deposited. Then at a later date the area was connected with the sea and a marine fauna left its imprint. This was followed by shallow-water deposits part of which were perhaps terrestrial.

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 later 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.

SOURCE OF THE PERMIAN SEDIMENTS

The mountain ranges in southern Oklahoma furnished the material for the conglomerates, sandstones, and shales in the upper Pennsylvanian as noted by the great series of clastics of this age adjacent to these high land areas. Sedimentation continued from these same sources into the following period. Northward from the mountains, thick formations of red sandstones, sandy clays, and shales of Permian age grade into thinner sections of nonred clays and limestones. Southwestward from the Wichita system, the same gradation prevails. That the Wichita ranges were the upland regions from which the principal part of these sediments were derived is shown by (1) the known high areas in late Pennsylvanian and early Permian times, and (2) the characteristic change in sedimentation.

31. Branson, E. B., Triassic-Jurassic "red beds" of the Rocky Mountain region: Jour. Geology, vol. 35, no. 7, pp. 607-630, 1927.

SOURCE OF THE RED COLORING

The reddish color of the rocks begins in the upper Pennsylvanian in south-central Oklahoma and grades upward into the Permian. To the eastward it forms roughly a large semi-circular area around the Wichita Mountains as a center. Close to the center the reddish section is thicker and more completely red than it is farther out toward the periphery. At the outer edges the red beds are interstratified with non-red beds.

The igneous rocks of the Wichita Mountains carry a relatively high percentage of magnetite. The gabbroid rocks contain from 1 to 6 per cent, the average being about 3 per cent. The granophyric rocks are very acidic and are composed largely of quartz and feldspar. They are quite unusual, however, in that they carry an ample supply of magnetite. The amount varies between nothing and 4 per cent, but most of it contains an average of 1 per cent. It is evident that the supply of iron oxide for coloring matter is quite sufficient.

Twenhofel[32] states that red beds may be arkoses produced through the disintegration and partial decomposition of red granitic rocks . . . However, as most of the red beds do not appear to contain a great deal of feldspar, the hypothesis has little application. With this argument Gould[33] eliminated the igneous rocks in southern Oklahoma as the source of the red color. These statements disregard the fact that an igneous rock can undergo complete katamorphism and still produce sands and clays with a reddish color. If weathering is complete, certainly no feldspar would be present. Leith and Mead[34] make the following statement, under, "Qualitative consideration of mineral alteration of a granite."

> In the progress of katamorphism the feldspars and the ferromagnesian constituents lose their bases and by hydration, become kaolin. In the absence of iron stains, this causes a whitening or bleaching of the rock. The iron in the ferromagnesian minerals under surface conditions may be oxidized in place, becoming hematite or limonite, giving yellowish and reddish colors to the altered product. Under reducing conditions part of the iron may be taken into solution, to be later precipitated as iron carbonate or hydrous oxides, commonly limonite. The silica leached from the rock is deposited as chert or quartz. The small amounts of magnesia and the lime taken from the granite are principally deposited as calcite and dolomite, either in limestone or dolomite formations, or mixed with the fragmental formations. Soda largely goes to salt in the sea, although some sodium salts may be precipitated under appropriate conditions of desiccation. Potash remains largely with the clay in more or less doubtful combination. The ultimate mineral

32. Twenhofel, W. H., Treatise on sedimentation: Williams & Wilkins Company, p. 178, 1926.
33. Gould, Chas. N. and Wilson, Roy A., The upper Paleozoic rocks of Oklahoma: Oklahoma Geol. Survey, Bull. 41, p. 21, 1927.
34. Leith, C. K. and Meade, W. J., Metamorphic geology: Henry Holt & Co., p. 4, 1915.

products of the alteration of a granite, therefore, are clay or kaolin, quartz, iron oxide, calcite, dolomite, and salts in the sea.

From a consideration of the above it is seen that the complete weathering of the igneous rocks in the Wichita Mountains could produce the identical conditions found today. The character of the Permian red beds indicates that they were deposited in widespread shallow seas or as river or delta beds, or a combination of both. Deposits formed under conditions such as these types would indicate could easily have been weathered nearly to completion.

Probably not all of the red beds in this general area were formed thus. The weathering of the igneous rock could account for the red beds of the upper Pennsylvanian and lower Permian, during which time the Wichita Mountains were undergoing rapid erosion. Later Permian beds probably covered much of the Wichita Mountains. At this stage the sediments were furnished by the land areas of low or moderate elevations surrounding these shallow seas and basins. As the seas retreated the shore lines were composed of the red sediments formed earlier in the period. The later red beds may to a large degree be the redeposited sediments of late upper Pennsylvanian and early Permian age.

MESOZOIC EVENTS

Following the Permian, the area was subjected to erosion. The principal drainage flowed southwesterly. No important movements are recorded in southwestern Oklahoma until the Laramide revolution. The folding of the Rocky Mountains altered the geography east of it. Regional tilting took place in Oklahoma, changing the general slope from southwesterly to southeasterly. The major drainage, similar to that existing today, was initiated at this time.

POST-MESOZOIC EVENTS

During the Pleistocene period a bed of coarse gravels and boulders was deposited in and around the Wichita Mountains. This has been suggested as evidence of a more humid climate than that of the present. Rock waste, which had accumulated under an earlier aridity as slope debris, was rapidly removed during this time.

PETROLOGY

The rocks of the Wichita Mountains will be described approximately in the order of their ages,—quartzites, gabbros and anorthosites, granophyres,[34a] and dike rocks,—the quartzites being the oldest.

34a. Granophyres are hypabyssal or extrusive rocks of granitic composition in which the quartz and alkali feldspars are, to a large extent, intergrown. Micropegmatitic texture is common.

Their modes have been determined by the Rosiwal method.

The acidic rocks are granophyres and not granites as they have usually been regarded. These were intruded as thick sills, and not as parts of a batholith or a combination of several batholitic masses. A discussion of this problem will be taken up following the rock descriptions.

QUARTZITES

Three small exposures of quartzites, which have been named the Meers Quartzite, were found in the north central portion of the Wichitas. Two have been intruded by gabbro and the third by granophyre.

One of the exposures southwest of Meers is a small, roughly circular area about one-fourth mile wide. It is found along the banks of Medicine Bluff Creek and also in the creek bottom. This is the outcrop referred to by Taylor[35], and is included entirely within the gabbroid rocks. The other is a small mass which cuts across the road immediately south of the Meers townsite.

A specimen which was taken from the creek bed was examined microscopically. It contained the following minerals: quartz grains 91 per cent, sillimanite needles 5 per cent, biotite 3 per cent, magnetite 1 per cent, many small grains of zircon, and a few small grains of apatite.

The quartz grains (Pl. XVB) are sub-angular to rounded and average from 0.2 to 0.3 mm. in diameter. They contain many minute granular inclusions and also an abundance of extremely fine needles.

Most of the sillimanite, biotite, and magnetite is clustered together. The sillimanite is present as slender needles up to 0.5 mm. in length (Pl. XVc). The biotite forms small grains most of which are chloritized. The magnetite occurs in small irregularly shaped grains. Most of the zircons have an average diameter of about 0.05 mm.

The third outcrop of quartzite was found on top of the hill in the SE¼ SW¼ SE¼ Sec. 34, T. 4, N., R. 14 W. It is a small exposure elongated northwest-southeast and is about 50 feet wide and 200 feet long. This area is included completely within the granophyre. It is unlike the mass included within the gabbro for sillimanite and biotite are absent. There is an abundance of small magnetite grains. Apatite and zircon are present in moderate amounts, but mostly in grains less than 0.03 mm. in diameter.

The quartz grains vary from 0.7 to 1.0 mm. in length. They depart from a rounded form and fit closely against one another.

35. Taylor, C. H., op. cit., p. 32.

The rock is cut by thin dikes of granitic material (Pl. XVIA) which have an average thickness of about 1 mm. These are composed of quartz with a small amount of sodaclase[36] and orthoclase.

GABBRO AND ANORTHOSITE

Gabbroic rocks are exposed in several isolated areas, three of which are large and seven are small. They can be readily located on the map accompanying this report. These will be described in order beginning with the northeastern mass, then continuing south and westward.

NORTHERN AREA

Flanking the northeastern side of the Wichita Mountains is an elongated strip of anorthosite and gabbro. Its orientation is approximately parallel to the axis of the range which is N. 60° W. This exposure is 12 miles long and varies from a narrow wedge at its southeastern limits to 2¾ miles across its middle portion and 1½ miles across its northwestern extremity. These basic rocks are bounded by granophyres on all sides except along the northeastern edge. Here it is limited by sedimentary rocks. South and southwest of Meers two small areas of quartzite occur as inclusions.

The gabbroic rocks vary from dark gray to black in color. Some of the specimens carry small greenish patches which are chloritized or uralitized zones of ferromagnesian minerals. The grain is from medium to coarse and uneven. The plagioclase laths which form the major portion of the rocks range in length from 2 mm. to 14 mm. or possibly even more.

The general character of the rocks is anorthositic rather than gabbroic. The greater portion of this entire exposure carries more than 80 per cent labradorite. Much of it can be classified as an anorthosite as it carries as high as 96 per cent labradorite.

Without exception the anorthosite is found along the northeastern edge of the mass where the adjoining rocks are sedimentaries. The distinctly gabbroic types, in which the ferromagnesian minerals comprise from one-third to one-half of the rock, are found adjacent to the granophyres along the southwestern side and at the northwestern end. Throughout the central portion of mass, transition types, which carry not less than 72 per cent labradorite, were found.

In two localities the specimens collected were quartz-gabbros. At the northwestern end in the NE cor., SE¼ SW¼ Sec. 8, T. 4 N, R. 14 W., one specimen was examined which contained 7 per cent

36. Johannsen, Albert. Essentials for the microscopic determination of rock-forming minerals and rocks: Univ. of Chicago Press, 2nd. ed., 1928.
Sodaclase is a new term introduced by Albert Johannsen for the soda end of the plagioclase series, and replaces the mineral name albite.

quartz. This rock should really be classified as a granogabbro since it also contained 16 per cent of microperthite and orthoclase. The other quartz-bearing rock was obtained from the Hazel quarry (Pl. XVIB, c) on the eastern slope of Mount Sheridan. It contained a few grains totaling 3 per cent of the rock, filling the interstices between the other constituents. The gabbro in this locality is cut by many aplite, diabase, and quartz dikes.

The texture of the mass varies from ophitic, through hypidiomorphic-granular, to schistose. Some of the gabbro is characterized by ophitic texture. A few varieties of gabbro, anorthosite-gabbro and anorthosite are hypidiomorphic-granular, the schistose texture (Pl. XVID) is confined entirely to the anorthosite. Parallel textured anorthosite forms a band along the outer edge of the gabbroic intrusion. It is present in a belt N. 60° W. and extending northwesterly for five miles from a point about a mile northwest of the old Meers townsite (fig. 3).

Although the rock appears to be a schist it is more probable that the parallel texture was developed at the time and as a result of the intrusion. It is present in a belt N. 60° W. and extending northwest-margin which is the contact of the gabbro with granophyre. If the parallel arrangement of the crystals was induced by metamorphism it should be found along this zone where the granophyre is known to be younger and to have intruded the gabbroic rocks. The northeastern edge is bounded by sedimentary rocks. There is no evidence present to suggest any agency which might have produced recrystallization

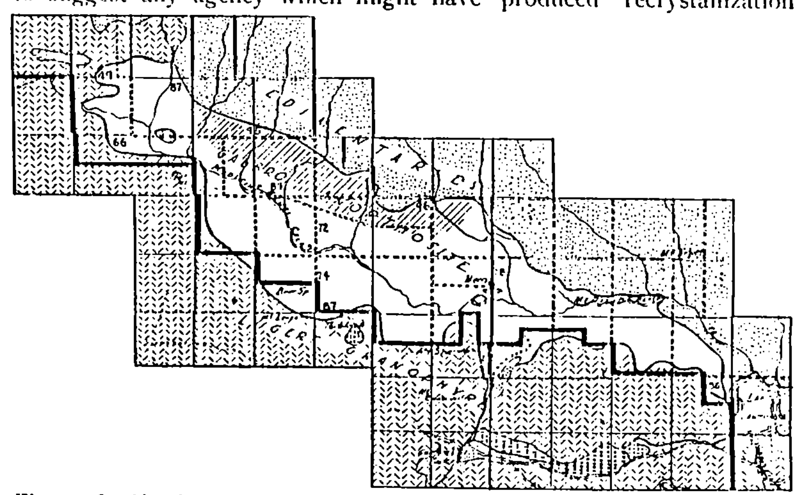

Figure 3. Northern gabbro-anorthosite area. Shading indicates areas in which parallel texture occurs. Figures show the per cent of labradorite in the rock collected at those localities.

along this belt. Furthermore the small amount of diallage (4-6 per cent), which fills the interstices between the labradorite laths, shows no parallel orientation nor crystal outlines. Rather it seems to be the final product of crystallization which was still liquid at the time of the intrusion. It solidified with little regard to compressional directions.

ROCK FORMING MINERALS

The most abundant mineral is labradorite. It varies from 96 per cent in the anorthosite along the northeastern edge, to 72 per cent in the central portion of the mass, and drops to 55 per cent in the quartz-gabbro of the Hazel quarry and 49 per cent in the grano-gabbro at the northwestern end. The plagioclase content is lower in the vicinity of the granophyre than along the outer edge, but the feldspar percentage along the contact varies considerably. Some of the specimens collected were more of the anorthosite-gabbro type than true gabbros. At the northeastern foot of Mount Scott, labradorite forms 86 per cent of the rock, and at the northwestern foot of Tarbone Mountain it forms 87 per cent.

The labradorite crystals vary in size from stout tablets, which are as wide as they are long, to slender crystals four to six times as long as they are wide. The elongated forms are found in the rocks which have parallel texture. They are nearly panidiomorphic (Pl. XVID). The only minerals which do not exhibit almost complete crystal forms are the ferromagnesian constituents.

In the gabbro and anorthosite-gabbro the grain sizes vary from medium to very coarse. The texture is usually hypidiomorphic-granular, but is sometimes divergent-granular.

The labradorite is almost always stained a grayish brown. This coloring varies from a very pale tinge to a rather intense shade. It is best seen in the rocks which carry the higher percentage of plagioclase. The amount of pigment gives the anorthosite its color, which, megascopically is of all shades from gray to black.

The coloring of the labradorite is due to inclusions both of finely disseminated granular material and small thin black blades of titaniferous mica (Pl. XVIE). Most of the crystals contain three sets of these blades oriented parallel to three lines at 60° to each other.

The labradorite in the anorthosite is quite fresh and shows very little fracturing. In the anorthosite-gabbro and normal gabbro the feldspars are very much fractured, sometimes even shattered. They are also altered, particularly along the fracture planes. The principal product of alteration is white mica but a small amount of kaolin is also developed.

The usual albite twinning is well defined and common to nearly all of the crystals of labradorite. Carlsbad twins are abundant, as are also twins developed according to the pericline law. All three forms are often developed in a single crystal (Pl. XVIF).

Of the ferromagnesian minerals, diallage is the most abundant. It shows typical cleavage and has a maximum extinction angle of 39°. It is usually altered to chlorite, epidote and uralitic hornblende. The greatest degree of alteration was found in the gabbros and the least in the anorthosites.

Hornblende and biotite also occur as primary constituents. They are of insignificant amount except in the quartz gabbros. In these each may form as much as 7½ per cent of the rock. The hornblende is green, strongly pleochroic, and with well defined amphibole (110) cleavage. The biotite varies from golden brown to a very deep brown.

In the granogabbro at the northwestern end, the pyroxene is surrounded by rims of hornblende and biotite. A few examples were noted where the hornblende forms a rim around the diallage, and this is surrounded by a rim of biotite (Pl. XVIIA).

Hypersthene was found only in the quartz-bearing gabbros. It is most abundant in the rock from the Hazel quarry and here it amounts to about 5 per cent. This rock also carries 3 per cent quartz, some of which is graphically intergrown with a small amount of kaolinized orthoclase. The granogabbro carries 7 per cent quartz and 16 per cent of kaolinized orthoclase and micropherthite. Part of the quartz occurs as large irregularly shaped grains while the remainder is micrographically intergrown with the alkali feldspar.

The accessory minerals are magnetite, apatite, titanite, zircon, and pyrite. They are listed in the order of abundance. Their quantity in the rock in general varies inversely with the amount of labradorite. Magnetite is found in very insignificant quantities in the anorthosite and as high as 6 per cent in the gabbros. That it is titaniferous is shown by its partial alteration to leucoxene. A few of the partially altered grains have surface striations closely resembling sagenite, indicating an intergrowth of ilmenite and magnetite. Apatite forms a common accessory of the gabbros, particularly in those which are quartz bearing. It occurs in medium sized prisms, needles, and hexagonal grains. Titanite is found occasionally while zircon and pyrite are but rarely present.

CENTRAL PEAK AREA

A small exposure of gabbro forms the saddle between the central and northeastern hills of Central Peak. The outcrop is roughly circular in shape and not over one-eighth mile across.

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.

CENTRAL AREA

The interior lowland, extending from a mile west of Buffalo Lodge on the northwest to Sulphur Spring at the southeastern end, is underlain by anorthosite and gabbro-anorthosite. This area is six miles long and ranges in width from three-fourths mile to 1½ miles.

The rocks are dark gray to black and medium to coarse grained. Their textures range from hypidiomorphic-granular to parallel. The

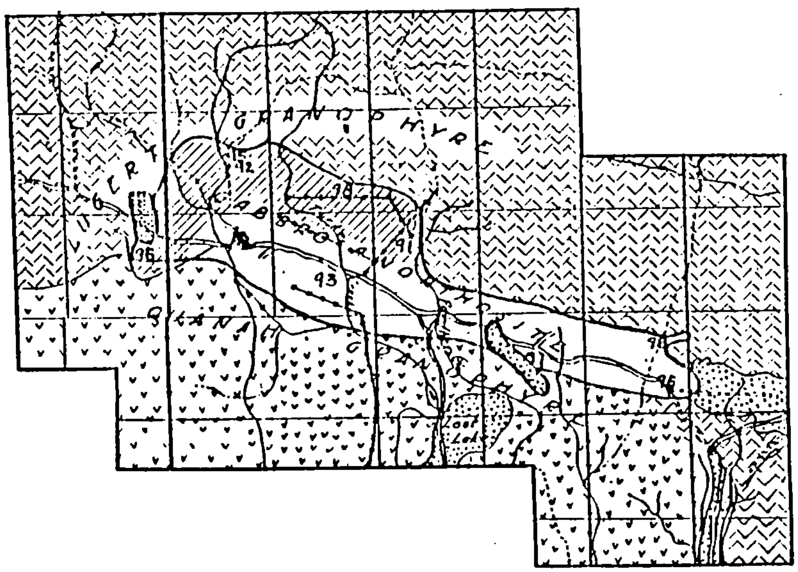

Figure 4. Central gabbro-anorthosite area. Shading indicates areas in which parallel texture occurs. Figures show the per cent of labradorite in the rock collected at those localities.

latter type is confined to the northwestern portion of the mass. The anorthosites at both the western and eastern extremities are cut by thin dikes, of granitic material, which are composed of small spherulites of quartz and orthoclase.

The schistose texture in this instance, just as in the northern area, is regarded as a parallel arrangement induced at the time of the intrusion and not by subsequent metamorphism. Granitic dikes (Pl. XVIIB) have intruded the gabbroid rock at both the western and the eastern ends, while parallel texture is present only in the western portion. These dikes must have been intruded about the time when the adjacent granophyre was injected and crystallized. That both ends of the gabbroid mass were subjected to approximately the same kind of contact activity and still have such unlike fabrics indicates that their textures were fully developed before the granophyric intrusion.

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 specimen collected near the contact in the cen. S½ NE¼ sec. 7, T. 3 N., R. 14 W. was an anorthosite which contained about 4 per cent augite. 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 an 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.

WOLF CREEK AREA

A small isolated gabbro outcrop occurs in the south central part of section 28 and the north central part of sec. 33, T. 4 N., R. 15 W. It is approximately one-third mile across. This exposure occupies a relatively low area along Wolf Creek.

The rock is a gabbro, dark gray, coarsely grained, and of hypidiomorphic granular texture. Its mode is labradorite 68 per cent; diallage 18 per cent, biotite 7 per cent, hornblende 4 per cent, magnetite 2 per cent and titanite ½ per cent. The labradorite is very much fractured. It is altered along the fracture planes to kaolin and white mica. Much of the diallage is changed to uralite, epidote, and chlorite. Practically all of the biotite is chloritized. Titanite is rather abundant. Apatite is also an accessory mineral but of minor amount. The magnetite is titaniferous and is partially altered to leucoxene.

BOGGY FLAT AREA

From the east side of Grace Mountain to the west side of Mount Pinchot is an elongated quartz-gabbro exposure. It is two miles long and averages one-fourth mile wide. It occupies the low area in Boggy Flat.

The mode of this rock is approximately as follows: labradorite 60 per cent, hornblende 19 per cent, diallage 2 per cent, quartz and micropegmatite 11 per cent, biotite 5 per cent, magnetite 2 per cent, apatite ½ per cent.

The labradorite is similar to that already described. The hornblende is quite fresh but some of it is altered to chlorite. Wherever diallage is found it is surrounded by a rim of hornblende. The separate amounts of quartz and micropegmatite vary considerably while their total does not. Sometimes as much as 7 per cent quartz may be present, and again there may be no individual quartz grains but as much as 14 per cent micropegmatite.

The biotite is fresh and strongly pleochroic from light tan to golden brown. Within the magnetite grains are included some crystals of apatite and titanite. Apatite is quite abundant. Pyrite occurs in small amounts.

BOGGY HOLLOW AREA

A large gabbroid area adjoins the Wichita Mountains on the west. This rock forms many of the hills in the Raggedy Mountain group.

An edge specimen from SE cor. SW¼ NE¼ sec. 19, T. 4 N., R. 15 W., was found to be an anorthosite which contained 98 per cent labradorite. The feldspar contains numerous inclusions of grains and needles of magnetite and ilmenite which give the rock its dark gray to black color. A small amount of calcite is formed as an alteration product.

The remaining 2 per cent is magnetite and hornblende. The greater part of it is amphibole which is almost completely altered to epidote and chlorite.

No apatite or titanite was found in this rock.

ORDER OF CRYSTALLIZATION

The sequence of crystallization in these rocks in general followed the normal order. The first to come out were the accessories such as apatite, titanite, ilmenite, and pyrite. These were followed by magnetite. Next came hypersthene to be followed by diallage or augite. Hornblende and biotite then appeared, succeeded by plagioclase. The last to form were the alkali feldspars, quartz, and micropegmatite. Considerable overlapping was noticeable. The hornblende and biotite were simultaneous to some extent, the hornblende usually starting earlier. The greatest amount of variation was seen in the labradorite. In the anorthosites it crystallized entirely or to a considerable extent even before the diallage. In general, the higher its percentage in the rock, the earlier did its crystallization begin.

GRANOPHYRES

The greater part of the Wichita Mountains is composed of granophyres. It is especially noticeable that all of the high hills are of these rocks. Several types are distinguishable and will be described in the order in which their relative ages have been determined.

DAVIDSON GRANOPHYRE

The Davidson granophyre outcrops on the western half of Davidson Hill and northwest along Little Medicine Creek for about one-half mile. It can also be seen over a small area south of Mount Scott, as an inclusion at the top of the northeastern hill of Mount Wall, southeast of Mount Sheridan as a long strip one-quarter mile wide and 1¼ miles long, and as an included mass on top of Mount Tarbone.

This rock is very fine grained to dense and varies in color from light pink to dark gray with blackish streaks. In only a few instances does it show a tendency to become porphyric 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.

CARLTON GRANOPHYRE

Nearly all of the Carlton Mountains is 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 (Pl. XVIIE) 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 (Pl. XVIIF). The edges show some mingling with the fine grained quartz and orthoclase of the groundmass. Some of the crystals are very markedly corroded (Pl. XVIIIA). 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.

SADDLE MOUNTAIN GRANOPHYRE.

Near Saddle Mountain and centering in and around sec. 36, T. 5 N., R. 15 W., is another type of granophyre which is named for the locality. Several miles south a mass of this rock occurs as an inclusion in the Lugert granophyre. It is about 200 feet wide and is located in the NW¼ SW¼ NW¼, sec. 30, T. 4 N., R. 14 W.

This granophyre is very dark gray, dense and porphyritic. Red orthoclase crystals 1 to 4 mm. long, are set in a dark gray dense groundmass. The rock is quite fresh and rings like an anvil when struck with a hammer.

The phenocrysts total about 20 per cent of the rock. They are orthoclase and sodaclase 13 per cent, quartz 4 per cent, hornblende 3 per cent. The feldspars are altered to sericite and kaolin, and stained with ferric oxide. Some of the orthoclase crystals poikilitically enclose quartz grains, minute aggregates of micropegmatite, and many small needles of aegirite (Pl. XVIIIB). The quartz crystals are of intermediate size, usually about 0.2 to 0.4 mm. across. They have corroded edges but are clear and quite fresh.

The hornblende is found closely associated with the magnetite and biotite. The amphibole is considerably altered and stained with iron rust. Much of the biotite is altered to chlorite, and the magnetite shows an appreciable amount of oxidation. Accessory minerals are zircon, titanite and apatite.

Granite west of Mount Sheridan, Wichita Mountains
(Collected by J. P. Iddings. Analysis by G. Steiger.[37])

SiO_2	73.61	H_2O above 105°	0.35
Al_2O_3	11.97	TiO_2	.46
Fe_2O_3	2.34	P_2O_5	.15
FeO	1.51	MnO	.09
MgO	.19	BaO	.04
CaO	1.38	SrO	.02
Na_2O	3.76	ZrO_2	.00
K_2O	4.32	CO_2	.00
H_2O at 105°	.32		100.51

The groundmass is spherulitic-granophyric. It is composed largely of feathery spherulitic sheaves and needles. In addition there are small masses of very fine grained micropegmatite, and groups of minute grains of quartz and orthoclase. Many of the feathery microlites are arranged radially about the phenocrysts (Pl. XVIIIC). A considerable number of aegirite needles are distributed throughout the groundmass. In the coronas these take the radial arrangement of the microlites. Most of them are very small, usually 0.1 mm. long, but others attain a length of 0.3 mm.

LUGERT GRANOPHYRE

The term Lugert granophyre is here used for the rocks referred to by Taylor[38] as Lugert granite. All of the high hills in the northern range are of this rock.

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

The average mode is micropegmatite 60 per cent, microperthite, orthoclase, and sodaclase-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 sam-

37. Steiger, G., U. S. Geol. Survey, bull. 419, p. 41, 1910. This is undoubtedly an analysis of a specimen of the Lugert granophyre.
38. Taylor, C. H., op. cit., p. 60.

ples it is as low as 20 per cent. The feldspar in this mixture is usually very much altered, the products being kaolin and a lesser amount of sericite. The quartz is fresh and clear, and contains only a moderate amount of inclusions.

The feldspar 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 Granme Flat contained a crystal of oligoclase which was surrounded by a zone of orthoclase (Pl. XIXB).

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 (Pl. XIXC). 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.

Lugert granophyre is younger than the anorthosite-gabbros, and younger than all the granophyres described above. The granophyre plug which rises above the Hazel quarry on the eastern side of Mount Sheridan is completely surrounded by gabbro. This is interpreted as an intrusion through the basic rock. At the contact, granophyric dikes are seen to cut the gabbros. Only along the contact are these acidic dikes known. Xenoliths of the Davidson, Carlton, and Saddle Mountain granophyres are found in the Lugert.

The grain size in the Lugert rock along the anorthosite-gabbro contact is little different from that in the central portion of the mass. Evidently the intrusion took place while the basic rocks were still very hot.

QUANAH GRANOPHYRE

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 (Pl. XIXD). Coarse grained micropegmatite up to 28 per cent occurs as an interspace filling in the central and along the northern portion of the mass (Pl. XIXE). The quartz is fresh and moderately clear, while the feldspars are kaolinized and slightly stained with ferric oxide.

The ferromagnesian mineral 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. In the southern half riebeckite is the more abundant. It totaled 1½ per cent at the southwestern edge (Pl. XXA). The hand specimen appeared to carry about 6 per cent, but the thin section showed the lesser amount. Magnetite is here a minor accessory and largely oxidized to hematite.

At only a few places could the contact between the Quanah and Lugert granophyres be recognized. Along the southern side of Sunset Peak small blocks of Lugert are included in the Quanah, and a few apophyses of the latter extend into the former. These indicate that the Quanah is younger than the Lugert.

SUMMARY OF GRANOPHYRES

The five types of granophyres can be briefly summarized.

They are all poor in ferromagnesian minerals, the greatest amount being found in the Lugert, and in that rock it rarely reaches 8 per cent. They are composed almost entirely of quartz and alkali feldspars. The principal distinguishing feature in each case is the texture.

1. Davidson granophyre: fine grained intergrowth of quartz and alkali feldspar.

2. Carlton granophyre: porphyritic; quartz and alkali feldspar phenocrysts, in a fine grained granophyric groundmass which resembles the Davidson rock.

3. Saddle Mountain granophyre: porphyritic; small crystals of alkali feldspar and quartz surrounded by a spherultic and very finely grained micropegmatitic groundmass.

4. Lugert granophyre: medium grained, hypidiomorphic-granular; medium and large sized grains of quartz and feldspar surrounded by smaller grains of the same material, and medium to coarse grained micropegmatite. This rock also carries a very small amount of oligoclase, some of it in zonal growth.

5. Quanah granophyre: coarse grained, hypidiomorphic-granular; quartz, micropegmatite in varying amounts up to 28 per cent, microperthite and orthoclase; ferromagnesian mineral content very low, maximum 2 per cent.

DIKE ROCKS

Several types of dikes occur in the mountains. Those which are common along the contact between the Lugert granophyre and the northern basic area are ordinarily referred to as aplites. These differ somewhat from typical aplite dikes such as are seen in other parts of the area and will be described below under the heading of contact dikes. In addition to these, diabase and quartz dikes also occur. All of them will be described in the relative order of their ages beginning with the oldest.

CONTACT DIKES

In the basic rock near the contact with the Lugert granophyre, but particularly in and around the locality marked by the Hazel Quarry, are a number of light pink acidic dikes. They vary considerably in grain size and to some degree in texture. A few of them are pegmatitic in character and carry large quartz and orthoclase crystals, and long rods of altered amphibole. A microscopic study indicates that they are very much like the Lugert granophyre (Pl. XXD, E), to which they are closely related, with the difference that the dark mineral in the slides is biotite instead of hornblende.

The average mode for this rock is micropegmatite 55 per cent, microperthite and sodaclase 31 per cent, quartz 12 per cent, biotite 1 per cent, magnetite and other accessories as titanite, zircon and apatite 1 per cent. All of the feldspar is kaolinized. Quartz grades into the micropegmatite which varies from fine to coarse grained. Biotite is largely altered to chlorite. Some epidote is present which may have been derived from hornblende. A few sagenite webs are developed in the altered biotite (Pl. XXF).

Deeper into the gabbroid area these dikes become very fine grained to cryptocrystalline.

DIABASE DIKES

Several diabase dikes were seen in the Lugert granophyre in the central and northwestern area, and in the northern gabbroid area (Pl. XXIA, B). None was found in the Carlton or Quanah Mountains.

These intrusions are of dense black rock and vary in width from a fraction of an inch to 11 feet. The grain is always finest at the contact, which is usually very sharp, and becomes coarser toward the center. The rock in the middle of the larger dikes is medium grained.

The texture is ophitic. The mode is labradorite 52 per cent, titanaugite 29 per cent, uralitic hornblende and chlorite 16 per cent, magnetite 3 per cent. The accessories are a few grains of apatite, titanite and zircon. The uralite is an alteration product of the augite, and the chlorite of the biotite.

These intrusions are doubtless younger than the contact dikes since they cut the Lugert granophyre which is the parent of the latter.

APLITE DIKES

Dikes of light pink finely grained rock were found in all of the rocks from the anorthosites and gabbros to the Quanah granophyre. None was found which cut the diabase dikes, but they are regarded as younger since they are present in the Quanah granophyre which is of later age than any rock which contains the diabase dikes.

These aplite dikes are fine grained granophyres composed of micropegmatite and small grains of quartz and alkali feldspars (Pl XXIC). About 1 to 2 per cent of biotite is usually present and a small amount of magnetite. The feldspars are kaolinized.

QUARTZ DIKES

Quartz dikes from a small fraction of an inch to three feet in diameter, cut all the other rocks. They are unquestionably igneous and the last intrusion in the area.

A specimen from the southeastern end of Medicine Bluff is light bluish gray. It has a porphyritic appearance. Small clear grains of quartz 2 to 3 mm. in diameter are set in a cherty appearing groundmass. Microscopically it is entirely crystalline. The clear grains are surrounded by crystals of quartz which dovetail into one another and have a gray to dark grayish color due to inclusions. Some of the material forms rims around the clear grains and is oriented in the same manner. The inclusions are numerous small grains of titanite, leucoxene, magnetite, biotite, and kaolinized feldspar. Some of the biotite grains contain sagenite webs.

HISTORICAL SEQUENCE

The oldest rock in the region is the Meers quartzite. It has been intruded by both the anorthosite-gabbro and the Lugert granophyre. The next in order of age are the anorthosite and gabbros.

The Lugert granophyre intrudes the basic rocks; but it also intrudes the Davidson, Carlton, and Saddle Mountain granophyres. The latter three are not found in contact with the gabbros and anorthosites, so they cannot be definitely placed as either younger or older. In this report they are considered younger. They perhaps are not much older than the Lugert. The granophyres are so much alike, varying principally in texture, that they are in all probability successive intrusions of the same magma at different depths. The fine grained Davidson and Saddle Mountain granophyres came close to the surface, followed in the eastern section by the Carlton at slightly greater depth, and these in turn succeeded by the wide-spread Lugert at still greater depth. The Quanah intruded the Lugert. The former is much coaser grained than the latter and so must have crystallized deeper.

The contact dikes in the zone where the Lugert and gabbro meet were coincident with the Lugert intrusion. The diabase dikes perhaps preceded the Quanah since they are not found in it but do penetrate the rocks just older. The aplite dikes are present in the Quanah granophyre and are therefore younger than the diabase dikes. The quartz dikes were the last to appear. They intersect all of the other rocks.

WICHITA INTRUSIVES

The acidic rocks of the Wichita Mountains are composed to a large extent of quartz and alkali feldspar intergrown in micropegmatitic fashion. This is the type of rock referred to by Rosenbusch[39] as granophyre. Rocks of this texture are typically hypabyssal. Rastall[40] has noted that:

> * * * true deep-seated plutonic rocks, which have consolidated under a great thickness of rock-cover, do not show much graphic structure. On the other hand, this structure is very well marked in many rocks which appear, from independent evidence, to have consolidated under a comparatively thin covering, although occurring in large masses.

It is moreover noteworthy that the usual order of intrusion is first the basic followed by the acidic. This is shown in the descriptions of sills and laccoliths in various parts of the world. In most instances the gabbro grades from a very basic type to a less basic and even to an acidic phase containing micropegmatite as an interstitial filling between the plagioclase and ferromagnesian minerals. A brief statement about several occurrences of granophyric rocks will show their similarity to the Wichita Mountain types.

The Moyie sills in the Purcell Range of British Columbia have been described by Daly.[41] These vary in thickness from 135 feet or less up to 1,050 feet and cover an area measured by hundreds of square miles. The intruded rocks are Algonkian quartzites. The gradation in the intrusion is from gabbro at the lower portions of the sills to granophyres in the upper layers. Daly explains this change

39. Rosenbusch, H., and Wulfing, E. A., Mikroskopische physiographie: 1 band, 2 halfte, p. 186, 1927.
40. Rastall, R. H, Buttermere and Ennerdale granophyre: Geol. Soc. London, Quart. Jour., vol. 62, p. 271, 1906.
41. Daly, R. A., Geology of the North American Cordillera at the 49th parallel: Canada Geol. Survey, Mem. 38, pp. 247-255, 1912.

as due to gravitative differentiation after intrusion and to some extent assimilation of the overlaying quartzite.

The gabbro sills of the Marysville Mining District, Montana, have been described by Joseph Barrell.[42] They grade upward from a basic to an acidic phase. The rocks are intruded into the Greyson-Spokane formation which is a series of argillaceous and arenaceous beds of Algonkian age.

The Duluth laccoliths[43] bear a close resemblance to the Wichita intrusions. The basic rocks grade from a magnetitic gabbro through olivine gabbro to true gabbro and anorthosite. These are intruded by granophyres.

The gabbro and associated rocks at Preston, Connecticut[44] have a similar relationship. The gabbro has the usual gradation from basic in its lower portion to acidic in its upper portion. Laughlin interprets this as a dike rock which is cut by later intrusions of granitic sills.

The Pigeon Point rocks of Minnesota[45] are sills of gabbro followed by sills of granophyre. The basic rock grades upward into a keratophyre. These sills intrude quartzites and argillites of Animikie age. Bayley suggests that the acidic phase of the gabbro may be partially due to assimilation of quartzite.

The sills of southern Rhodesia have been described by Frederick P. Mennell.[46] They are gabbros intruded by granophyres. The upper layers of the gabbro carry micropegmatite as an interstitial filling.

In the English Lake District[47] basic dolerites and quartz dolerites have been intruded by granophyres. According to Rastall, these are hypabyssal rocks.

One of the earliest and the most important interpretations was that of Alfred Harker in regard to the granophyres of Strath (Skye).[48] Gabbros were followed by granophyres. Harker explains them as differentiates of a deep-seated magma which were intruded as sills into the overlying sediments.

The igneous rocks of the Wichita Mountains have intruded quartzites. The high quartz content of the granophyres, and the micropegmatite in the gabbros, can have been only slightly affected by

42. Barrell, Joseph, Geology of the Marysville mining district, Mont.: U. S. Geol. Survey Prof. Paper 57, pp. 46-49, 1907.
43. Van Hise, C. R. and Leith, C. K., Geology of the Lake Superior region: U. S. Geol. Survey Mon. 52, pp. 372-379, 1911.
44. Laughlin, G. C., The gabbros and associated rocks at Preston, Conn.: U. S. Geol. Survey 492, 1912.
45. Bayley, W. S., The eruptive and sedimentary rocks on Pigeon Point, Minn. and their contact phenomena: U. S. Geol. Survey Bull. 109, 1893.
46. Mennell, Frederick P., Geol. Soc. London, Quart. Jour., vol. 66, pp. 353-375, 1910.
47. Rastall, R. H., op. cit., pp. 252-274.
48. Harker, Alfred, Geol. Soc. London, Quart. Jour., vol. [illegible]

this circumstance. Harker has shown that the xenoliths in the igneous rocks of Skye were barely altered. N. L. Bowen[49] agrees that assimilation is of small importance. He further describes the manner by which a basaltic magma can differentiate into a series of rock types grading from ultra-basic to highly acidic. It is unnecessary to call upon assimilation of silica rich sediments to explain the occurrence of quartz-rich rocks.

Both the basic and acidic intrusions in the Wichita Mountains may be the differentiates of a deep seated gabbroic magma. They are closely related in age as indicated by the lack of chilling phenomena along the contacts. The granophyres followed the gabbros while they were still quite hot.

The first to be intruded was the gabbro. It was apparently an anorthositic phase of the deep seated source as it is feldspar rich. Some further differentiation took place after the injection which tended to accumulate the anorthosite in the upper portion of the mass and the gabbro in the lower. Shortly afterward the granophyres were intruded as a series of sills in more or less rapid succession. The Davidson, Carlton, and Saddle Mountain were perhaps extrusive or near surface phases of the Lugert. They are all closely related in composition but the first three are fine grained to porphyritic. The diabase dikes were intruded after the Lugert. The Quanah was last, and deeper than the preceding. It is more coarsely grained than the other granophyres. The aplite dikes which intersect the Quanah and older rocks were formed considerably later, most likely after the rocks had time to cool. They are fine grained and cut the Quanah which is very coarse grained.

The thickness of the sills could not be measured. Only small remnants of the Proterozoic quartzites, which they intruded, are still present. These do not give any indication of the dip. The entire series was base leveled by upper Cambrian time and unconformably overlain by the Reagan sandstone. The Pennsylvanian folding and tilting raised the south side of the mountains more than the north side, suggesting a thrust from the south. The coarse grained Quanah, which is the lowest of the hypabyssal instrusions, is exposed in the southern range of hills. The overlying Paleozoic beds dip at all angles up to 50°. To accept any one of these as an average for the dip of the intruded sills would be but a guess and of little value toward determining the thickness of the igneous intrusions. The only indication to be derived is that the thickness of the sills is of the order of thousands of feet.

49. Bowen, N. L., The evolution of igneous rocks: Princeton Univ. Press, 1928.

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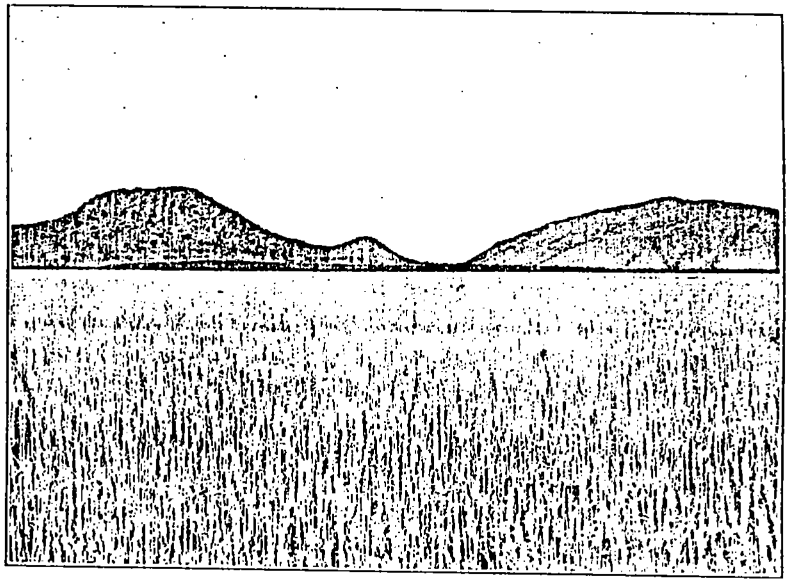
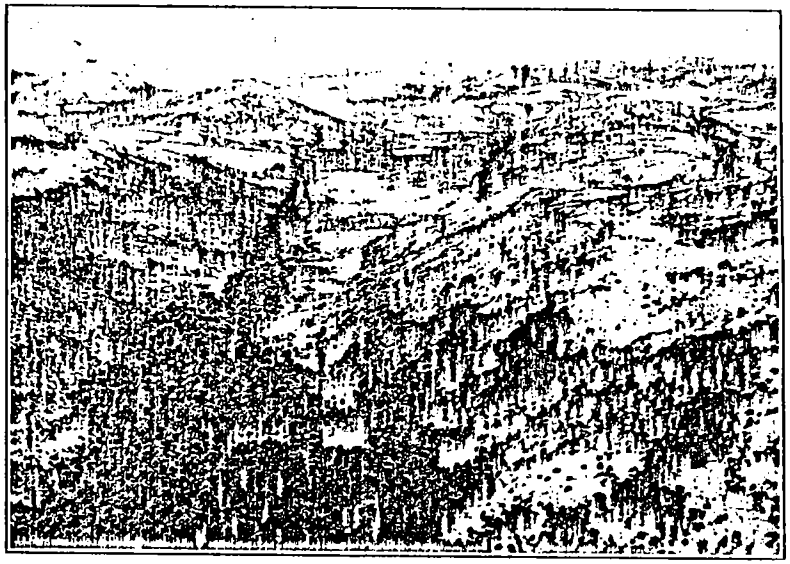
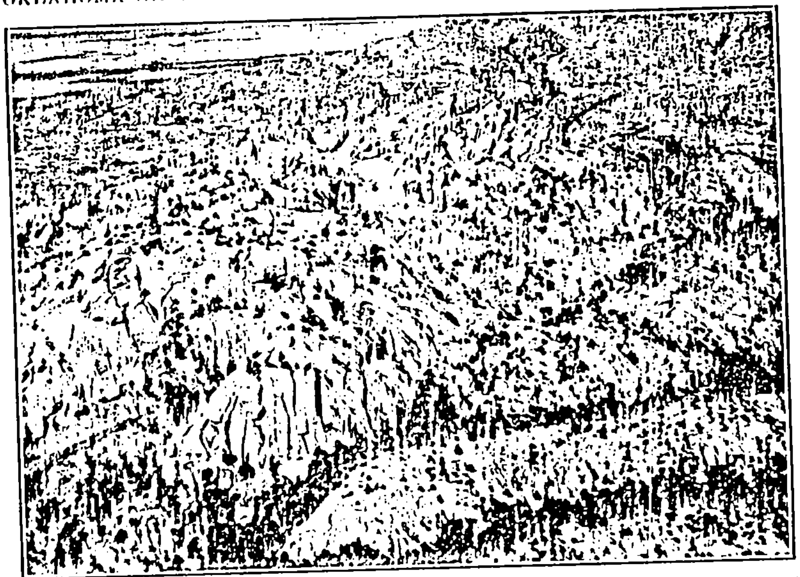


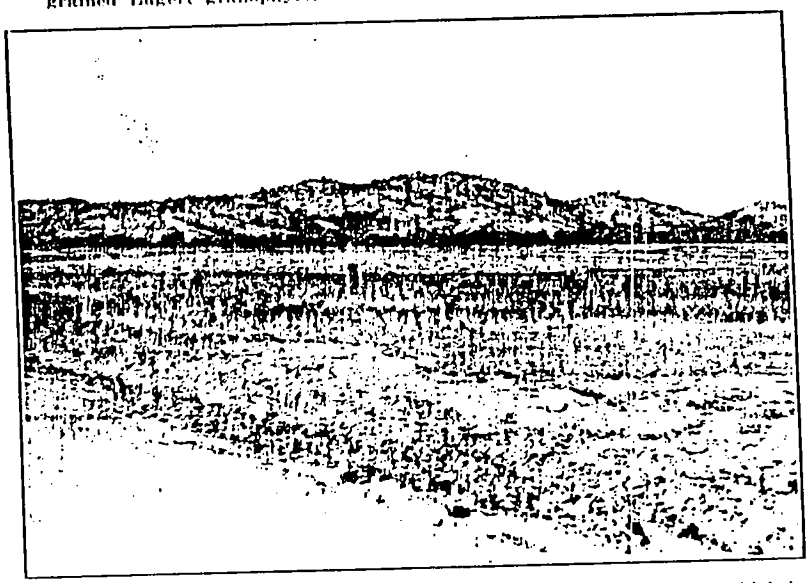
A. Wichita Mountains from the west showing abrupt rise from the plains. (D. B. Greene)



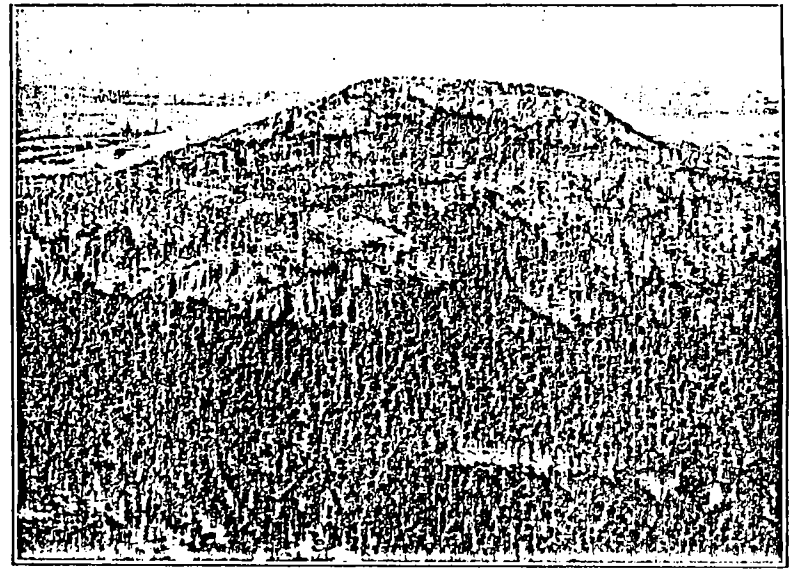
B. General View of northwestern portion of the Wichita Mountains, looking north. (U. S. Army Air Service.)



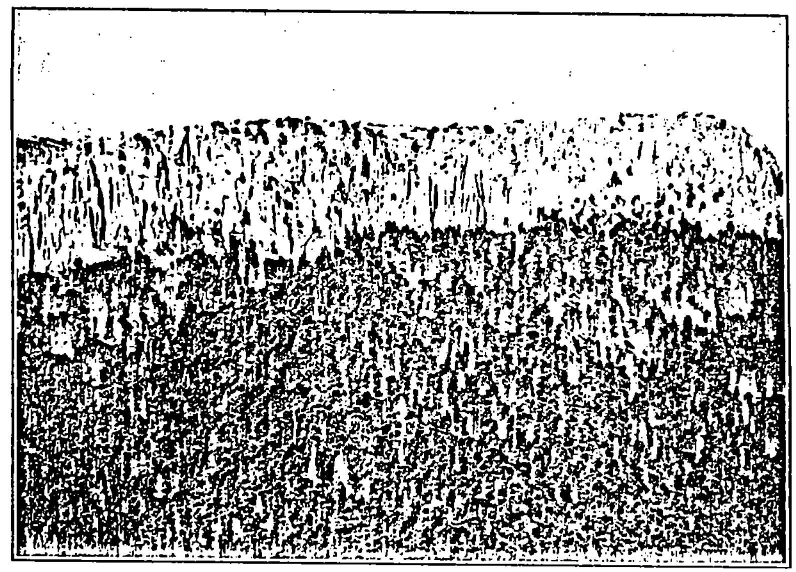
A. Looking northwest across Lincoln Mountain. Massive rock in foreground is the coarse grained Quanah granophyre. Rock in background is medium grained Lugert granophyre. (U. S. Army Air Service.)



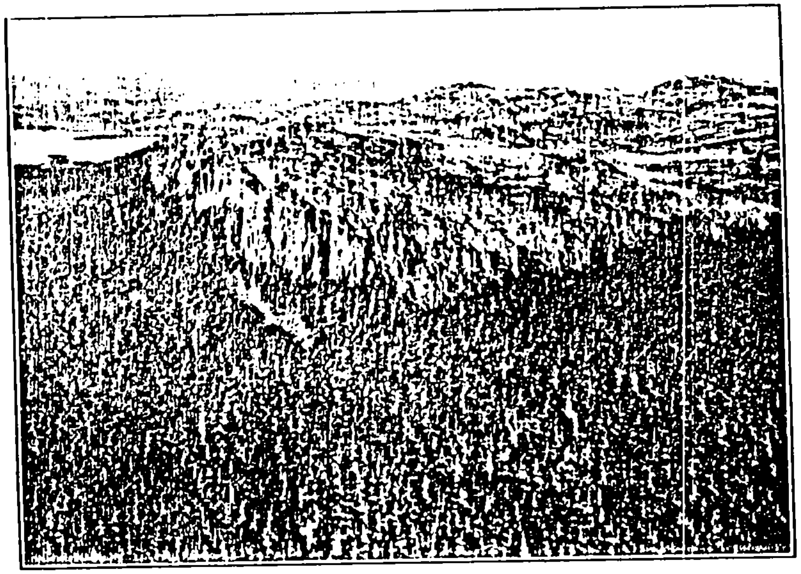
B. Quanah Mountain from the north. Looking across interior lowland which is underlain by anorthosite. (D. B. Greene.)



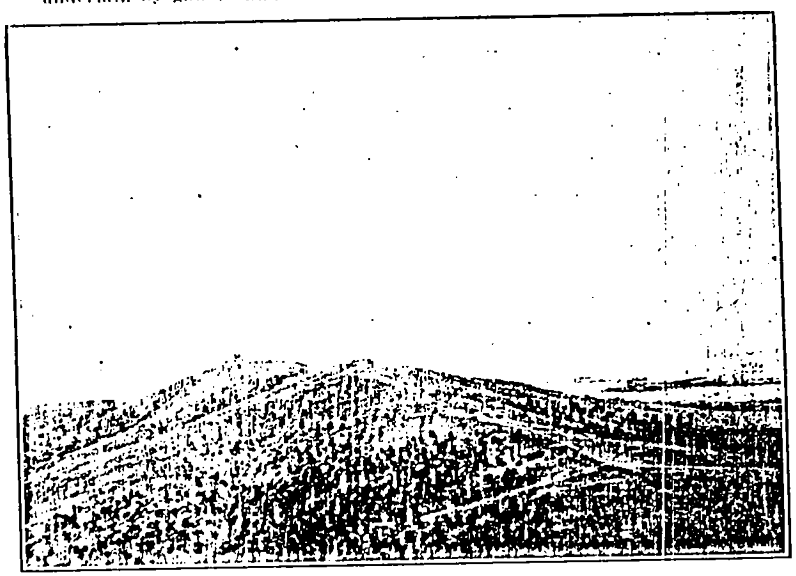
A. North Slope of Mount Scott showing well defined joints. Mountain composed of Lugert granophyre. Lower densely wooded slopes in foreground underlain by anorthosite-gabbro. (U. S. Army Air Service.)



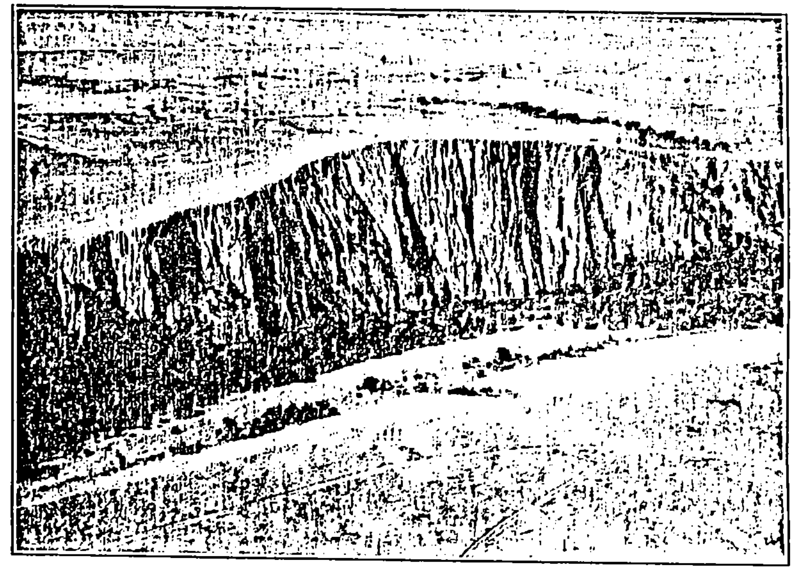
B. Northeastern face of Mount Sheridan. Cliff of Lugert granophyre about 350 feet high, wooded slope of basic rock. (U. S. Army Air Service.)



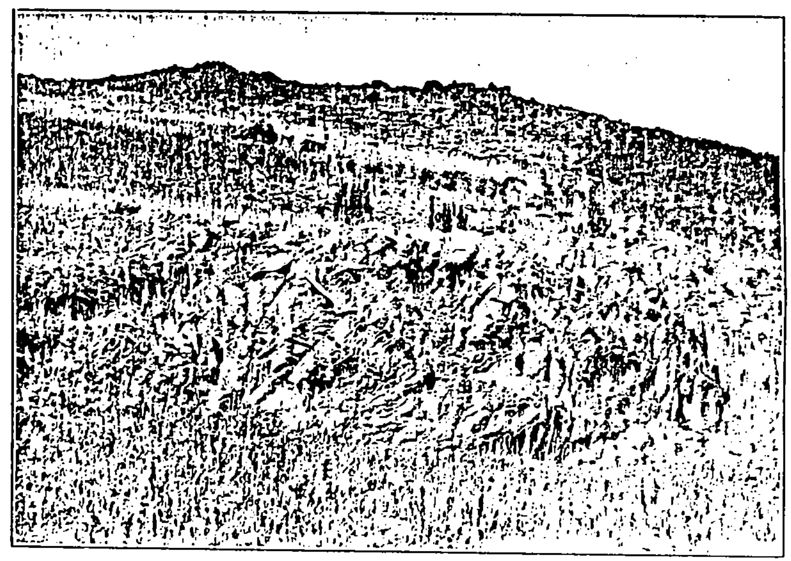
A. Tarbone Mountain as seen from the north. Steep eastern face about 350 feet high. Mountain composed of Lugert granophyre. Lower wooded slopes underlain by gabbro and anorthosite. (U. S. Army Air Service.)



B. Western slope of Signal Hill. Example of general appearance of the Carlton porphyry. (U. S. Army Air Service.)

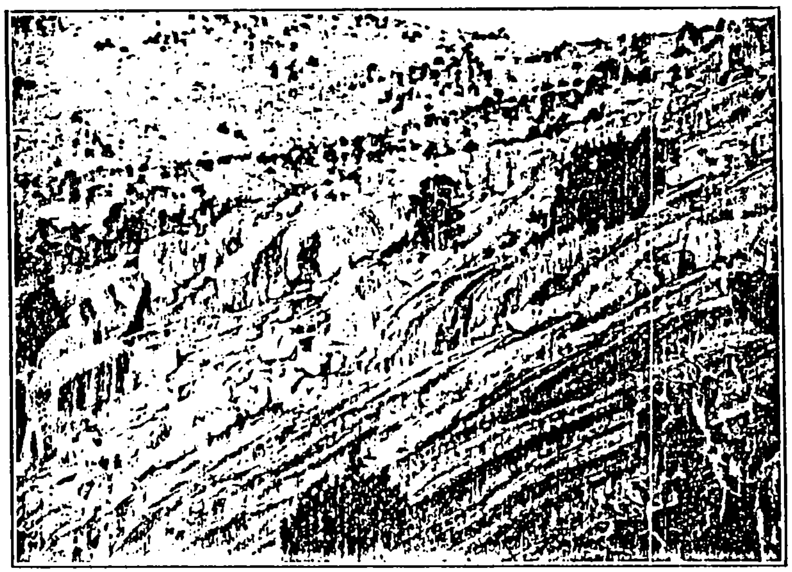


A. Medicine Bluff composed of Carlton granophyre. Maximum height of cliff 400 feet. (U. S. Army Air Service.)

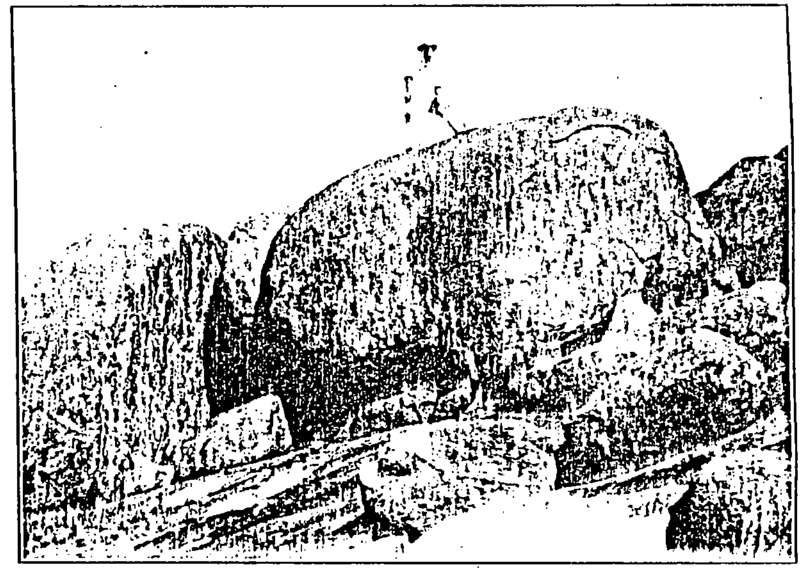


B. Lugert Granophyre intensely shattered, a mile southwest of Mount Pinchot. (D. B. Greene)

A. Typical weathering of Lugert Granophyre. (D. B. Greene.)



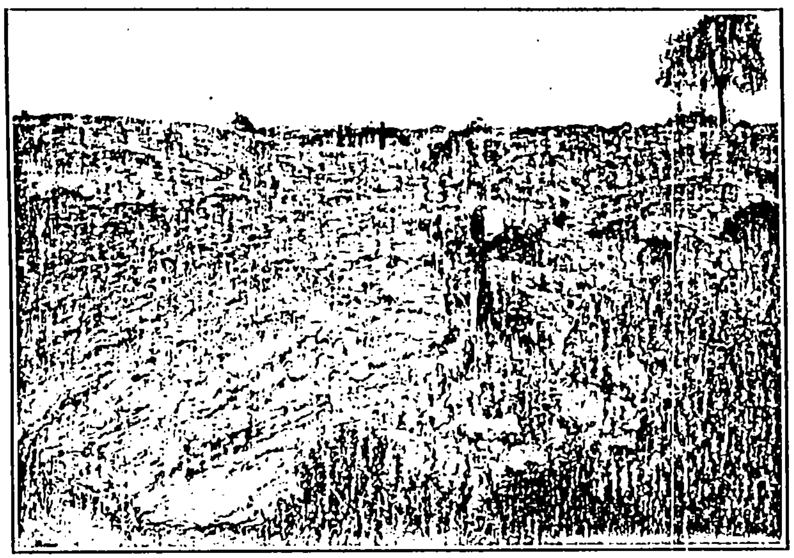
B. Weathering of Quanah granophyre on southeastern slope of McKinley Mountain.



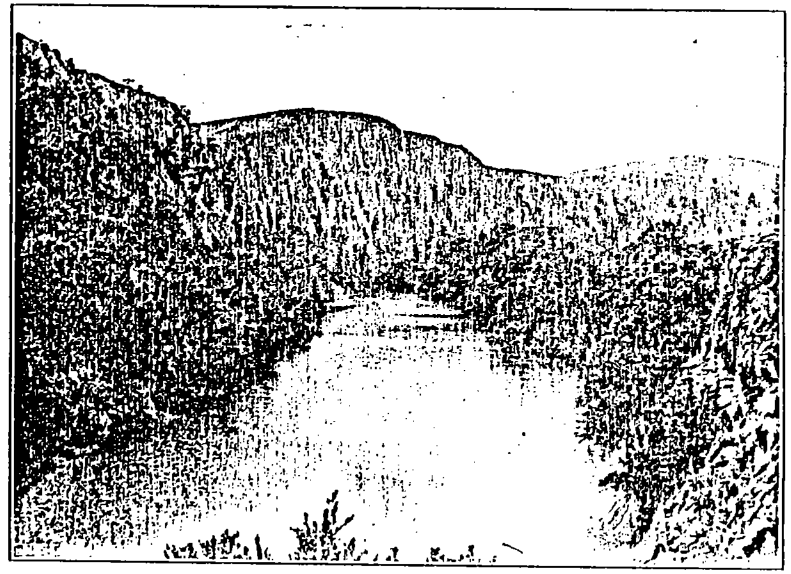
A. Close-up of Quanah granophyre showing exfoliation. Locality same as VI-B

B. Weathering of gabbro in Hazel quarry on eastern slope of Mt. Sheridan

A. General view of western portion of the Wichita Mountains. The lines of dense woods mark the joints. (U. S. Army Air Service.)

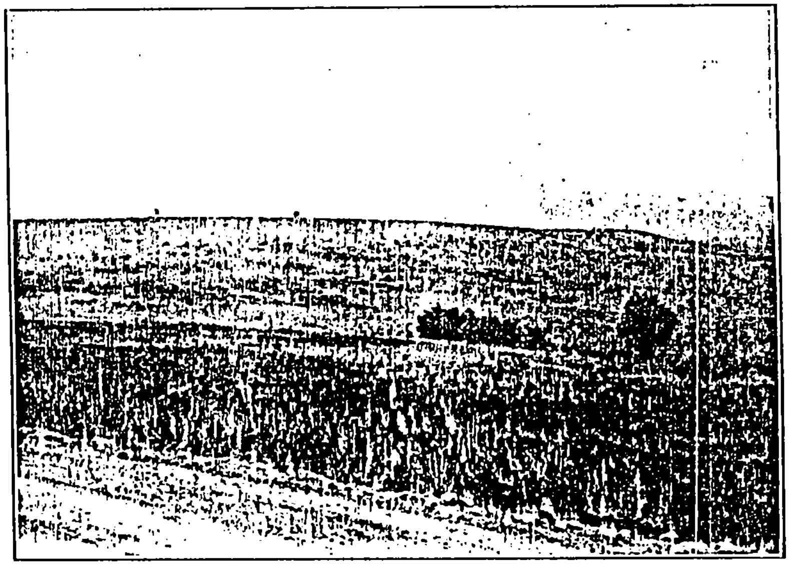


B. Contact of Lugert granophyre and Carlton porphyry at CNL SE¼ sec. 16, T. 3 N., R. 13 W. Trench oriented N. 70° W., granophyre on the left, porphyry on the right. (D. B. Greene.)

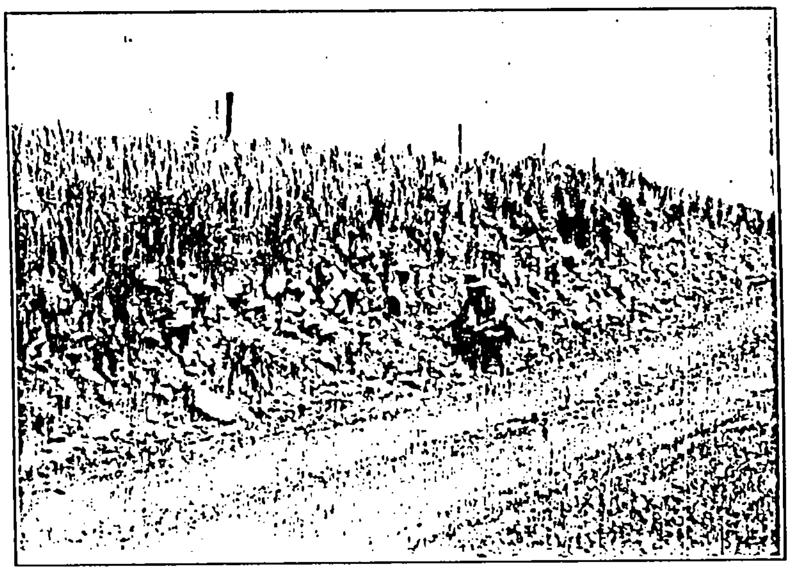


A. Medicine Bluff. Cliff 400 feet high. At lower right is remnant of original hill. (D. B. Greene.)

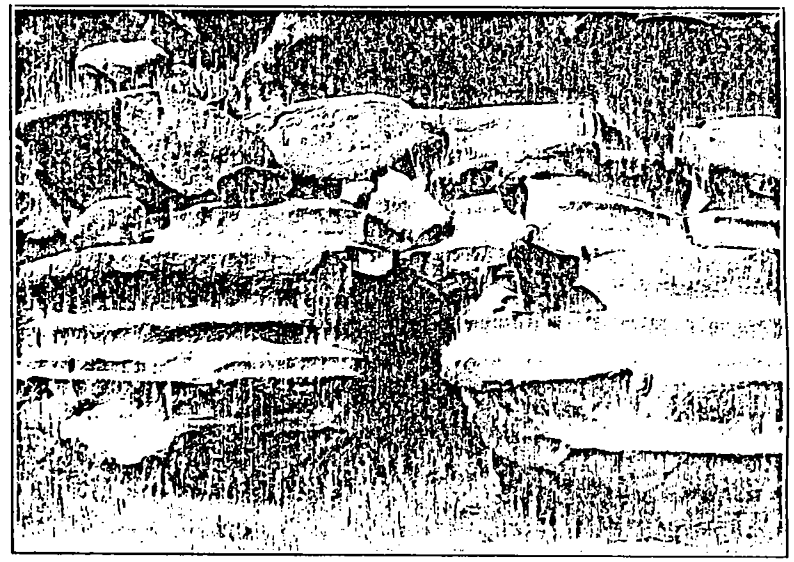
B. Vertical and cross joints in the Carlton granophyre, top of Medicine bluff



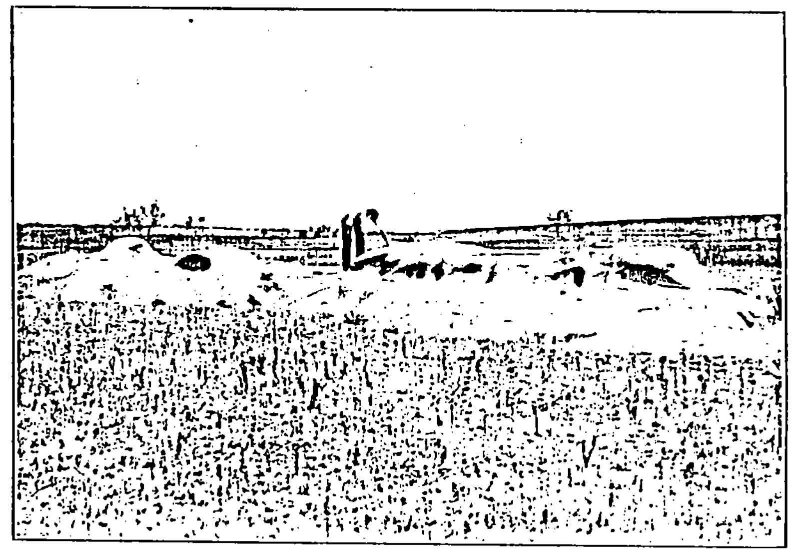
A. Gravel ridge two miles north of Mount Sheridan.



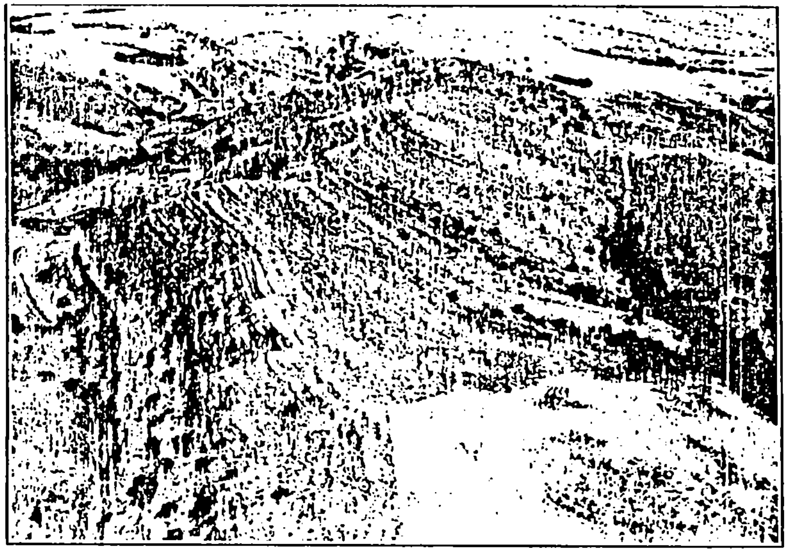
B. Gravel in road cut one-half mile east of Meers.



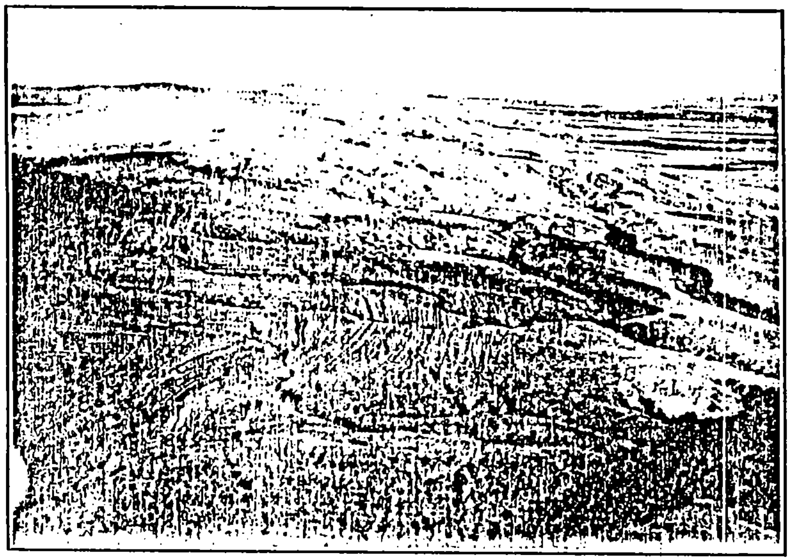
A. Grooves in granophyre six miles southwest of Hobart. The grooves can be followed back into reentrant. (D. B. Greene.)



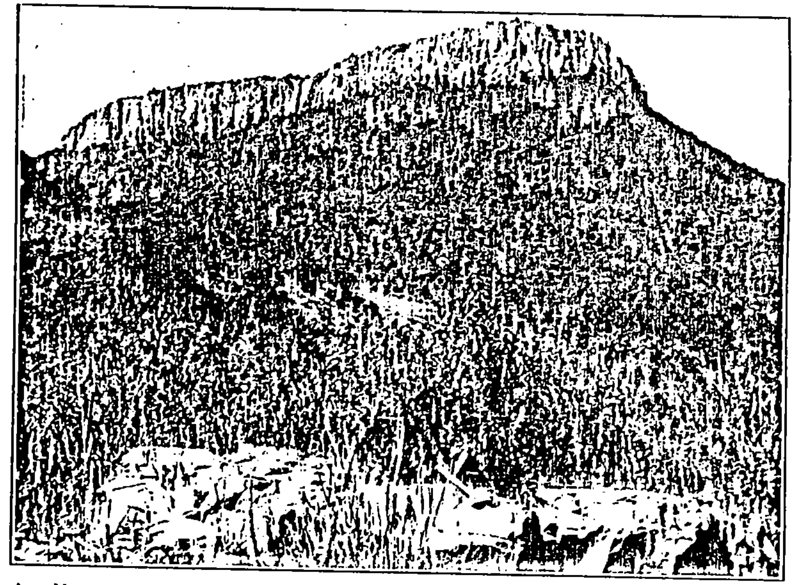
B. Solution cavities in granophyre which have been recently uncovered, six miles southwest of Hobart. (D. B. Greene.)



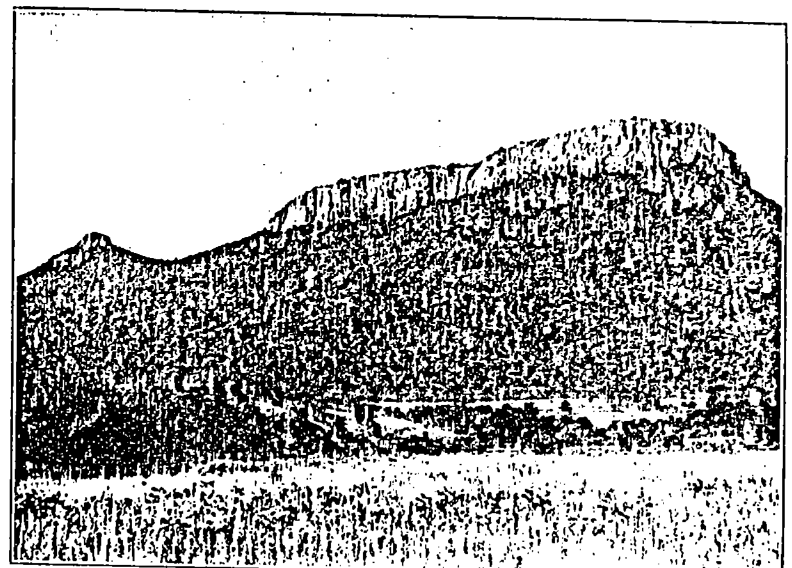
A. Valley at the left marks the contact between the Proterozoic porphyry and the Reagan sandstone. Limestone Hills, northeast Wichita Mountains. (U. S. Army Air Service.)



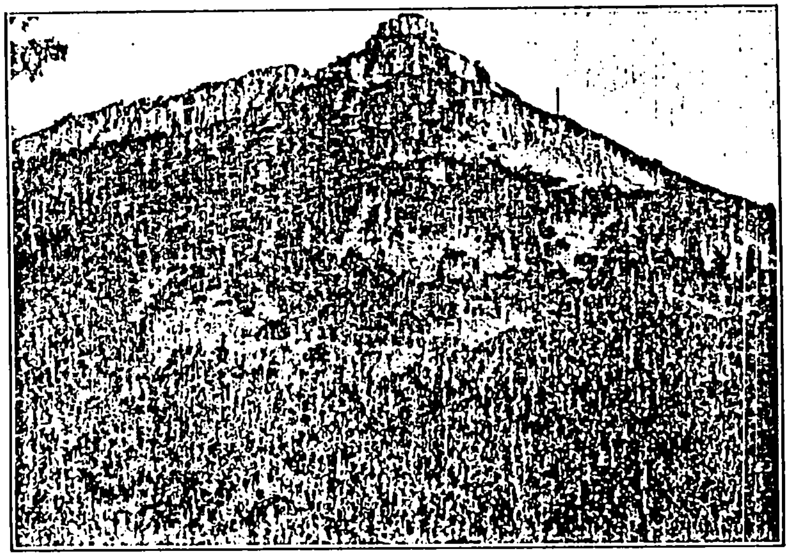
B. Aerial view of the Arbuckle limestone, Limestone Hills. (U. S. Army Air Service.)



A. Mount Sheridan from the northeast. Quartzite in the foreground, Lugert granophyre forming ridge in background, and gabbroic rock between. (D. B. Greene.)

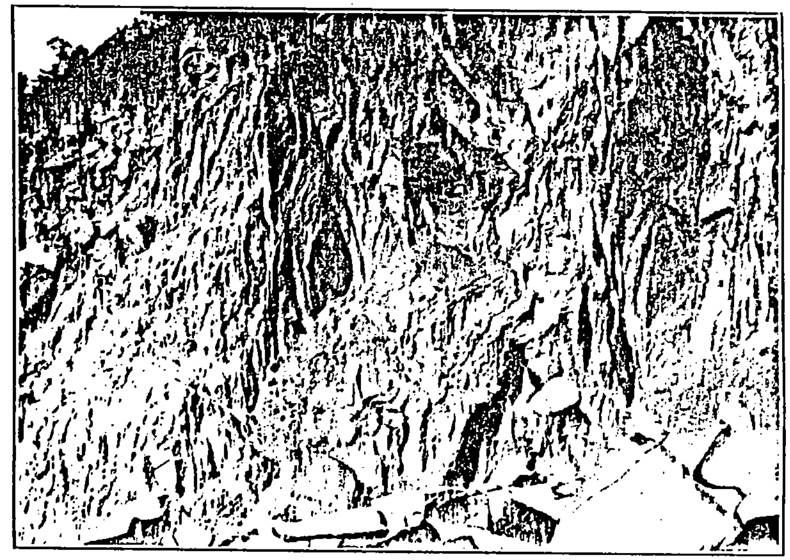


B. Northeastern slope of Mt. Sheridan. Knob at the left is of Lugert granophyre, completely surrounded by gabbro. (D. B. Greene.)

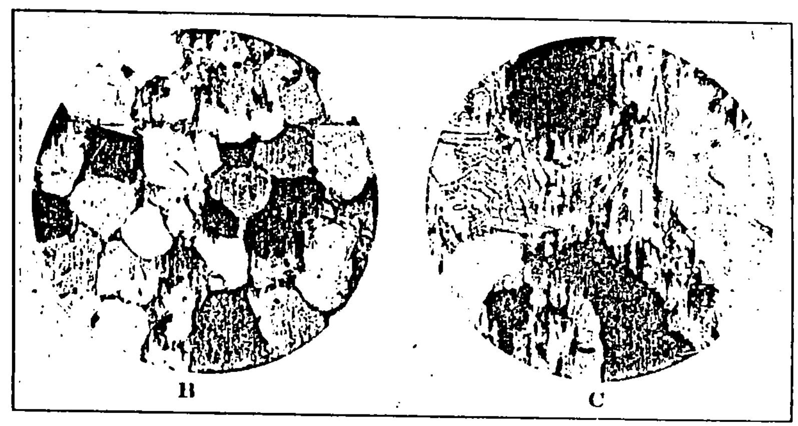


A. Closer view of knob shown in XIII-B. Quarry on slope is in gabbro. (D. B. Greene.)

B. Road cut ¾ mile south of Meers townsite. Diabase and acidic dikes cutting decomposed gabbro; diabase dike at left of picture; and acidic dike at right. (D. B. Greene.)



A. Hazel Quarry. Light streaks are acidic dikes cutting the gabbro. (D. B. Greene.)



B. Photomicrograph (x85) between crossed nicols. Quartzite included in the gabbro, from bed of Medicine Bluff Creek one-half mile southwest of old Meers townsite. Needles between the quartz grains are sillimanite.

C. Photomicrograph. Location same as B. Sillimanite needles in quartzite. (x85).

EXPLANATION OF PLATE XVI

A. Quartzite with granitic intrusion; from top of hill one mile northwest of Mt. Lauramac. Crossed nicols. (x53).

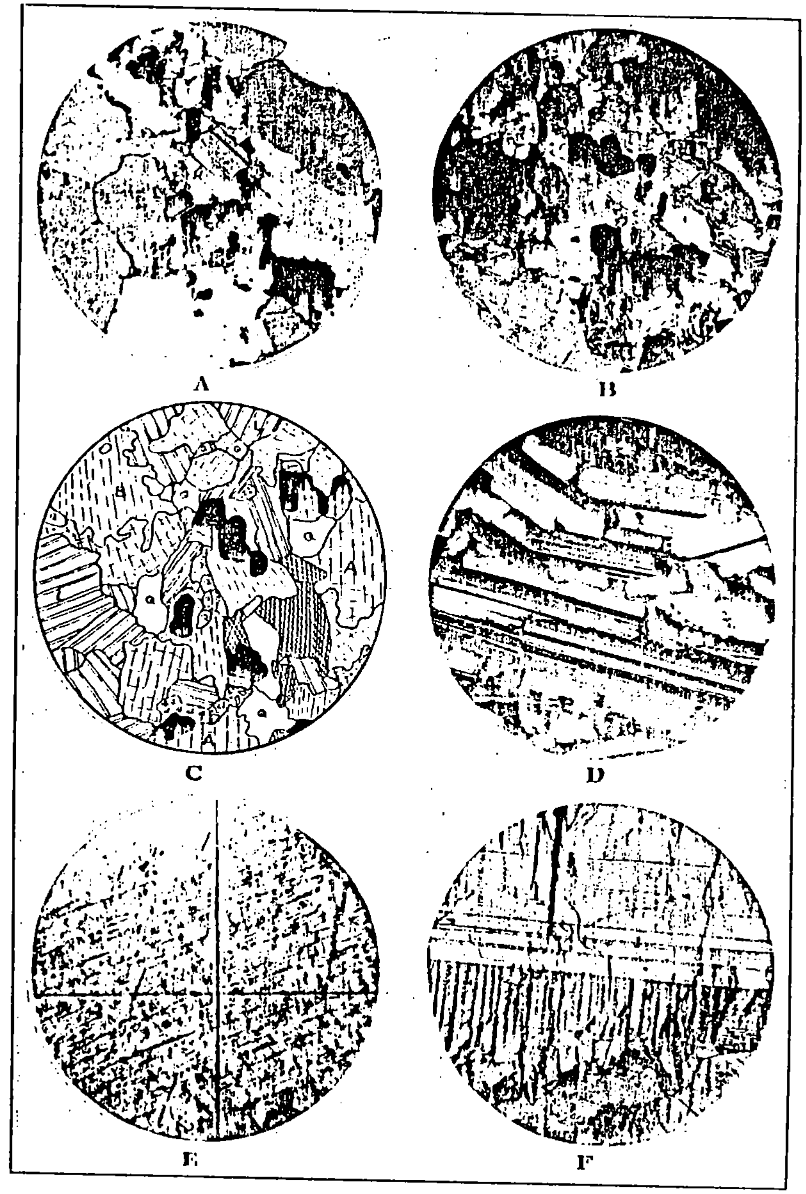
B. Photomicrograph of quartz gabbro from Hazel quarry on eastern slope of Mt. Sheridan. (x26).

C. Sketch of rock shown in B. A. augite; B. biotite; L. labradorite; Q. quartz; and solid black, magnetite.

D. Photomicrograph of anorthosite showing parallel texture; laths are labradorite, the interstitial mineral is diallage; from SW cor. sec 14, T. 4 N., R. 14 W. Crossed nicols (x26).

E. Photomicrograph showing small blades of titaniferous mica in labradorite. The blades are arranged in three sets oriented 60° to each other. (SE¼, NE¼ SW¼ sec. 16, T. 3 N, R. 14 W (x500).

F. Photomicrograph showing labradorite crystal in anorthosite-gabbro at northeastern base of Mt. Scott; it is twinned in three directions, according to Carlsbad, albite and pericline laws. Crossed nicols (x85).



EXPLANATION OF PLATE XVII

A. Photomicrograph of granogabbro from northwestern edge of northern gabbroid area. Crystal of diallage; upper rim is hornblende; lower rim is hornblende outside of which is a rim of biotite (x85).

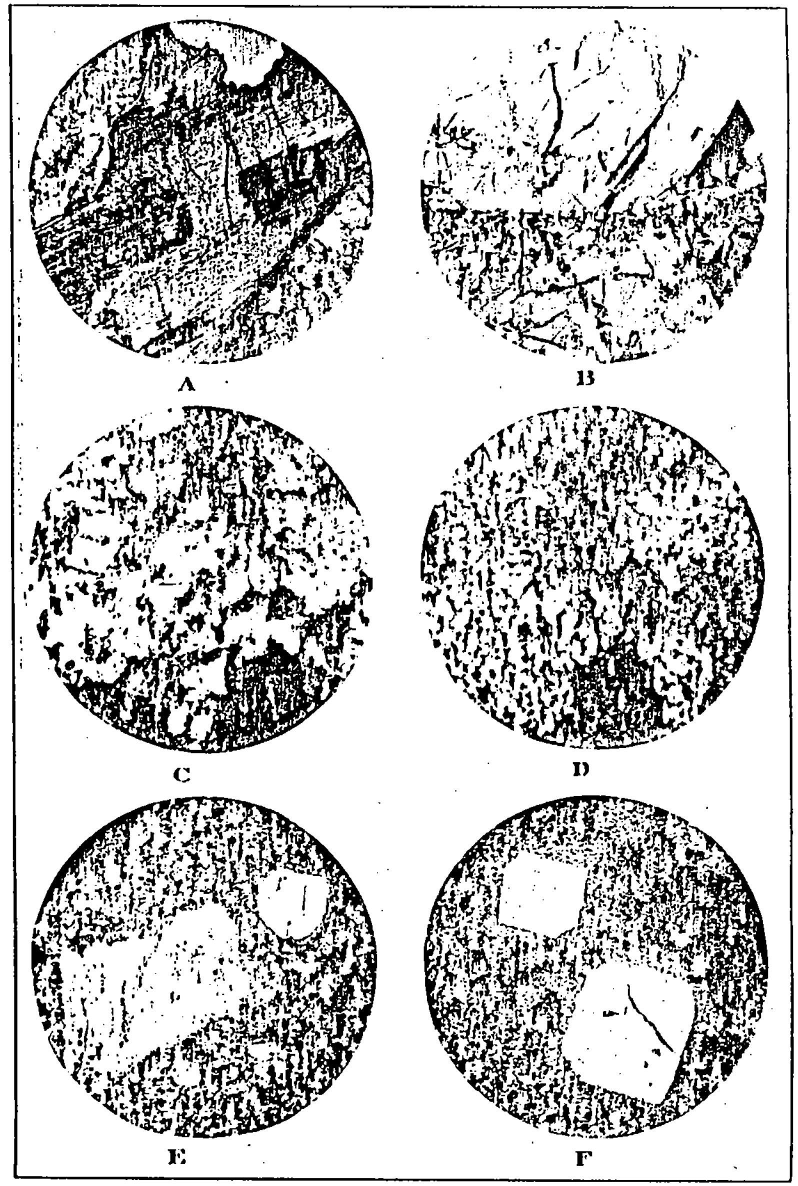
B. Photomicrograph of labradorite crystal fractured, and cut by granitic vein. Northeastern edge of central anorthosite-gabbro area. Crossed nicols (x85).

C. Photomicrograph of fine grained granophyre from northwestern slope of Davidson Hill. Crossed nicols (x85).

D. Photomicrograph of fine grained (Davidson) granophyre, one mile south of Cedar Creek planting. Crossed nicols (x85).

E. Carlton granophyre. Kaolinized orthoclase, and several quartz crystals in granophyric groundmass. Northeastern end of Jones Ridge. Crossed nicols (x16).

F. Carlton granophyre. Angular quartz crystals in granophyric groundmass. Eastern end of Medicine Bluff. Crossed nicols (x16).



EXPLANATION OF PLATE XVIII

A. Photomicrograph of Carlton granophyre, showing corroded quartz crystal. Northern base of Carlton Mt. Crossed nicols (x85).

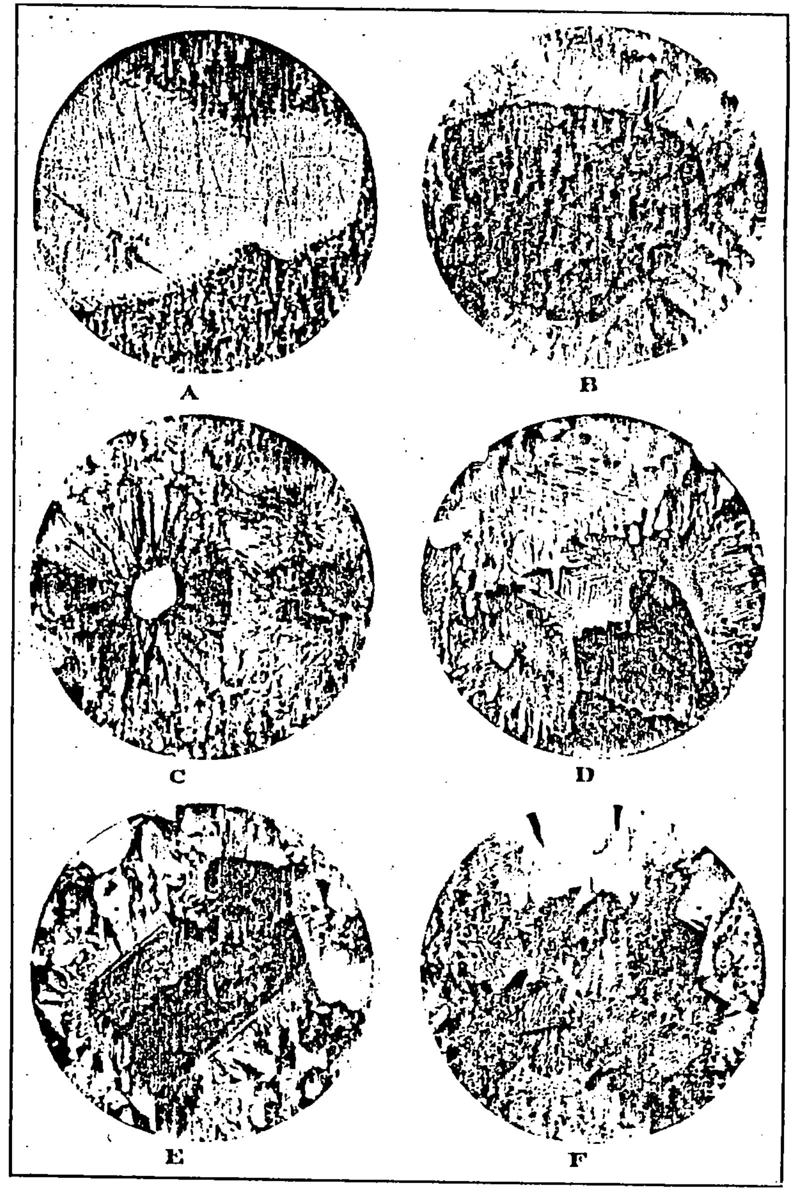
B. Photomicrograph of Saddle Mt. granophyre from NW.¼ NW.¼ sec. 36, T. 5 N., R. 15 W. Orthoclase crystal poikilitically including small grains of quartz, micropegmatite, and aegirite needles surrounded by a felty corona which grades into micropegmatite; needles in the corona are aegirite. Between crossed nicols (x53).

C. Photomicrograph of Saddle Mountain Granophyre. Felty corona about quartz. Black needles are aegirite. Location, one mile west of Saddle Mt. Corner. Crossed nicols (x85).

D. Lugert granophyre from southeastern nose of Welsh Hill at northea tern end of mountains. Crossed nicols (x10).

E. Photomicrograph of Carlsbad twin of orthoclase surrounded by micropegmatite. Lugert granophyre, from northeastern flank of Grace Mountain. Crossed nicols (x26).

F. Photomicrograph showing radial arrangement of micropegmatite. Lugert granophyre from extreme northwestern edge of mountains. Crossed nicols (x53).



EXPLANATION OF PLATE XIX

A. Photomicrograph of Lugert granophyre from southeastern end of Big Four Mt. Ferromagnesian mineral aggregate; magnetite (black) surrounded by rims of titanite and embedded in hornblende and biotite; small light gray and white grains are inclusions of quartz and orthoclase (x26).

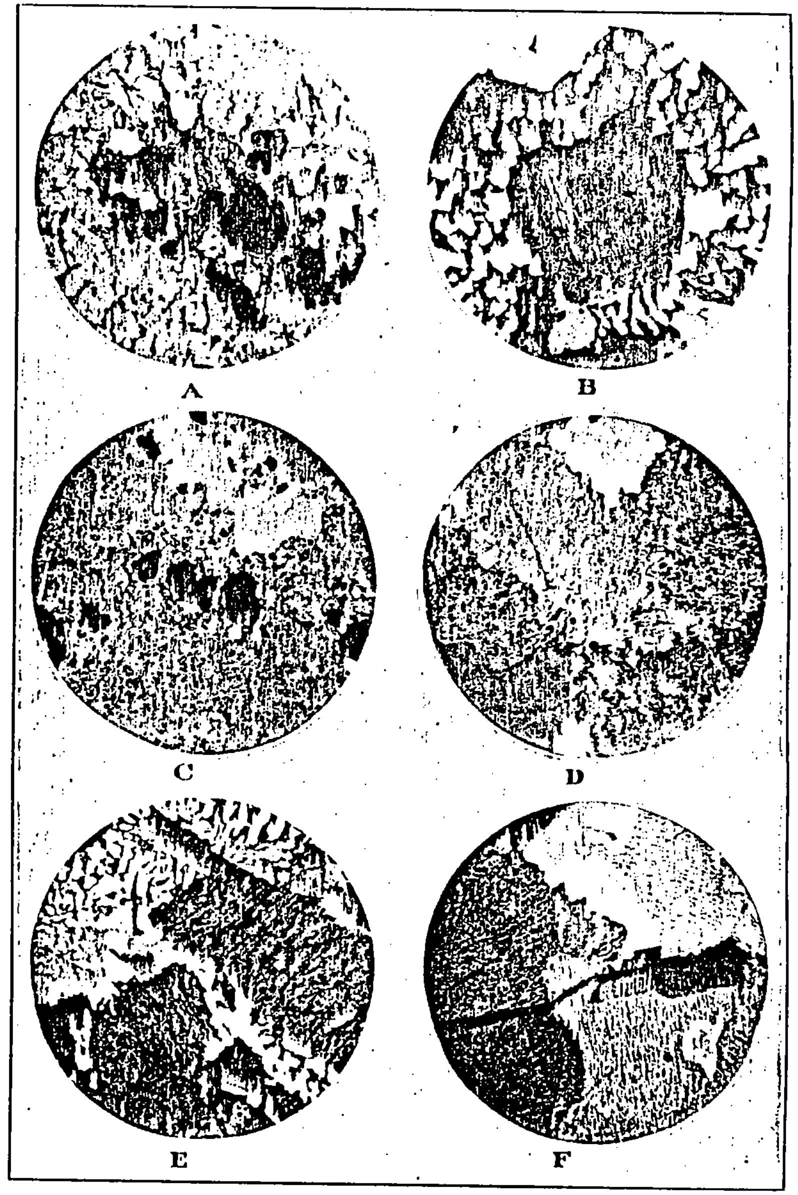
B. Photomicrograph of Lugert granophyre. from northeastern edge of Granme Flat. Oligoclase surrounded by orthoclase in micropegmatitic groundmass. Crossed nicols (x53).

C. Photomicrograph of Lugert granophyre. Magnetite (black) surrounded by grains of titanite. Two miles south of Mt. Sherman (x53).

D. Photomicrograph of Quanah granophyre from small exposure southwest of Granite Mountain. Quartz (smooth gray) and kaolinized microperthite (mottled gray) showing peculiar outlines of feldspar. Crossed nicols (x26).

E. Photomicrograph showing kaolinized microperthite crystals surrounded by micropegmatite. Quanah granophyre near contact with the Lugert, from southern edge of Sunset Peak. Crossed nicols (x26).

F. Quanah granophyre from southeastern edge of Charons Garden Mts. Light gray is quartz, mottled gray is microperthite. Carlsbad twin of microperthite at the left. Crossed nicols (x16).



EXPLANATION OF PLATE XX

A. Photomicrograph of Quanah granophyre. Location same as XIX-F. Riebeckite crystal surrounded by quartz and kaolinized feldspar (x26).

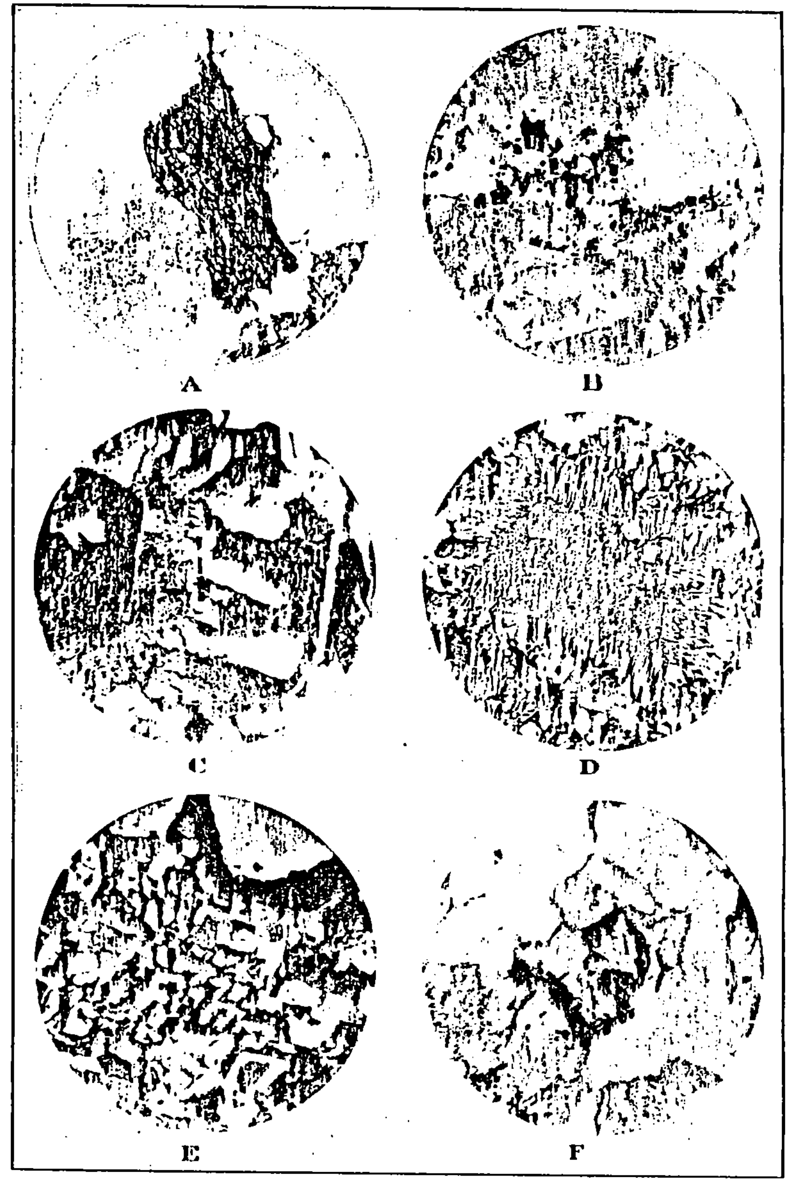
B. Photomicrograph of Quanah granophyre, from southwestern slope of McKinley Mt. Magnetite (black), quartz (smooth gray), intergrown with kaolinized feldspar (mottled gray) (53).

C. Photomicrograph of Quanah granophyre from locality one mile southeast of Bat Cave Mountains. Crossed nicols (x26).

D. Photomicrograph showing granophyric texture of acidic dike which cuts the gabbro in Hazel quarry. Crossed nicols (x26).

E. Photomicrograph showing granophyric texture of acidic dike in road cut ⅜ mile south of Meers townsite. Crossed nicols (x30).

F. Photomicrograph showing sagenite web in biotite, in acidic dike. Location same as E (x85).



EXPLANATION OF PLATE XXI

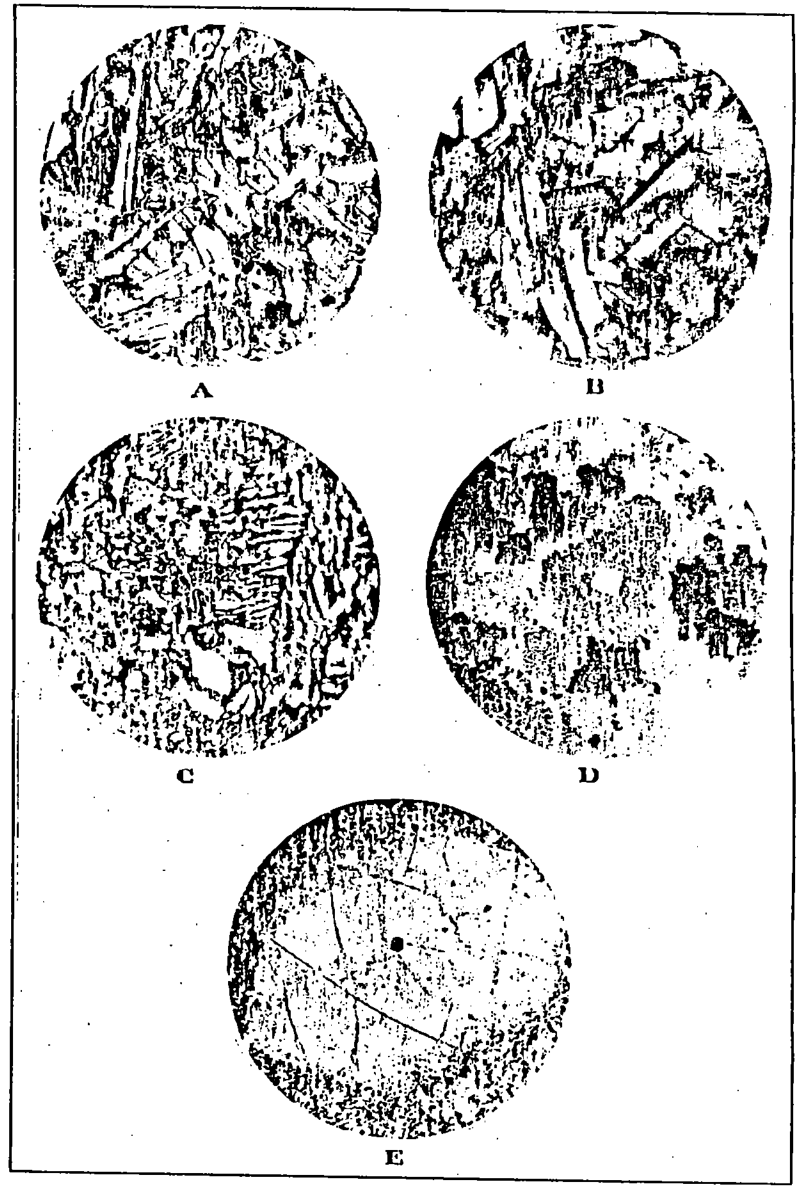
A. Photomicrograph of diabase dike cutting the gabbro ¾ mile south of Meers townsite. Labradorite laths in augite; black mineral is magnetite. Crossed nicols (x40).

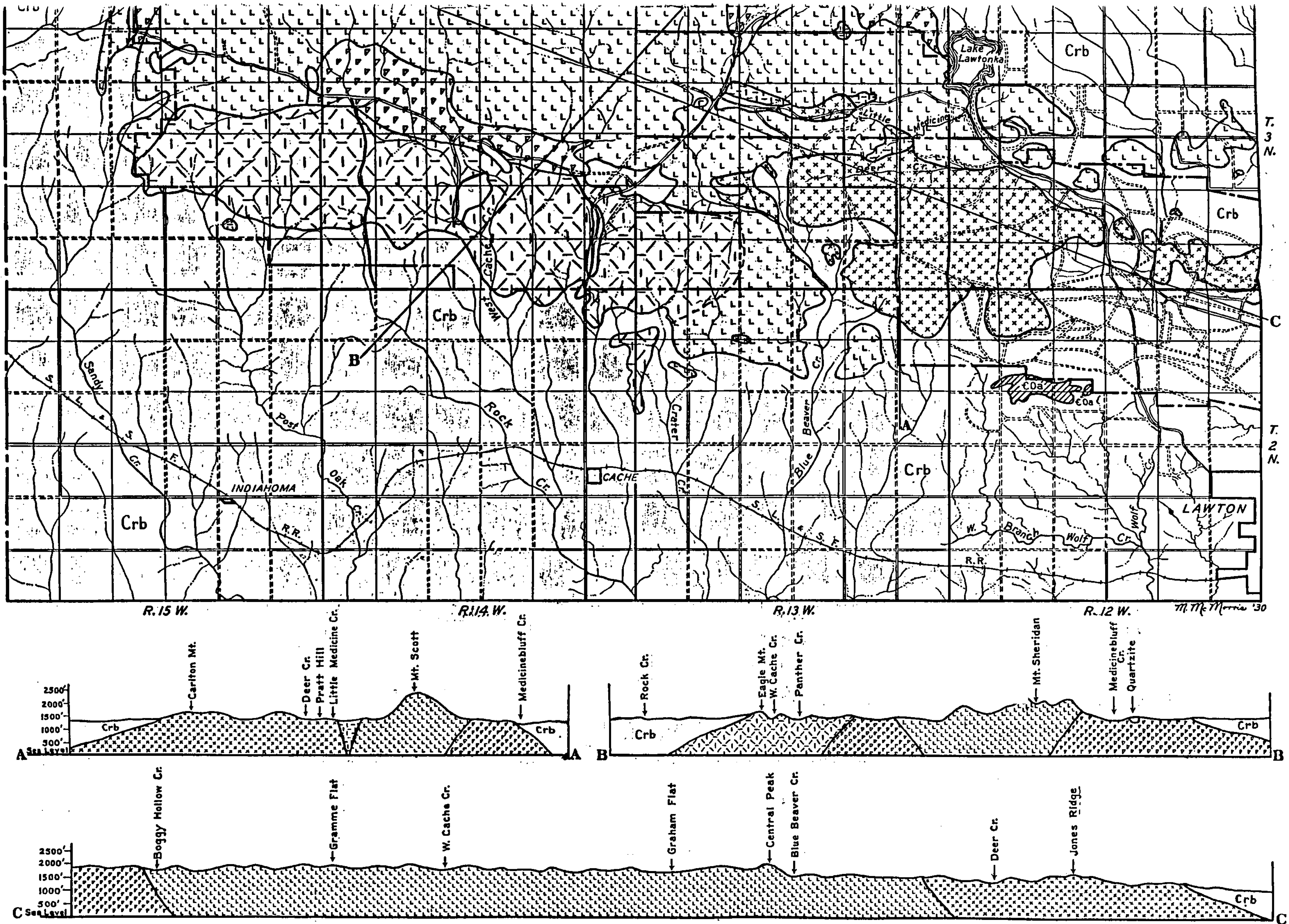
B. Photomicrograph of diabase dike in Lugert granophyre north of Haystack Mt. Laths are labradorite; other mineral is augite partially altered to uralite and chlorite. Between crossed nicols (x40).

C. Photomicrograph showing granophyric texture of aplite dike cutting Quanah granophyre on western slope of Quanah Mountain. Crossed nicols (x53).

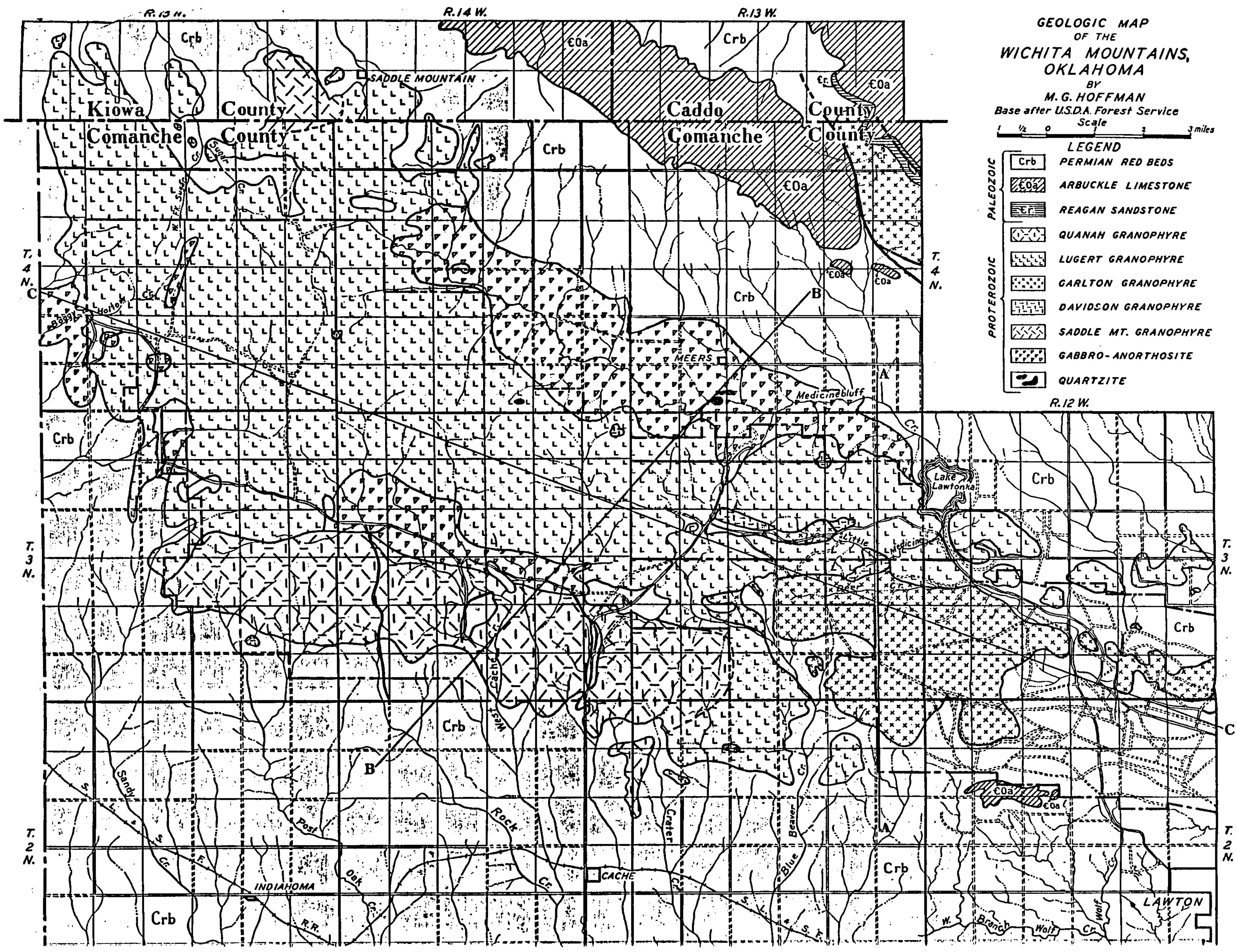
D. Photomicrograph of quartz dike from southeastern end of Medicine Bluff. Crossed nicols (x26).

E. Photomicrograph of quartz crystal surrounded by dike quartz. Optical orientation of both alike. Crossed nicols (x85). Locality same as D.





Crb
Lake Lawtonka
Little Medicine Cr.
Deer Cr.
West Cache Cr.
Sandy Cr.
Post Oak Cr.
Rock Cr.
Crater Cr.
Blue Beaver Cr.
W. Branch Wolf Cr.
Wolf Cr.
INDIAHOMA
CACHE
LAWTON
R.R.
COa
T. 3 N.
T. 2 N.
R. 15 W.
R. 14 W.
R. 13 W.
R. 12 W.
M. McMorris '30
A
B
C
Carlton Mt.
Deer Cr.
Pratt Hill
Little Medicine Cr.
Mt. Scott
Medicinebluff Cr.
Rock Cr.
Eagle Mt.
W. Cache Cr.
Panther Cr.
Mt. Sheridan
Medicinebluff Cr.
Quartzite
Boggy Hollow Cr.
Gramme Flat
W. Cache Cr.
Graham Flat
Central Peak
Blue Beaver Cr.
Deer Cr.
Jones Ridge
2500'
2000'
1500'
1000'
500'
Sea Level



GEOLOGIC MAP
OF THE
WICHITA MOUNTAINS,
OKLAHOMA
BY
M. G. HOFFMAN
Base after U.S.D.A. Forest Service
Scale
1 ½ 0 1 2 3 miles
LEGEND
PALEOZOIC
PROTEROZOIC
Crb PERMIAN RED BEDS
€0a ARBUCKLE LIMESTONE
€r REAGAN SANDSTONE
QUANAH GRANOPHYRE
LUGERT GRANOPHYRE
CARLTON GRANOPHYRE
DAVIDSON GRANOPHYRE
SADDLE MT. GRANOPHYRE
GABBRO-ANORTHOSITE
QUARTZITE
R.15 W.
R.14 W.
R.13 W.
R.12 W.
T. 4 N.
T. 3 N.
T. 2 N.
Kiowa County
Comanche County
Caddo County
Comanche County
SADDLE MOUNTAIN
MEERS
Medicinebluff
Lake Lawtonka
Little Medicine Cr.
Bee Cr.
West Cache Cr.
Sandy Cr.
Post Oak Cr.
Rock Cr.
Crater Cr.
Blue Beaver Cr.
W. Branch Wolf Cr.
Wolf Cr.
INDIAHOMA
CACHE
LAWTON
S. L. & S. F. R.R.
Crb
€0a
A
B
C