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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

PRELIMINARY REPORT

ON THE

GEOLOGY OF THE ARBUCKLE AND WICHITA MOUNTAINS IN INDIAN TERRITORY AND OKLAHOMA

BY

JOSEPH A. TAFF

WITH

AN APPENDIX ON REPORTED ORE DEPOSITS OF THE WICHITA MOUNTAINS

BY

H. FOSTER BAIN

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GEOLOGY OF THE WICHITA MOUNTAINS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C., February 6, 1904.

Sir: I transmit herewith the manuscript of a report on the geology of the Arbuckle and Wichita mountains, of Indian Territory and Oklahoma, by J. A. Taff, with an appendix on the reported ore deposits of the Wichita Mountains, by H. F. Bain, and recommend that these reports be published as a professional paper. They are of special interest at the present time in connection with the active search for deposits of precious metals in this region, and contain much valuable information which should be of material assistance to the prospector.

Very respectfully,

C. W. Hayes,
Geologist in Charge of Geology.

Hon. Charles D. Walcott,
Director United States Geological Survey.

PRELIMINARY REPORT ON THE GEOLOGY OF THE ARBUCKLE AND WICHITA MOUNTAINS.

By Joseph A. Taff.

GEOLOGY OF THE ARBUCKLE MOUNTAINS.

INTRODUCTORY REMARKS.

The Arbuckle Mountains consist of a moderately elevated table-land or plateau in the east-central part of the Chickasaw Nation, Indian Territory. The plateau ranges in elevation from 1,300 feet above sea, in its contracted western part, to 750 feet, at the east end, where it coalesces with the bordering plain.

Geologically the Arbuckle Mountain region consists of a great thickness of rocks, composed chiefly of limestones, which range in age from middle Cambrian to Devonian, and which are succeeded on the borders by an almost equal thickness of Carboniferous conglomerates, shales, and sandstones. In the central part of the district, unconformably beneath the Cambrian strata, there is a mass of granite, granite-porphyry, diabase, and associated crystalline rocks. The uplifting and folding of the region occurred previous to the deposition of the Permian "Red Beds," which were deposited across it on the west. The bearing of the Arbuckle uplift is approximately N. 70° W.

Sixty miles to the northwest are the Wichita Mountains, in southeastern Oklahoma, which are physiographically in marked contrast to the Arbuckle Plateau, being composed of a range of rugged mountains and straggling peaks and hills, set in a practically level plain. The Wichita uplift bears in approximately the same direction as the Arbuckles, N. 70° W. It consists of a central mass of igneous rocks which is partially surrounded, unconformably, by a thick section of Cambrian and Ordovician sandstone and limestone. The stratigraphy is in all essential respects a repetition of that of the Arbuckle uplift, as far as could be determined from the rock exposures. The outline map (fig. 1, p. 12) shows the geographic relations of the Arbuckle and Wichita mountains. Because of the close stratigraphic, lithologic, and structural relations of the two regions discussions of their geology may with propriety be brought together in a single report.

The name Arbuckle Mountains, as used in this report, includes the elevated country involved in the Arbuckle Mountains uplift. The name as it is used locally is applied to the higher western part of the uplift, chiefly west of Washita River. Full exposures of all the older Paleozoic strata which are found in the more elevated western part occur also in the eastern part surrounding a core of igneous rock. Devonian and Carboniferous rocks are involved in the uplift, but lie chiefly in a lower plain bordering the mountainous district. Across the northwestern part of the Arbuckle Mountains are late Carboniferous and Permian strata, which are separated from the older rocks by a great unconformity.

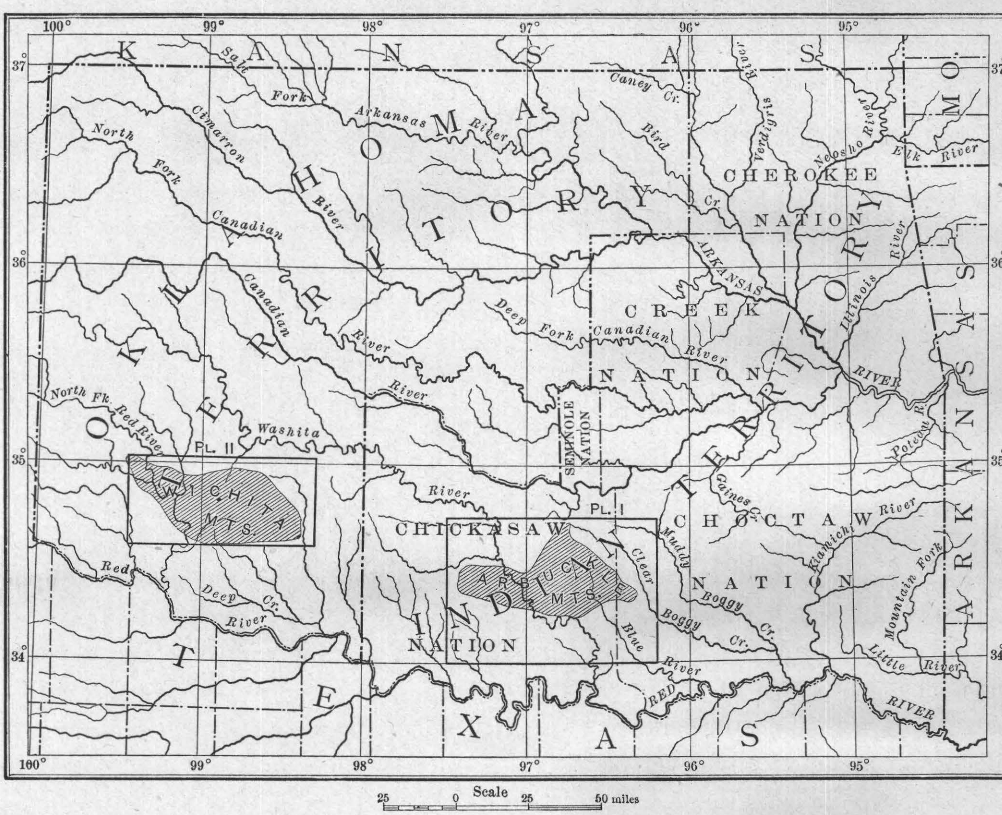


FIG. 1.—Outline map of Indian Territory and Oklahoma Territory, showing locations of Arbuckle and Wichita mountains and boundaries of mapped areas.

Cretaceous strata also lap across the southeastern and southwestern sides of the uplift. A brief discussion of the Carboniferous and Cretaceous geology is also included in this report.

The geology of the Atoka and Tishomingo quadrangles has been studied in detail, and the results have been published in folios 79 and 98 of the Geologic Atlas of the United States. These quadrangles extend from longitude 96° to 97° and from latitude 34° to 34° 30′, and include the eastern and central parts of the

Arbuckle region. The remaining portions of the region, included in the southern half of the Stonewall and the northern three-fourths of the Ardmore quadrangles, have been surveyed in special reconnaissances. In this work the formation boundaries were traversed and mapped, and the rocks have been studied in the light of the classification already established in the survey of the adjoining Tishomingo and Atoka quadrangles.

Dr. G. H. Girty and Mr. E. O. Ulrich collected and studied fossils in cooperation with the stratigraphic work. Without their assistance accurate mapping could not have been accomplished in much of the area.

Large collections of fossils were made from all the limestone formations above the Cambrian. Less abundant faunas occur in the basal Cambrian sandstone, in the Sylvan shale of the Silurian, in the Devonian chert, and in the Carboniferous rocks, yet the fossils are ample for rock classification. These collections are in hand for study preparatory to a monographic report. The classification of the pre-Carboniferous Paleozoic rocks and faunas was made by Mr. Ulrich. Dr. G. B. Richardson and Dr. George I. Adams assisted in the survey of that part of the Arbuckle uplift which is included in the Atoka quadrangle. A large part of the survey of the Tishomingo quadrangle is the work of Mr. Sydney H. Ball.

PHYSIOGRAPHY OF THE ARBUCKLE MOUNTAINS.

GENERAL TOPOGRAPHIC FEATURES.

When considered in a broad sense the Arbuckle Mountain district is coextensive with the area in which rocks older than the Devonian are found. So considered it forms a rudely triangular area approximately 30 miles upon each side, with an arm extending westward from the southwest corner. It is longest from northwest to southwest, which is the general direction of the uplift. The boundaries of the region mark only in part the limits of the uplift. Since the region was uplifted late Carboniferous and Cretaceous rocks have been deposited across it and now conceal the older rocks by unconformable overlap toward the northwest and southeast. The Cretaceous strata upon the southeast dip toward the southeast, and the Carboniferous on the opposite side dip toward the northwest. As erosion progresses these overlapping deposits which once covered the region recede, giving a continually broader section across the uplift. Previous to the deposition of the Cretaceous the older rocks in the region of the uplift were worn down nearly to a flat plain. Since the Cretaceous strata have been removed this plain has been preserved as a low plateau in the harder rocks of the central part of the uplift, while the softer strata upon the sides have been eroded to lower levels. Thus the central part of the uplift which is here termed the Arbuckle Mountain district remains as a low southeastwardly inclined plateau, with distinct escarpments facing northeast and southwest. The western part of the Arbuckle Mountains reaches an elevation of about 1,350 feet and is 400 feet above the plains on each side. The grade of the Arbuckle Plateau toward the southeast is greater than that of the bordering plain. As a result the two plains intersect along the Cretaceous contact on the southeast side. On the northwestern side the thick deposits of Carboniferous conglomerate and "Red Beds" sediments continue away to the northwest, making the broad plain which passes to and around the Wichita Mountains. The descent from the Arbuckle Mountains westward to this plain is inconsiderable. Toward the southeast the Cretaceous plain extends with slight change of grade from the Arbuckle district toward the Gulf coast.

The minor topographic details of the Arbuckle Mountains are due chiefly to the varying resistance of the formations, which has resulted in differential erosion since the removal of the Cretaceous rocks. Bordering the mountains upon the southwest side are five formations extending from the Ordovician to the basal formation of the Carboniferous, which are composed of hard limestones and soft shales steeply upturned and dipping toward the southwest. The Sycamore, Hunton, and Viola limestones, the first, third, and fifth formations, respectively, from above, are hard rocks making level-topped narrow ridges with their crests nearly in the level of the Arbuckle Mountain plain. Between these limestone ridges the softer Woodford chert of the Devonian and the Sylvan shales of the Silurian outcrop in wooded valleys. On the northeastern side of the district are similar ridges made by the same formations, excepting the Sycamore limestone. Between these belts of alternating ridges and valleys and toward the axial part of the uplift the broad plateau proper of the Arbuckle Mountains is chiefly in the truncated edges of the Cambro-Ordovician limestone and the reduced pre-Cambrian granite and porphyry. In the more elevated part of the uplift the small streams, because of their steep grades, have etched the border of the plateau into a frill of deep, short gulches. This border erosion is especially marked near the gorge of Washita River where it crosses the Arbuckle Mountains. Washita River was, without doubt, imposed upon the rocks of the Arbuckle Mountains from a former position in strata which are now removed. The explanation of this river erosion in the Arbuckle Mountains as a part of the physiographic history of the uplift will be discussed below.

HISTORY OF THE PHYSIOGRAPHIC FEATURES.

In the Arbuckle Mountains the rocks from the middle Cambrian, the lowest known in the region, up to middle Carboniferous, which were formed previous to and are involved in the uplift, are well exposed. The general physiographic history is learned from the extensive Coal Measures conglomerate in the northwest and southwest sides of the region, the later "Red Beds" conglomerate across the west end, and the Cretaceous sediments across the southeastern side of the uplift. Only a brief discussion of this history can be given in this paper.

From Cambrian time up to middle Carboniferous the stratigraphic succession is regularly conformable, showing that the rock beds remained practically flat during successive periods. There were probably oscillations which brought the sediments to the surface of the water at times, and gave occasion for slight erosion, which will be described in the discussion of the stratigraphy. About the middle of the Carboniferous period, near the beginning of Mississippian time, the rocks of the Arbuckle Mountain region were uplifted and folded, and mountainous conditions resulted. During and following the uplift and before the end of Carboniferous time the mountains, so far as can be observed, were worn down to moderate relief. During this time thick deposits of limestone conglomerates, derived from the Silurian, Ordovician, and Cambrian rocks toward the heart of the uplift, were laid down in the bordering Carboniferous seas. As erosion progressed, during late Carboniferous time folding and faulting occurred, as is shown by the infolding and faulting of some of the earlier Carboniferous conglomerates with older Paleozoic strata. Remnants of this Carboniferous conglomerate occur in the present Arbuckle Plateau in a number of places and conceal the whole northwestern extension of the uplift. The nearly flat limestone conglomerate, grits, and clays of the basal portion of the "Red Beds" rest unconformably upon the Coal Measures conglomerate and across the extreme western end of the Arbuckle Mountains. Between the Permian and the Cretaceous there is no record of sedimentation, and it is presumed that land conditions prevailed.

Development of the Arbuckle Plateau.—The basal formation of the lower Cretaceous lies across the southeastern side of the Arbuckle uplift, on a nearly smooth floor, composed of granite and interstratified with thick and hard limestone and thinner limestone, sandstone, and shale formations. This formation, which is slightly inclined toward the southeast, is composed of the beach and near-shore deposits of the Cretaceous sea, which transgressed northward and most likely beyond the region of the Arbuckle Mountains. The nature of these deposits of the Cretaceous and of the flat floor upon which they rest suggests strongly that the land upon which the Cretaceous sea advanced had been reduced to a low peneplain. Whatever the condition of the pre-Cretaceous land, it appears that the Cretaceous degradation reduced all the rocks from the soft shales of the Carboniferous to the massive hard limestones of the Cambro-Ordovician and the granite to a nearly flat plain. The basal Cretaceous formation was rapidly eroded toward the south, in the direction of the drainage and of the dip of the strata. After these sands were removed from the rock floor of varying hardness on which they had been deposited, differential erosion produced the topographic forms of the Arbuckle Mountains and the bordering parallel hills and valleys and etched plateau. The plain of the Arbuckle Mountains when projected southward passes beneath the Cretaceous sediments, approximately in the Cretaceous floor.

As the soft Cretaceous rocks above the Arbuckle uplift were removed the streams which flowed in them without obstruction toward the south descended and were imposed upon the hard rocks of the Cretaceous floor. Thus Mill and Pennington creeks and Blue and Washita rivers were imposed upon the Arbuckle Mountains. As Mill and Pennington creeks and Blue River are near the eastern end of the uplift from which the Cretaceous was last removed, and do not flow beyond the limits of the Arbuckle Plateau, they have wide, shallow valleys, extending southward in Paleozoic and Cretaceous strata with very slight increase in grade. Washita River, however, flows in a lower plain for long distances in the soft rocks before reaching and after its passage through the Arbuckle Mountains. These soft rocks were worn down more rapidly than the hard limestones, and the river was required to keep pace in cutting its deep and narrow gorge across the Arbuckle Mountains.

Peneplain of probable Tertiary age.—Toward the northeast and southwest there is a descent of 100 to 400 feet from the plateau in the Arbuckle Mountains to the general level of the plain formed upon the softer Carboniferous rocks. The erosion which produced this lower plain has uncovered and obliterated a large part of the marine Cretaceous plain northeast and southwest of the Arbuckle district. Southeastward, in the general direction of the drainage toward the Gulf of Mexico, this plain descends approximately with the grade of the rivers. Along these river valleys there are elevated remnants of old channels slightly below the level of the plain. They contain deposits of gravel and sand, similar to the material transported by the river at the present time.

These deposits occur upon the worn surfaces of Carboniferous, Cretaceous, and early Tertiary rocks. Upon approaching the Tertiary border in southwestern Arkansas and eastern Texas these gravel deposits become more abundant and finally come to an end or descend beneath latest Tertiary deposits bordering the Gulf coast. Farther toward the northeast these elevated shallow and wide river channels lying nearly in the peneplain have been studied and mapped, along Canadian and Arkansas rivers, from the western border of the Creek Nation to the Arkansas line in Indian Territory. This peneplain stretches westward into Oklahoma and northward across Indian Territory. It has a lower inclination toward the southeast than the marine Cretaceous plain represented in the Arbuckle Plateau. Northward the horizon of the latter plain projects above the land, while the former continues nearly flat and is now preserved throughout southern and central Indian Territory in almost innumerable level-crested ridges and hills. These ridges and hills are supported usually by beds of hard rock, and their crests occur at elevations approximating 850 feet. Outside the mountainous regions there are few hills which rise above this general level. These are usually table-like and are protected by flat and hard strata.

In the eastern part of Indian Territory the Ouachita Mountains rise above this plain, as do also certain isolated mountains in Arkansas Valley. In the Ouachita Mountains this peneplain is represented by wide, flat valleys which have been produced upon the softer rocks. In Arkansas Valley the mountains which rise above the plain are limited areas where the rocks occur in broad, synclinal folds containing the harder and thicker sandstone strata. These mountains rise above the plain, as monadnock-like eminences and peaks, to elevations of 1,700 to 2,500 feet above the sea. The wide distribution of the surficial deposits connected with old river channels, but slightly depressed below the peneplain, their relations to the more abundant gravel deposits near the Tertiary, as already described, and the widespread degradation of the hard and soft rocks to the same general level support the hypothesis that the surface nearly reached sea level at the time of its reduction to the peneplain stage.

Recent peneplanation in the broad valleys.—It would appear that since the formation of the probable Tertiary peneplain the land has been tilted slightly toward the southeast. In support of this it is observed that the larger streams have descended in softer strata to depths approximating 200 feet below the general level of the Tertiary peneplain, cutting for themselves wide and flat valleys. These wide valleys may be considered to form rudely a lower peneplain representing the present stage of erosion. The smaller streams tributary to the large creeks and rivers have steeper grades, especially toward their sources, and occupy various levels between two peneplains.

STRATIGRAPHY OF THE ARBUCKLE MOUNTAINS.

IGNEOUS ROCKS (PRE-CAMBRIAN).

Igneous rocks are exposed in three areas in the Arbuckle uplift. The largest of these in the eastern portion is composed, for the most part, of granite, of a small amount of rocks related to granite, and of intrusive dike rocks, chiefly diabase. The other two areas, which are situated near each other in the western part of the mountains, are composed of granite-porphyry and aporhyolite, containing also basic dikes. The granite occurs in the extreme southeastern side and is partially concealed by the lower Cretaceous sediments which lie across this portion of the Arbuckle region. It occurs in a rudely triangular area about 20 miles in length and 10 miles in width at its broadest part, near the western end. It is overlain across the western end and at a few points upon the northern side by middle Cambrian, the oldest stratified rocks of the region. Throughout the northern side, with two exceptions, the granite comes in contact with the sedimentary rocks along lines of faulting.

The two porphyry areas occur in the Arbuckle Mountains proper, near the western part of the uplift. Like the granite, the porphyry upon the western and southwestern sides is overlain by the middle Cambrian sediments, and upon the eastern and northeastern sides it comes in contact with the sedimentary rocks along lines of faulting.

In middle Cambrian time the granites, porphyries, and other associated or included igneous rocks were eroded and their materials deposited as the oldest Cambrian sediments, which here rest on them. Their approximate age, however, can not be determined further than is indicated by their position beneath middle Cambrian rocks.

GRANITE AND ASSOCIATED IGNEOUS ROCKS.

The granite is a reddish or pinkish rock moderately coarse in texture. Associated with it are numerous dikes of gray to dark-blue or black basic rock, besides less numerous dikes of pale-pink to white aplite, and rarely dikes of granite-porphyry. These dikes of basic rock penetrate the granite in many directions, though the largest number have a bearing generally toward the northwest and southeast. The surface of the granite is nearly flat and is in large measure concealed by materials resulting from its own disintegration and by residual sands from the Trinity formation, so that it is not possible to locate or trace many of the dikes beyond the immediate valleys of the streams where the rocks have their best exposures. In the eastern part of the area the basic dikes are few in number, though the granite is usually so concealed by surficial deposits that satisfactory observations could not be made. Toward the west these dikes increase in number, until in the vicinity of Tishomingo they are of such frequent occurrence and have increased in size so greatly as to form a considerable part of the igneous mass. In this part of the area they range from thin stringers to dikes 40 feet in thickness.

Quartz-monzonite has been found to occur in association with and apparently as phases of the granite. In some places it has a well-defined boundary, while at others it seems to grade into the granite.

Usually the exposures of the granite are such that its true relation to the aplite was not accurately determined. In certain fresh exposures the aplite occurs as dikes or stringers penetrating the granite. They are usually but a few feet thick, and were not found in association with the basic dikes.

The granite-porphyry was found in but two places. It occurs in granite in distinctly defined bands, 20 feet wide, trending toward each other. It is probable that they belong to the same dike. The granite-porphyry is cut by a basic dike which passes also into the ordinary pink granite. The granites and associated igneous rocks in the Arbuckle region have been studied by Mr. Ernest Howe, of the United States Geological Survey, and the petrographic descriptions of the igneous rocks are from Mr. Howe's report.

Granite.—The typical granite is in general a biotite-granite, rich in microcline and poor in ferromagnesian silicates. Associated with the granite are pegmatite veins, which contain the same minerals as the granites, but in coarser aggregates. The feldspars are principally orthoclase or microcline, with plagioclase, albite, and oligoclase almost always associated. Titanite, which occurs in extremely perfect crystals, is, under the microscope, a noteworthy constituent. Garnet, also, occurs in some specimens as an important accessory mineral.

Quartz-monzonite.—Quartz-monzonites are associated with the granite and occur apparently as phases of it. As far as observations could be made, monzonites occur in small areas. In most places where this rock was noted the exposures are poor and the relations of the rocks could not be satisfactorily determined. In all the specimens examined petrographically, plagioclase, ranging in composition from oligoclase to labradorite, is almost as prominent as orthoclase or microcline; quartz, usually in the form of pegmatitic intergrowths, with orthoclase, is always present, but never in abundance. With these minerals biotite occurs almost invariably; in all but two of the specimens hornblende is abundant. One of the rocks contains hornblende equal in amount to the plagioclase and alkali feldspar, and is remarkable in its very considerable development of quartz. It is a middle type between granite and diorite. From this intermediate type the tendency seems in the majority of cases to lean toward the side of the granites. One of the specimens is a nearly pure diorite, consisting largely of plagioclase, feldspar, and hornblende, with a very little alkali feldspar and quartz. These rocks indicate a very interesting series, worthy of more extended study.

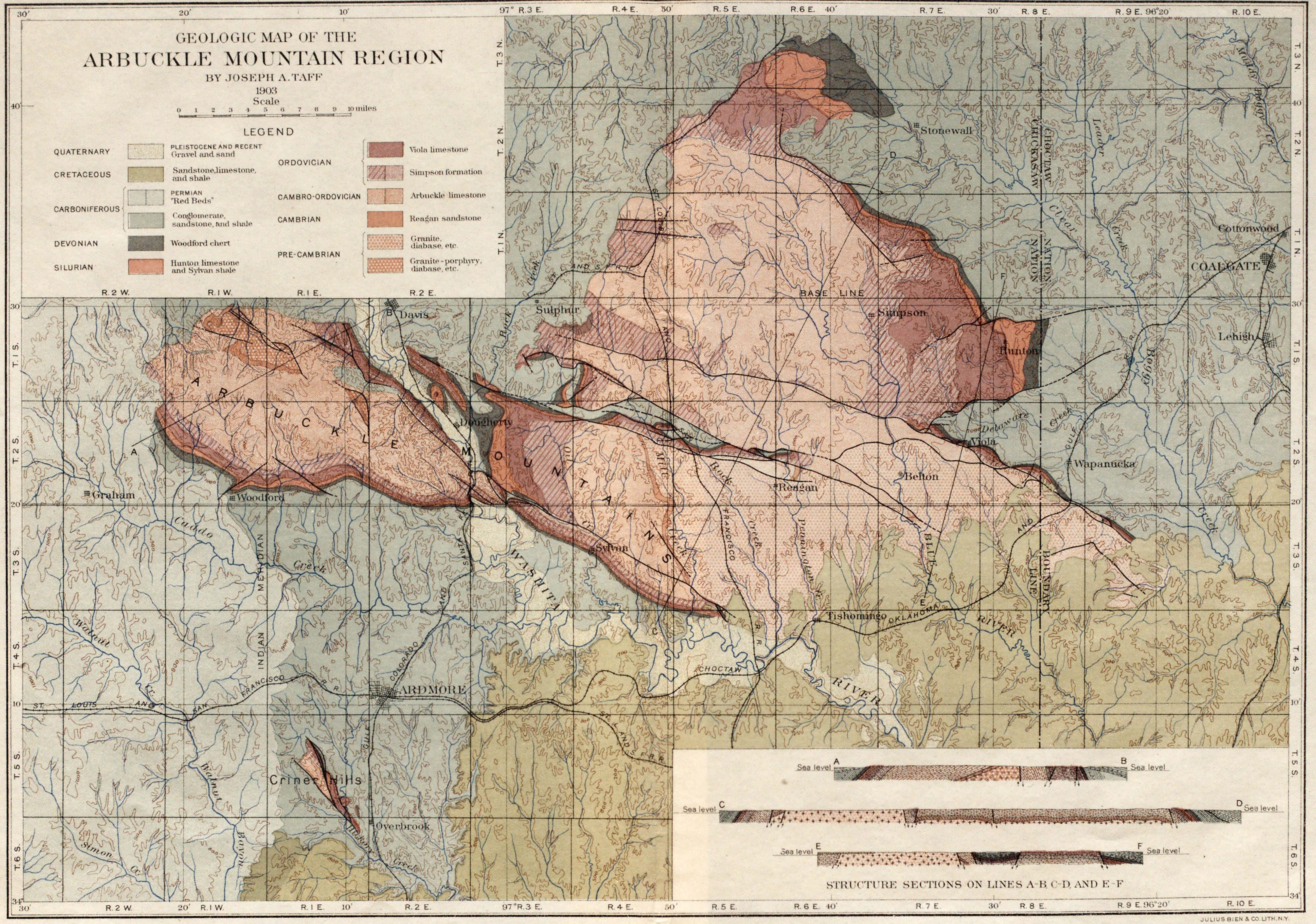
Aplite.—Aplite occurs also in association with the granite in a manner similar to that of the diabase. In places the exposures are such that the true relations between the aplite and the granite could not be determined. Where erosion had removed the disintegrated rock the aplite appears as well-defined dikes. Specimens examined petrographically are pale pink or nearly white in color, containing no ferromagnesian silicates, and composed almost entirely of feldspars and quartz, with very little magnetite or hematite. The texture of the aplites is even and finely granular. Orthoclase, microcline, and plagioclase are present in all and are slightly greater than quartz in amount.

Granite-porphyry.—Granite-porphyry occurs in well-defined bands, apparently as dikes in the common granite. The only exposure of this porphyry noted is in a small tributary of Rock Creek in the western side of sec. 1, T. 4 S., R. 5 E. The granite-porphyries are fine textured and brick red. The phenocrysts, distributed in a dense groundmass, are irregular in size and consist of orthoclase, quartz, and some dark silicates, probably hornblende, which is now completely altered to chlorite and the hydrous oxides of iron. The feldspars and what remains of the ferromagnesian silicates are in large imperfect crystals, while the quartz is in very much smaller, rounded and dihexagonal grains. The groundmass is partly a finely granular aggregate of quartz and feldspar and partly a micropegmatitic intergrowth of these two minerals. Magnetite is an abundant accessory.

Diabase dikes.—Dikes of diabase are common throughout the granite, but increase in abundance from east to west. Near the western end of the granite, in the mass northwest of Tishomingo, they are so numerous as to form in places a network of sheets and stringers. These dike rocks have considerable variation in texture, but are all to be considered as diabase. They vary from dense, finely porphyritic contact facies to coarse rocks which might almost be considered gabbro. Their composition is very uniform. Augite, labradorite, and magnetite are always present; biotite rarely occurs; and in only one instance was olivine found, or, more correctly, pseudomorphs of serpentine after olivine. These diabase dikes usually weather more rapidly than the granite, and as a result fresh specimens in many cases can not be obtained. The secondary minerals—chlorite, kaolin, calcite, muscovite, and epidote—are very abundant. In the dense rocks, evidently near the contacts, the groundmass, although very fine grained, is still distinctly ophitic. Delicate skeleton crystals of magnetite add materially to the felt-like appearance. Phenocrysts are seldom perfect and never large. The plagioclase laths average about one millimeter in length. The coarser specimens, probably from the central portions of large dikes, show a tendency to assume a granular structure, which, however, is never perfect; their structure would still be described as ophitic.

PORPHYRY AND ASSOCIATED BASIC DIKES.

The porphyry of the Arbuckle Mountains occurs in two areas, known as the East and West Wooded Hills, which rise slightly above the general level of the Arbuckle Mountain table-land. These igneous masses have the same relations to the surrounding stratified rocks as the granite above described. The relations are graphically shown on the geologic map (Pl. I). These igneous rocks, of pre-Cambrian age, consist of granite-porphyry and aporhyolite of various shades of pink, red, and brown. In so far as could be determined by a general survey the aporhyolite is intrusive through the granite-porphyry. In places the aporhyolite, like the granite-porphyry, is strongly porphyritic and shows large clearly defined phenocrysts of pink feldspar in a reddish and darker fine ground-



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mass. In other places it is even textured, without porphyritic character, and shows a beautifully banded structure. In thin sections a fluidal, vesicular structure is shown. The base is generally devitrified, but certain bands show perlitic structure.

Like the granite in the eastern part of the uplift, the igneous mass is penetrated by numerous dikes of diabase, which are themselves older than the middle Cambrian, since sediments of that age rest uncomformably upon them. These dike rocks vary somewhat in character and in color, from very dark blue to gray, but in general are of the same nature as those occurring in the granite area.

SEDIMENTARY ROCKS.

In pre-Cambrian time the region of the Arbuckle uplift was submerged and the Reagan sandstone, the lowest Cambrian sediment, was laid down upon the eroded surface of the granite and porphyry as a beach and off-shore deposit. The pre-Cambrian land, composed of igneous rocks, possessed some relief at the time of the submergence, as is shown by the uneven contact of the igneous rocks with the Reagan sandstone and also by the variable nature of the sandy deposits. The land in the immediate vicinity of the uplift was soon submerged, however, as is shown by the presence of fossiliferous horizons representing the same mid-Cambrian time in the upper member of the Reagan sandstone wherever it is exposed.

CAMBRIAN ROCKS.

Reagan sandstone.—This sandstone is a variable formation, as regards both its thickness and the nature of its materials. In the eastern part of the uplift, in contact with the granite, it varies in thickness from a few thin beds to approximately 500 feet, with an average thickness of about 300 feet. In its thickest portion, at the western end of the granite, the lowest beds are composed for the most part of coarse arkose grit. The following is a record of the thickest section of the Reagan sandstone as it occurs at the western end of the granite area, beginning at the base:

Section of Reagan sandstone.

	Feet.
Quartzite and arkose conglomerate, composed of poorly sorted granitic materials	30
Coarse grit and sand, with some clay and green sand in upper part, generally well stratified	370
Thin-bedded and laminated sandstone, becoming calcareous in the upper part	60

This section is followed by generally thin-bedded siliceous limestone and shaly strata through several hundred feet to the top of the middle Cambrian. The calcareous beds at the top and above the Reagan contain numerous fossils of well-defined middle Cambrian forms.

The Reagan sandstone overlying the porphyry in the southern sides of the East and West Wooded Hills has a section similar to that in contact with the granite. The coarse materials which make lentils of conglomerate near the base, however, are here composed of porphyry and associated dike rock. In the upper part of the formation greenish clays are probably more abundant, and the green sand continues higher up into the more calcareous beds. As in the occurrence near the granite, here the calcareous rocks contain numerous middle Cambrian fossils.

CAMBRO-ORDOVICIAN ROCKS.

Arbuckle limestone.—The Arbuckle limestone, with the exception of thin, shaly strata and occasional siliceous and cherty beds, is composed entirely of light-blue and white limestone and cream-colored to white crystalline dolomite. The section ranges in thickness from 4,000 to 6,000 feet, and includes the whole of the upper Cambrian and the Calciferous of the Ordovician. From the base of the formation upward to the top of the middle Cambrian the rocks are composed of thin-bedded and, in part, intraformational conglomerate and shaly limestones. While pursuing stratigraphic field work in connection with the study and collection of the fossils, Mr. E. O. Ulrich noted the occurrence of what appeared to be shaly lentils at the top of the middle Cambrian, indicating to his mind an unconformity between the upper and lower Cambrian.

Beginning with the upper Cambrian the rocks are composed of massive and hard, pink to yellow crystalline limestone and dolomite, which weather to various shades of brown and almost black. Rocks of this character have a thickness of 500 to 600 feet, and are followed by lighter-colored massive dolomite and limestone, without any indication of time interval, up into the Ordovician. Beginning approximately 450 feet below the top of the Arbuckle formation the limestones become more thinly bedded and are associated with thin and, in places, shaly strata. Very near the top occasional sandy beds occur.

In the massive beds in the central part of the formation fossils are found, but not in great abundance. Near the top, however, where the rocks become argillaceous, fossils are more common. Fossils of the following genera, mostly undescribed, occur in the upper 1,250 feet of the Arbuckle limestone.

Fossils of upper portion of Arbuckle limestone.

Billingsella, 2 species.
Polytoechia?
Stromatocerium.
Calathium, 2 species.
Maclurea.
Ophileta.
Eccyliomphalus.
Eccyliopterus.
Raphistomina.
Leiospira (? Helicotoma).
Euconia (near E. ramsayi Billings).
Hormotoma, 2 species, one very near H. artemesia Billings.
Trochonema.
Orthoceras.
Trochoceras.
Leperditia.
Isochilina.
Primitia.
Bathyurus.
Isotelus canalis?

On account of its thickness and its position the central part of the uplift of the Arbuckle formation, though generally steeply upturned, occurs over broad areas, and forms a large part of the table-land of the Arbuckle Mountains. It extends from the southeastern end of the Arbuckle Mountains, where it is overlapped and concealed by Cretaceous strata, to the northwestern end, where it passes beneath Pennsylvanian and "Red Beds" conglomerates.

ORDOVICIAN ROCKS.

Simpson formation.—After the Arbuckle limestone was deposited there was a general change in the nature of the sediments. The top of the limestone seems to have been slightly eroded locally and upon the surface were deposited beds of pure sand. At other places the Arbuckle limestone is overlain by shaly and impure lime—the basal beds of the Simpson formation. On these local sandy beds at the base there were deposited greenish shales and thin crystalline and shelly limestones interstratified with a number of beds of sandstone, making a total thickness ranging from about 1,200 to 2,000 feet. Following is a general section of the Simpson formation on the south side of the Arbuckle uplift west of Washita River, the beds being given from above downward.

Section of Simpson formation on south side of Arbuckle uplift, west of Washita River.

	Feet.
1. Thin limestone with green shales interstratified	400
In the lower part the limestone is subcrystalline, resembling beds lower in the formation, while higher it becomes fine grained and argillaceous, resembling that of the succeeding Viola formation.	
2. Sandstone	90
3. Limestones and shales interbedded	400
Some of the limestones are highly fossiliferous: *Orthis tricenaria*, *O. deflecta*, *Monticuliporoid* Bryozoa, highly ornamented cystid plates, and species of *Ctenodonta*.	
4. Sandstone	100–200
5. Shaly limestone	195
The lower 50 feet highly fossiliferous, containing Ostracoda with numerous Bryozoa and bases of crinoid columns, making a fauna sufficiently peculiar to be easily distinguished.	
6. Sandstone	33
7. Thin-bedded limestone and shales interstratified	295
Contains fossils in great abundance, chiefly Ostracoda of large and small species, and numerous gasteropods, pelecypods, brachiopods, and trilobites.	
8. Greenish shales with few thin limestone layers	245
Thin sandstone.	
9. Granular crystalline limestone in thin beds	350
Contains an abundance of Ostracoda (*Leperditia* chiefly) and other fossils so rare as to appear wanting.	
10. Thin limestone and shales interstratified with occasional thin sandstone	29
11. White to light-brown sandstone, occurring locally	0–100

The sandstone bed No. 4 in the section is more persistent in its characteristics, including thickness, than the others, and serves as a convenient datum for reference. It also separates the formation into two divisions of nearly equal thickness.

In the northern portion of the region, and especially on the northern side of the Arbuckle Mountains west of Washita River, the Simpson formation is found to be much thinner than in the southern portion. This is due chiefly to the absence of the lowest beds, which have an aggregate thickness of several hundred feet. The upper division of the formation is found to become thinner northward, owing to the decrease in the quantity of lime and clay. With the decrease in amounts of lime and clay northward there is a general increase in the abundance of sand, the whole formation becoming more siliceous.

On the northern side of the region the Simpson formation is exposed much farther east than on the southern side, where it is found in its typical thickness and consistency. Near the east end, in the valleys of Blue River and Delaware Creek, the structure is so variable that accurate estimates of thickness could not be made. It is approximately 1,200 feet thick, and the sand is relatively more abundant than in the northern part of the Arbuckle Mountains farther west. In all places noted the sand is fine grained, and in many cases is completely separated from clay and lime sediments.

The Simpson formation contains a very abundant fauna. Large collections of fossils were made by Mr. Ulrich, especially from the district west of Washita River. Only a preliminary study of this fauna has been made, but it is sufficient for accurate classification and general correlation. Below are lists of readily recognized forms, separated according to the two divisions of the formation.

Fossils of lower Simpson formation.

Plates of cystidian (? Glyptocystites).
Siphonotreta sp. undetermined.
Crania sp. nov.
Orthis costata.
Orthis (Dalmanella) pogonipensis Walcott.
Orthis sp.? nov. (near holstoni Safford).
Ctenodonta sp. nov. (of C. nasuta type).
Ctenodonta sp. nov. (large, ovate species).
Cyrtodonta sp. undetermined.
Modiolopsis sp. nov.
Modiolopsis sp. nov.
Bucania sp. undet. (small, with flat dorsum).
Bucania sp. undet. (larger, with subcarinate dorsum).
Bucanella sp. undetermined.
Maclurea sp. undetermined.
Eccyliopterus sp. undetermined.
Leperditia sp. near fabulites.
Leperditia bivia White.
Leperditella of several undetermined species. This division is particularly characterized by these Ostracoda, many of the limestone layers being crowded with large and small species.
Bathyurus sp. undetermined.
Ceraurus of two undetermined species.
Amphion nevadensis? Walcott.

Fossils of upper Simpson formation.

[Most of these species known only in the upper 300 feet. Those occurring also in the lower part of the subdivision are distinguished by an asterisk.]

Receptaculites sp. nov.
Protarea sp. nov. (massive-laminar form).
Archæocrinus sp. undetermined.
Platycystites (?) sp. nov.
Amygdalocystites sp. nov.
Glyptocystites sp. nov.
*Numerous monticuliporoid Bryozoa.
Stomatopora proutana-pertenuis Ulrich.
Phylloporina sublaxa Ulrich.
Rhinidictya nicholsoni Ulrich.
Arthroclema sp. nov.
Pachydictya cf. foliata Ulrich.
Lingula coburgensis Billings.
Schizambon (? Siphonotreta) minnesotensis H. and C.
Crania granulosa Winchell.
Craniella ? ulrichi Hall.
Pholidops trentonensis Hall.
Plectambonites sericea (Stones River variety).
Strophomena filitexta Hall.
Rafinesquina minnesotensis Winchell.
Scenidium anthonense Sardeson.
*Orthis tricenaria Conrad.
*Dalmanella perveta Conrad.
*Dinorthis near pectinella Emmons.
*Orthis (? Dinorthis) deflecta Conrad.
Orthis (? Dinorthis) sp. nov.
Hebertella bellarugosa Conrad.
Triplecia sp. nov. (striated).
Zygospira (Hallina) nicolleti W. and S.
Zygospira (Hallina) sp. nov.
Clionychia lamellosa Hall.
Ctenodonta contracta Salter.
Eurymya plana Hall.
Tetranota obsoleta ? Ulrich.
Pterotheca attenuata Hall.
Ampyx sp. undetermined.
Harpina sp. undetermined.
Platymetopus sp. nov. near bicornis Ulrich.
Platymetopus sp. nov. near cucullus M. and W.
Pterygometopus near schmidti Clarke.
Numerous undetermined small Ostracoda of the families Cypridæ and Beyrichiidæ.

The fauna of the lower division of the Simpson formation is decidedly similar to that of the Chazy of New York and Canada and of the Pogonip formation of Nevada. Considering these east-and-west connections, it is surprising to note that the lower Simpson fauna, so far as known, contains none of the prolific fauna of the lower division (Murfreesboro limestone) of the Stones River group in middle Tennessee, which is believed to be of equivalent age. As a whole, the fauna of the upper part of the Simpson is closely related to the upper division of the Stones River group in Tennessee and Kentucky and the equivalent beds in the upper part of the Mississippi Valley.

Viola limestone.—There is a gradual transition from the top of the Simpson formation up into the basal part of the Viola formation. The top layers of the Simpson are usually argillaceous, are thinner, darker, and more evenly stratified than those at the base of the Viola, and in places contain partings and beds of clay. The rocks at the contact on each side, however, vary somewhat in different parts of the field.

The Viola formation is a continuous but slightly variable deposit of limestone 500 to 700 feet thick, which usually appears massive on very fresh exposures. Upon weathering, however, the bedding is pronounced, showing layers rarely more than a foot in thickness. In the middle and lower parts especially there are occasional bands and nodular masses of chert.

The Viola limestone is divisible into three members, distinguished by variations in bedding, in texture, and to a less extent in the color of the limestone. The upper and middle members are approximately 300 feet thick. The lowest member is somewhat thinner and more variable than the others. The lowest member consists of light-colored, coarse-textured, and usually roughly bedded limestone. It probably will not exceed 100 feet in thickness anywhere, and in places is much less.

The middle member consists of white to light-blue and generally even- and thin-bedded limestone. On account of the abundance of fossil trilobites of the genus *Trinucleus* in certain layers it might be known as the *Trinucleus* member. It is characterized by white surface where weathered and even bedding.

The highest member resembles in part the lowest in essential physical characters. In its lower part the beds are thicker, more earthy, and more uneven than those of the middle part. In the middle part the beds are thin and more argillaceous. The limestone at the top of this member resembles very much the lowest beds in character of bedding. It is more crystalline and usually lighter in color, being light gray and occasionally pink.

On the whole the Viola limestone varies but slightly in thickness and general characteristics throughout its occurrence in the Arbuckle Mountain region.

An investigation of the fossils by Mr. Ulrich, who collected and studied the rock section, shows that there are three faunal divisions, which correspond to the three lithologic members above described. The most fossiliferous development of the basal member was noted at the extreme northern occurrence, in the region at the base of Double Mound, 6 miles northeast of Roff. A preliminary study of the fossils collected shows the following-named forms:

Fossils of lower member of Viola limestone.

Streptelasma profundum var.
Tetradium columnare Hall.
Homotrypa intercalaris Ulrich.
Bythopora subgracilis Ulrich.
Phylloporina reticulata Hall.
Rhinidictya mutabilis Ulrich.
Rhinidictya mutabilis major Ulrich.
Escharopora subrecta Ulrich.
Phænopora incipiens Ulrich.
Arthropora bifurcata Ulrich.
Plectambonites sericea var.
Strophomena filitexta Hall.
Rafinesquina deltoidea Conrad.
Dalmanella hamburgensis? Walcott.
Dinorthis pectinella Hall.
Platystrophia sp. undetermined (small).
Rhynchotrema increbescens Hall.
Zygospira recurvirostris Hall.
Vanuxemia gibbosa Ulrich.
Technophorus subacutus? Ulrich.
Cyrtolites retrorsus Ulrich.
Protowarthia pervoluta U. and S.
Lophospira bicincta Hall.
Strophostylus textilis U. and S.
Holopea obliqua? Hall.
Pterotheca attenuata Hall.
Bumastus trentonensis Emmons.

Nearly all of the above fossils occur in the *Phylloporina* and *Clitambonites* beds of the Ordovician section in Minnesota. These beds are correlated with latest Black River and earliest Trenton. Many of the species occupy these horizons in New York and Canada and what are regarded as equivalent positions in middle Tennessee and Kentucky.

As a whole the middle member or *Trinucleus* bed of the Viola limestone is not abundantly fossiliferous. The organic remains occur chiefly in three horizons, one near the base, another above the middle, and the third near the top. The first and second contain an abundance of graptolites. Next to the *Trinucleus* the graptolites are the most characteristic and commonest fossils of the middle member.

Fossils of middle member (Trinucleus beds) of the Viola limestone.

Diplograptus pristis? Hall.
Climacograptus typicalis Hall.
Schizotreta minutula W. and S.
Conotreta, sp. undetermined (? rusti Walcott).
Rafinesquina deltoidea Conrad.
Conularia trentonensis Hall.
Trinucleus concentricus Eaton.
Trinucleus sp. undetermined.
Proetus parviusculus var.
Pterygometopus (near callicephalus Hall).
Nileus vigilans Meek and Worthen.

These fossils indicate that the *Trinucleus* beds were deposited during the latter half of the Trenton age.

The upper member of the Viola limestone is approximately 300 feet in thickness, but only in the upper 25 feet is it abundantly fossiliferous. The lower 50 feet yielded no fossils. In the middle portion the fossils are not only rare, but poorly preserved. The fossils in the following list occur only in the upper 50 feet of the formation:

Fossils of upper member of Viola limestone.

Bead-like joints of the stalk of an undescribed crinoid or cystid, one-quarter inch in thickness.
Pachydictya gigantea Ulrich.
Ptilotrypa obliquata Ulrich.
Plectambonites sp. nov. (with denticulate hinge).
Strophomena wisconsinensis Whitfield.
Leptæna unicostata M. and W.
Rafinesquina sp. nov. (near camerata).
Orthis kankakensis sweeneyi Winchell.
Dinorthis subquadrata Hall.
Dinorthis proavita W. and S.
Hebertella insculpta Hall.
Dalmanella macrior Sardeson.
Platystrophia acutilirata Conrad.
Rhynchotrema capax Conrad.
Parastrophia divergens H. and C.

These are all species characterizing the upper divisions of Richmond age in Minnesota, Wisconsin, Illinois, Indiana, and Ohio. In northern Arkansas the same fauna occurs in the Polk Bayou limestone and in middle Tennessee in the Fernvale formation. This is one of the most widespread horizons, and certainly the easiest to recognize, of the Ordovician rocks.

SILURIAN ROCKS.

Sylvan shale.—The Sylvan shale and the succeeding Hunton limestone are comparatively thin formations, and because of their narrow outcrop they are necessarily mapped together. While these formations present strong contrasts, lithologically they belong to the same system.

The nearly pure lime deposits laid down at the close of Viola time were succeeded by dark-blue to black and green clay in apparently conformable succession. The deposition of the greenish Sylvan shale continued without interruption until it reached a thickness of from 60 to 300 feet, when it was succeeded abruptly by the Hunton limestone.

The Sylvan shale increases gradually in thickness westward. At the east end of the uplift its thickness is estimated to be 60 feet, while west of Washita River it is approximately 300 feet. Being a soft clay shale and bounded above and below by hard, ridge-making limestone, it invariably makes smooth swales or valleys, which are protected by forests. As a result fresh exposures of the rocks, especially at the contact with adjoining formations, are rare.

Only one exposure of the shale at its base was noted; this is about 2 miles northwest of Dougherty. At this place from the base upward through several feet the rock is a compact, dark-blue to black calcareous and bituminous shale, containing an abundance of graptolites and shells. Elsewhere in the shale fossils are exceedingly rare. This basal bituminous shale is harder than the succeeding greenish shale and is distinctly stratified. The greenish shale higher in the formation is homogeneous and massive and shows usually but slight indication of lamination, particularly on weathering.

A preliminary study of the fossils occurring in the dark basal shale shows the following forms:

Fossils of the lower part of the Sylvan shale.

Diplograptus sp. undetermined.
Climacograptus sp. near typicalis.
Leptograptus sp. undetermined.
Lingula; short, obtuse form.
Lingulops? sp. nov. (platform obsolete).
Leptobolus sp. near insignis.
Leptobolus? sp. nov. (has six strong radiating plications).
Conularia sp. nov., with surface sculpture very similar to that of the Trenton C. papillata Hall.
Conodonts of forms resembling those referred by Hinde to Prioniodus and Polygnathus.

The fauna of the Sylvan shale as far as known is generally remarkably similar to that of the Utica. The specific differences, however, are such as to distinguish them; yet a study of the fossils convinces one that the fauna of the Sylvan is a direct development from the much older fauna of the Utica shale and not of the intervening faunas of the Cincinnati group. From this evidence it would seem that the position of the Sylvan shale in the time scale is problematical. The highest known fauna of the Ordovician, that of the Richmond group, occurs at the top of the Viola limestone, beneath the Sylvan shale, and the Clinton occurs immediately above the Sylvan, in the base of the Hunton limestone. According to the present classification, therefore, the Sylvan shale should be correlated with the Medina, and the line separating the Ordovician and Silurian in the Arbuckle Mountains should be placed between the Viola limestone and the Sylvan shale.

SILURO-DEVONIAN ROCKS.

Hunton limestone.—The green clay shales of the Sylvan are succeeded abruptly by hard, white to light-blue limestone of the Hunton formation. Usually the contact rock at the base of the Hunton is a massive bed of oolitic limestone. Locally hard bluish limestone beds are found at the base, with rarely a thin layer of brecciated limestone or limestone conglomerate in contact with Sylvan shale. At the eastern end of the Arbuckle uplift the thickness of the Hunton limestone is estimated to be about 160 feet. It increases gradually westward on the northern side of the uplift, until it reaches nearly 200 feet in the vicinity of Franks, where it is concealed by overlap of Coal Measures conglomerates. On the southern side of the uplift, east of Washita River, the formation thins out and is absent for a distance of about 10 miles. Where it is thinnest the beds are more or less siliceous. Farther west, beyond Washita River, the formation increases until it is nearly 300 feet thick on the southern side of the Arbuckle Mountains where it passes beneath the "Red Beds" conglomerate, northwest of Woodford. On the northern side of the Arbuckle Mountains south of Washita River it is about 170 feet thick.

The Hunton formation is composed of hard, thick crystalline limestones, thin earthy limestone, and marls. It may be separated into three fairly distinct members according to lithologic characteristics, and to a less extent according to color. Except where the formation is very thin, as on the southern side of the uplift east of Washita River, the three members can always be distinguished. An average section of the formation on the south side of the Arbuckle Mountains west of Washita River is approximately as follows:

Section of Hunton limestone.

	Feet.
UPPER MEMBER.	
Semicrystalline limestones, in places cherty, interstratified with occasional thin marly layers	30
MIDDLE MEMBER.	
Marly limestones and calcareous clays, with some hard limestone layers, more abundant in the lower part	170–190

LOWER MEMBER.

	Feet.
Thick-bedded crystalline limestone succeeded by hard thin limestone with occasional marly layers. At the base of this limestone is an oolite, 4 to 5 feet thick, which locally is silicified	35–40

The upper member contains locally, at the top, beds of crystalline and very cherty and flinty limestone. While the thickness of the formation becomes greater westward, that of the individual members does not increase in the same proportion, as the greatest variation in thickness of the formation is due to the middle member. West of Washita River the upper member has a thickness of 10 feet on the northern side of the Arbuckle Mountains and 30 feet on the southern side. East of the same river it increases northward from a thin bed on the southern side to 35 feet on the northern side of the uplift near Franks.

The lithologic differences by which the members are distinguished are accompanied by faunal changes which afford a basis for age distinctions. The more massive crystalline beds in the lower part of the basal member, ranging in thickness from a thin bed to 25 feet or more, contain the following forms, which are distinctly Clinton. The four Bryozoa and the *Triplecia ortoni* are characteristic of the Clinton limestone of Ohio, and their horizon occurs in the St. Clair limestone of northern Arkansas.

Fossils of the lower member of the Hunton formation.

Favosites favosus Goldfuss.
Rhinopora verrucosa Hall.
Phænopora magna Hall and Whitfield.
Pachydictya bifurcata (Van Cleve) Hall.
Hemitrypa ulrichi Foerste.
Orthis flabellites Hall, var.
Triplecia ortoni Meek.
Atrypa marginalis Dalman.

The hard thin limestone beds in the upper part of the basal member contain the fossils listed below, which indicate Niagara age.

Fossils of the upper layers of the lower member of the Hunton formation.

Thecia swinderiana Roemer.
Orthothetes subplanus Hall.
Atrypa reticularis var.
Platyceras niagarense Hall.
Strophostylus cyclostomus? Hall.
Orthoceras sp. undetermined; very slender.
Calymene niagarensis Hall.

The middle member of the Hunton limestone as a whole is abundantly fossiliferous, the *Camarocrinus* horizon especially, near the middle of the member, being remarkably persistent. The fossils listed below are some of the easily recognizable forms:

Fossils of the middle member of the Hunton formation.

Streptelasma waynense Safford.
Favosites conicus Hall.
Camarocrinus ulrichi Schuchet.
Camarocrinus stellatus Hall.
Orthostrophia strophomenoides Hall.
Dalmanella subcarinata Hall.
Rhipidomella oblata Hall.
Bilobites varicus Hall.
Strophonella punctulifera Hall.
Strophodonta varistriata.
Uncinulus nucleolatus Hall.
Delthyris perlamellosus Hall.
Spirifer cyclopterus Hall.
Anastrophia verneuili Hall.
Gypidula galeata Dalman.
Rensselaeria aequiradiata Conrad.
Rhynchospira formosa Hall.
Meristella arcuata Hall.
Megambonia lata Hall.
Orthoceras rude Hall.
Dalmanites pleuroptyx Green.
Phacops logani Hall.
Phacops hudsonicus Hall.
Proetus protuberans Hall.

With a list of species like the above there can be no question as to the Helderbergian age of this member of the Hunton formation.

The uppermost member of the Hunton formation is probably lower Oriskany in age and equivalent to the Camden chert of Tennessee. The fossils secured from this member are not now at hand, so it must suffice for the present to say that they consist chiefly of Gasteropoda and large crinoid columns. According to the classification of the Paleozoic rocks at present in vogue, this member should be called Devonian, but it is so intimately united, both faunally and structurally, with the underlying Helderberg member, that, for this region at least, it would be doing a violence to the natural classification of the rocks to draw a line of systemic importance between them. According to a classification taking into account both the life history and structure of the strata, this divisional line should be drawn either between the flinty beds at the top of the Hunton limestone and the base of the black shale and chert of the overlying Woodford formation, or between the Niagara and Helderberg members. In the latter case the lower member only would be Silurian, and the two upper members Devonian.

DEVONIAN ROCKS.

Woodford chert.—Excepting the flinty Oriskany limestone occurring locally at the top of the Hunton limestone and possibly the Helderberg member of the latter, Devonian rocks in the Arbuckle region are limited to a single formation of chert and black shale, known as the Woodford chert. While this chert is apparently conformable with the limestone below in any single locality, it appears that this is not true in a broad sense. The Oriskany beds at the top of the Hunton limestone, consisting of several feet of cherty limestones, are present in one place but do not occur in another. In the northeastern part of the uplift, notably near Franks, cherty limestones are present at the top of the Hunton. Near the western end of the uplift, on the southern side of the Washita Valley, this upper member of hard limestone is absent and the thickness of the entire formation is reduced to a little over 100 feet. In all places there is an abrupt change in sedimentation from the top of the Hunton limestone to the chert or shale of the Woodford formation.

The Woodford chert has an estimated average thickness of 650 feet. It varies somewhat in lithologic character. In places massive chert rests upon the limestone; in other places black shale occurs at the base of the formation. As a rule, however, the formation becomes less cherty from the base upward. It is usually even bedded, occurring in layers from a few inches thick to thin laminæ. In places, especially in the northeast side of the uplift, the formation is composed almost entirely of thin, fissile, siliceous and distinctly bituminous black shale. In this part of the region, a few miles west of Hunton, lentils of almost pure flints were noted interstratified with the black shale near the base. In the western part of the region bluish shales were seen interstratified with the black shale in the upper part of the formation. At various positions in the section, especially in the more cherty beds, are small, rounded, marble-like concretions of a calcareous nature. In places there are large segregations of a similar character, concentrically banded, which occur intersecting several layers of cherty shale.

The Woodford chert is present throughout the Arbuckle region wherever its horizon reaches the surface. In the southern part of the uplift massive beds of Sycamore limestone occur above it, and the equally prominent Hunton limestone beneath it, and since these rocks are steeply tilted the Woodford chert crops in gullied valleys and rough hilly land between the prominent ridges of limestone. Elsewhere it occurs as gullied slopes and rough woodland bordering Hunton limestone ridges.

Fossils are very rare in the Woodford chert, and those found are not well preserved. In the lower part of the formation in the western part of the region a small *Lingula* of the type *L. spatulata* Hall and a few conodonts have been observed. In the shales of the upper part the only recognizable fossils seen are two concentrically plicated species of *Productella*, one of which seems referable to *P. concentrica* Hall. Fragments of fossil wood were found on the surface in many places, but with one exception it could not be determined whether they belonged with the chert or with the Cretaceous beds which are considered to have extended over the region. In one instance, however, in the southern side of the uplift northwest of Norton, a tree trunk approximately 15 inches in diameter was found embedded in the chert in the lower part of the formation. The chert here is steeply upturned and the fossil tree rests parallel to the bedding. Thin sections of the wood have been studied microscopically by Mr. David White, of the United States Geological Survey, and determined to belong to a species of *Dadoxylon*, a form common to the Devonian.

This formation is believed to be of the age of the Chattanooga formation of Tennessee, the Ohio shale of Ohio, and the Portage and Chemung of New York. At the top it doubtless includes strata corresponding in age with the Noel shale of northern Arkansas and the basal shale of the Tullahoma formation of Tennessee, which are believed to be of Kinderhook age, or, according to the present classification, earliest Carboniferous.

At present it is not possible to determine the exact parting between the Devonian and Carboniferous, since there is no clear stratigraphic distinction in the shales, and fossils are rare.

CARBONIFEROUS ROCKS.

MISSISSIPPIAN SEDIMENTS.

Sedimentation continued through lower Carboniferous time without apparent cessation. With the exception of a limestone lentil occurring near the base on the southern side of the Arbuckle uplift, the whole section of Mississippian rocks, approximately 1,600 feet thick, consists of black and blue clay shales. The black shales contain argillo-calcareous and limestone concretions and segregations, and the blue shale carries small ironstone concretions, occasional local sandstone strata, and small lime septaria.

Sycamore limestone.—The limestone outcrops very near the base of the Carboniferous throughout the southern side of the uplift. It occurs also on the northern side of the main Arbuckle Mountain and extends eastward into the central part of the uplift almost to the granite. It is mapped and described in the Tishomingo folio under the name Sycamore limestone. This rock is a light-bluish to yellow and probably argillaceous massive limestone. Upon weathering it separates into thin beds, a foot and less in thickness, and changes to shades of yellow. Near the extreme western end of the Arbuckle Mountains it has a thickness of nearly 200 feet. Near Washita River in the central part of the Arbuckle uplift the limestone has a thickness of about 50 feet, but it thins out eastward near the granite in the northeast corner of T. 2 S., R. 3 E. Elsewhere in the uplift, toward the northeast, it is absent or represented by local thin siliceous limestone strata at the top of the Devonian chert. No fossils have been found in this limestone.

Caney shale.—The remaining Mississippian strata above the limestone are mapped as the Caney shale in the Atoka and Tishomingo folios. This formation consists in the basal part of black bituminous clay shale containing limestone and argillo-calcareous segregations. This black shale grades upward into bluish shale containing small clay ironstone concretions and occasional lime septaria. The whole formation is estimated to be about 1,600 feet thick. The limy concretions and segregations in the black shale in the lower part of the Caney formation contain a number of fossil shells. The fossils of the Caney shale were collected and studied by Dr. G. H. Girty, who concludes that the fauna is peculiar and that many of its species are new. Associated with a species of *Leiorynchus* resembling *L. quadricostatum*, and a small undetermined *Posidonomya*, which at certain horizons is extremely abundant, are found *Productus hirsutiformis*, *Seminula* sp., and a number of *Goniatites*, related to *G. subcircularis*, *G. crenistria*, *G. striatus*, and *Gastrioceras kingi*. The age of this fauna can probably safely be placed as post-Devonian, and evidence thus far obtained is favorable to correlating it with the upper portion of the Mississippian series.

PENNSYLVANIAN SEDIMENTS.

Franks conglomerate.—At the close of the Mississippian epoch the Arbuckle region, especially the western part, was uplifted into land and remained so during a large part of Pennsylvanian time. In the western part of the uplift the sediments from the top of the Mississippian well down into the Ordovician, and probably to the Cambrian, were subject to erosion, and lower Carboniferous limestone conglomerates derived from them were spread across their worn edges. The westward extension of these older rocks, now concealed unconformably by the lower Cariboniferous and "Red Beds" (Permian) conglomerate, most probably formed the larger part of the uplift, since the lower conglomerate especially increases both in volume and in coarseness westward. The Carboniferous conglomerate varies greatly in thickness as well as in coarseness of materials. In the western part of the region the conglomerate with associated shale and sandstone is many hundred feet thick. On the northern side of the uplift it decreases in thickness eastward, and changes from complete unconformity upon the edges of the Mississippian, Devonian, Silurian, and Ordovician strata to apparent conformity above the Caney (Mississippian) shale. In the Tishomingo folio this conglomerate is mapped in detail and described as the Franks conglomerate.

Wapanucka limestone.—From the vicinity of Franks southeastward the Franks conglomerate rapidly decreases in thickness and coarseness, giving place to limestones, sandstones, and shales. At the northwest corner of the Atoka quadrangle, north of Hunton, is a thin oolitic limestone which is believed to represent the Franks conglomerate, in part at least. This limestone has been mapped here and farther east, and is described as the Wapanucka limestone in the Atoka folio. It is the lowest Pennsylvanian sediment known in Indian Territory. This limestone continues eastward beyond the limits of the Arbuckle uplift, increasing in thickness to nearly 400 feet in the central part of the Choctaw Nation.

Still farther eastward it decreases and comes to an end near the Arkansas-Indian Territory line north of the Ouachita Mountain range.

Sandstone, shale, and coal.—Above the Wapanucka limestone and the Franks conglomerate, northward from the eastern part of the Arbuckle uplift, known Pennsylvanian sediments aggregate a thickness of 10,000 to 11,000 feet. The rocks of this section, comprising many formations of the sandstones and shales, have been mapped in detail and described in the Coalgate and Atoka folios. The lowest coal-bearing rocks occur approximately 3,000 feet above the Wapanucka limestone, and outcrop in the extreme southeast end of the Choctaw coal field, against the east end of the Arbuckle uplift. These rocks consist entirely of sandstones, shales, and coal. The coal-bearing strata comprise approximately 3,000 feet of sandstone and shale, with eight to ten workable beds of coal, besides many thin coal seams. These rocks outcrop across the Choctaw Nation and northward to Kansas. Continuing westward these Coal Measures rocks, especially in the lower part, are overlapped unconformably and concealed by the later "Red Beds" of the late Pennsylvanian and Permian. In the same direction the coal seams become thinner and decrease in number, so that no coal of importance is known west of the vicinity of Stonewall, north of the central part of the Arbuckle uplift.

The Pennsylvanian deposits south of the Arbuckle Mountains differ considerably from those north and east of the uplift. They occur only south of the Arbuckle Mountains proper, being concealed by overlap of the Cretaceous rocks on the east and south, and of the "Red Beds" on the west. They consist of shales, sandstones, thin limestones, and limestone conglomerate. Unlike the rocks of the same age north of the Arbuckle region, the thick deposits of limestone conglomerate do not occur at the base, but are found at various positions in the section up to the coal-bearing strata in the vicinity of Ardmore. These limestone-conglomerate beds are relatively thin and appear as lentils interbedded with shale and limestone. Coarse conglomerate deposits occur in contact with the older rocks in the north side of the Criner Hills southwest of Ardmore. On account of the excessive folding the thickness of the Pennsylvanian sediments in this district can not now be estimated.

PERMIAN?

"*Red Beds.*"—Rocks of very late Pennsylvanian or early Permian age have been deposited across the western end of the Arbuckle uplift. The unconformity of these sediments with the lower rocks in the western part of the uplift has been discussed under the heading "Physiography." They lie in a nearly flat position across the eroded edges of several thousand feet of the Pennsylvanian, all of the Mississippian, Devonian, Silurian, and a large part of the Ordovician rocks. These older formations were sharply folded and eroded prior to the deposition of the "Red Beds."

Near the base the "Red Beds" deposits consist of local limestone conglomerate composed of well-worn limestone pebbles in a calcareous and usually red clay matrix, red and bluish clays, grit, and sand. The limestone conglomerate occurs only above and in the vicinity of the Silurian and Ordovician limestones and Carboniferous limestone conglomerates from which its limestone pebbles were derived. Westward, away from the source of the deposits, the limestone conglomerate changes gradually to a bed of massive, tough argillaceous limestone. In the vicinity of the outcrop of the Devonian chert a large part of the basal deposits of the "Red Beds" consists of fragmental chert, sand, and clay. Above the Carboniferous strata of sandstone and shale the basal deposits are composed of gritty sandstone, sand, and bluish and red clay.

These "Red Beds" deposits are exposed on the plain from the Arbuckle Mountains westward to and around the Wichita Mountains, and are described more fully in the discussion of the geology of the Wichita Mountains (pp. 72–76).

CRETACEOUS ROCKS.

The relations of the Cretaceous sediments to the older rocks of the Arbuckle region have been explained under the heading "Physiography of the Arbuckle Mountains" (pp. 13–16). The Cretaceous rocks rest upon a nearly flat floor, slightly inclined southward from the southern edge of the Arbuckle region. The basal formation of the Cretaceous is known as the Trinity. It has a thickness approximating 240 feet and consists of sand with local conglomerate at the bottom. The Trinity sand is followed by a nearly pure limestone formation, 20 to 30 feet in thickness, known as the Goodland limestone. Succeeding the purer limestone there are blue clay marls, white limestones and marls, ferruginous clays with thin shell limestones, and finally a thin fossiliferous limestone at the top of the lower Cretaceous. These formations, known as the Kiamitia clay, Caddo limestone, Bokchito formation, and Bennington limestone, respectively, aggregate nearly 840 feet in thickness. Each is conformable with its contact formations, and all dip toward the south-southeast at a grade approximating 40 feet to the mile. At the close of the lower Cretaceous the sediments were lifted above the sea, but not folded. Slight erosion was followed by depression and the deposition of the extensive ferruginous sand and clay which constitute the basal formation of the upper Cretaceous. This basal formation of the upper Cretaceous is known as the Silo sandstone, and is in part at least of Dakota age. These Cretaceous formations have been carefully mapped and are described in detail in the Atoka and Tishomingo folios. South of Red River above the Silo sandstone is a thick formation composed of blue clay shales. These are succeeded by white, chalky limestones, and these in turn by blue marls, which extend to the top of the upper Cretaceous in southeastern Choctaw Nation and northeastern Texas, beyond the limit of the area shown on the accompanying map (Pl. I).

STRUCTURE OF THE ARBUCKLE MOUNTAINS.

In discussing the physiography of the region it was necessary to make brief mention of the orogenic movements involved in the Arbuckle uplift. The history of the geologic structure will be described more fully in the following pages.

In discussing the stratigraphy it has been shown that the formations remained in an approximately flat position from the earliest Cambrian to the end of Mississippian time. That there were oscillations of the ocean bed, and probably elevations of the sediments into lowlands at times, is shown by the varying nature of the rocks. A study of the fossils by Mr. Ulrich has shown without much doubt that comparatively short intervals of nondeposition and probably of slight erosion have occurred. The first change in sedimentation, and probably slight erosion, occurred between lower and middle Cambrian time, when argillaceous limestones, intraformational conglomerates, and clays were succeeded by massive limestone. Another change occurred at the end of the Arbuckle limestone deposition, as there is an abrupt transition from Arbuckle limestone to the basal sandstone of the Simpson formation, which is of Chazy age. Other breaks occurred at the close of the Simpson formation, where there is a change from siliceous to purer limestone sediments; at the top of the Viola formation, where there is an abrupt change from limestones to clays; and at the close of the Sylvan, where there is an equally abrupt return to limestone of the Hunton formation, which was introduced locally by deposits of conglomerate. The rock bedding, however, remained practically parallel, and the sediments, with the exceptions noted, are finely divided and evenly distributed, showing that the oscillations of the sea bottom were of broad extent and that if erosion occurred it was in very low and flat land. It is neither impossible nor improbable that a break in the fauna accompanied by a change in sedimentation may be due to marine conditions, a prominent part being performed by ocean currents. A belt of shallow sea bottom swept by an ocean current, it is considered, would receive neither the fauna nor the sediments being deposited in a district of more quiet waters.

Near the beginning of the Pennsylvanian or near the close of the Mississippian, the rocks of the Arbuckle region were folded and the western part was elevated into land, probably into mountains. The formations involved in this uplift are 8,000 to 10,000 feet in thickness, and are composed chiefly of massive limestone. Faulting on a large scale also occurred, involving the whole Paleozoic section below the top of the Mississippian, besides the pre-Cambrian granite and porphyry. After the elevation into land there was extensive erosion.

which exposed the rock section down to the Cambrian in the western part of the Arbuckle Mountains. Either by erosion or by erosion and subsidence combined the western part at least of the uplift was submerged and large deposits of Carboniferous conglomerate were spread across the edges of the older faulted and folded strata. At a still later time, before the close of the Carboniferous, the sediments were again folded and elevated into land. This folding affected the recently formed conglomerates as well as all the rock previously deposited. Faulting occurred also after the deposition of the conglomerate. Near the close of Carboniferous time another period of subsidence occurred and the "Red Beds" sea encroached upon the region from the west. The extent of this encroachment eastward is not now determinable beyond the vicinity of the present occurrence of the deposits. These deposits have not suffered deformation to any appreciable extent. At a later period, between Permian and earliest Cretaceous times, the whole region was elevated into land. Following this regional elevation there was depression and a reduction of the surface to a relatively flat plain. Then followed a submergence and the deposition of the Cretaceous sediments. After Cretaceous time the region was broadly uplifted into land, without deformation, and has so remained to the present time.

The deformation of the rocks now exposed in the Arbuckle region commenced near the beginning of upper Carboniferous time and ended before its close.

CHARACTER OF FOLDING AND FAULTING.

The Arbuckle uplift includes a number of low, wide anticlines and corrugated faulted synclines, which together make a broad geanticline, the borders of which are flexed steeply downward. As explained in discussing the stratigraphy, erosion has removed the rocks down to the heart of the uplift, exposing all the sedimentary rocks as well as the pre-Cambrian granite and porphyry. In the faulted synclinal folds in the central part of the uplift, which have depressed and preserved later softer and thinner formations, there are indications of more complicated folding than occurs in the massive Cambro-Ordovician limestones.

The geologic sections accompanying the map (Pl. I) show the broad as well as the detailed structure of the Arbuckle uplift. The central part of the uplift east of Washita River is composed of several broad, shallow folds. In the axial parts of the anticlines great thicknesses of massive Cambro-Ordovician limestones are exposed and are generally but slightly flexed. The thinner and softer Silurian, Devonian, and Carboniferous rocks in the intervening synclines have been crumpled into many small folds. These synclines are broken, in general longitudinally, by many faults. Since the faulting erosion has so removed the strata that only parts of these numerous small folds in the broader synclines are now preserved. The essential features of the folding and faulting will be described, beginning with the north side.

Hunton anticline.—On the northern side of the Arbuckle uplift, beginning in the vicinity of Hunton and extending northwestward, the rocks have been bent into a broad and low upward fold, which is sharply flexed and faulted on the northern side and faulted throughout the southern side. In its western part it is 15 miles in breadth and extends over almost half the width of the Arbuckle Mountain district. Eastward the fold grows gradually narrower for 20 miles, where it is contracted more abruptly by the axial pitch of the rocks and by the oblique faulting. The faulting upon the northern side of this fold is local, the fractures bearing generally east and west at various angles to the axial trend of the main anticline, but in most cases across or oblique to the strike of the formations. The longest of these faults, however, follows the strike of the beds in the northwest side of the fold. The displacement of the beds due to this fault decreases northwestward. Near the southeastern end the whole of the Simpson formation is displaced, bringing the succeeding Viola limestone against the Arbuckle. Some of these local faults extend from the thick Ordovician limestones, across Silurian and Devonian strata, into the Carboniferous shales, and the rocks upon the north are generally depressed with respect to those upon the south in the direction of the dip of the strata. In T. 2 N., R. 6 E., near the extreme northern limit of the uplift, there is a triangular basin of Carboniferous limestone conglomerate resting unconformably across older Paleozoic rocks. The beds are steeply upturned upon the northwestern and southwestern sides, and faulting has occurred at the contact of the conglomerate with older rocks, so that the rocks are depressed by faulting as well as by folding. The faulting upon the southern side is more extensive, with downthrow toward the south. The rocks on the southern side of the Hunton anticline are inclined at low angles except locally near the faults, where the dips are usually increased. In the axial part, and near the western end of the anticline, where it is overlapped and concealed by later Carboniferous strata, there are local shallow basins, and at the extreme western end a local basin containing rocks of the Simpson formation has been faulted down as a triangular block in the Arbuckle limestone. For the most part the faults bordering this depressed block bear east and west, with displacements toward the south. A single fault bearing northeast intersects the faults in the axial trend and displaces the rocks downward toward the west.

Wapanucka syncline.—A flat and eastward-pitching syncline occurs immediately south of the Hunton anticline. In the broad, flat valley of Wapanucka Creek, from which it has received its name, its axial part is occupied by Mississippian shale. This fold becomes broader and flatter eastward, until it is lost in the Coal

Measures northeast of the Arbuckle uplift. Toward the west it contracts by faulting upon each side until it practically ceases as a fold in the northern part of T. 2 S., R. 7 E. Parts of the syncline may be said to occur along the fault which extends through the uplift on the south side of the Hunton anticline. The south limb of the Wapanucka syncline is intersected by many faults, which have strikes varying from transverse to directions parallel with the trend of the folding. A striking characteristic of the faulting is that the older and harder rocks, including the granite, are displaced to a greater extent than the soft Carboniferous shales. On the southern side of the Wapanucka syncline the faults are more numerous than on the northern side, and with the exception of a local transverse fault west of Wapanucka the depression of the strata due to faulting is in all cases toward the axial part of the syncline.

Excluding the transverse fault referred to, the faults may be considered in two classes, viz, those which bear nearly east and west, and those which trend in northwest-southeast directions, more nearly with the strike of the rocks. These two classes of faults, however, coalesce, and by their junction augment the displacement of the strata. Many of the larger faults have vertical displacements of several thousand feet, and, where two such approach, the throw is doubly great. Two nearly parallel faults approach each other south of Wapanucka, and their combined throw brings Devonian shales almost in contact with the granite, concealing 8,000 feet of Cambrian, Ordovician, and Silurian strata.

The faulting in the northern side of the syncline bears nearly N. 70° E., intersecting the older rocks almost at right angles to their strike, and the rocks in all cases are depressed southward toward the axis of the syncline. The displacement due to faulting in the northern limb of the Wapanucka syncline is less than that on the southern side, and as a consequence the resultant throw west of their junction is downward toward the north, along the axial trend of the fold.

Belton anticline.—The elongated granite area which extends from the southeast end of the Arbuckle uplift northwestward beyond Belton occupies the axial part of a poorly defined anticlinal fold. Both sides of this fold have been faulted in such manner that the rocks represented in it occupy only the axial part. The stratified rocks now in this fold above the granite consist of massive Cambrian and Ordovician limestones which are folded only to a moderate degree and which strike toward the fault at various angles. Near the faults on either side of the fold the beds are usually more steeply inclined toward the fault or locally folded. In places, however, only a slight increase in dip is all the disturbance to be noted on account of the fault. The contacts between the granite and limestones, with the exception possibly of that at the west end, are marked by faults, and on both northern and southern sides the stratified rocks are depressed with respect to the igneous mass, and the dip near the fault is usually toward the downthrow. The faults marking the limits between the granite and the limestone at the east end of the anticline extend westward and bound the long block of Arbuckle limestone which constitutes the axial part of the fold. The rocks upon each side of this faulted anticlinal block have been depressed with respect to the rocks within. The Belton anticline is concealed by Cretaceous deposits toward the southeast and by Carboniferous conglomerates toward the northwest.

Mill Creek syncline.—The district of most intricate folding and faulting in the Arbuckle region is a narrow strip of country immediately south of the Belton anticline in the central part of the Arbuckle uplift. The belt varies from one-half mile to 3½ miles in width and is as a whole synclinal. The town of Mill Creek, for which the syncline is named, is located near its center. The syncline consists of parts of many subordinate folds, bearing generally northwest and southeast, in the trend of the Arbuckle uplift, and is bounded upon each side by well-defined faults. These bounding faults, as well as most of those in the interior of the syncline, trend generally parallel with the main folding of the uplift. In no case, however, do the faults follow straight lines for any considerable distance. While the fault lines take the general direction of the major folding, the beds usually strike against them on one side or the other, and in places on both sides, at angles between 30° and 90°.

The rocks occurring at the surface and involved in the folding and faulting include the entire section from the Cambrian to the Coal Measures and have a thickness approximating 10,000 feet. The rocks exposed in the smaller folds are for the most part the thinner and softer formations of the Silurian, Devonian, and Carboniferous. It is probable that these folds in the higher rocks are minor crumplings which were developed in the axial part of the syncline, above the broader trough of the thick and hard deep-seated limestone, before the faulting occurred. These massive limestones exposed in the eastern part of the fold are for the most part gently inclined, approaching the faults upon each side at wide angles. The faulting, especially in each side of the fold, is very extensive, and in places brings the Carboniferous rocks in contact with the Ordovician and the upper Ordovician strata against the granite, showing displacements of several thousand feet.

For the most part the folding and faulting occurred before the deposition of the Carboniferous conglomerate which extends across the western end of the fold. Certain faults in the vicinity of Mill Creek and near Buckhorn, however, occurred since the deposition of the conglomerate, which is involved in the disturbances.

Parts of folds in Cambrian and Ordovician limestone occur faulted against the granite at the extreme southeastern end of the uplift. So large an area is overlapped and concealed by Cretaceous strata that the relations of these parts of folds to other structures can not be determined. Parts of two flat irregular synclines are represented and the faulting appears to follow their axial trends. Near the east end of the limestone exposures the 5,000 to 6,000 feet of Arbuckle limestone is cut at right angles to the bedding and brought against the granite.

Tishomingo anticline.—South of the Mill Creek syncline and forming the southern part of the Arbuckle Mountain region is a broad, flat fold called the Tishomingo anticline. The large granite area lying northwest of Tishomingo occupies the axial part of this anticline. Above the granite and upon its western side the whole section from lower Cambrian to Carboniferous is exposed, pitching westward at an angle of about 10°. The northern limb of this anticline is for the most part displaced and concealed by faulting. A large part of the southern limb of the fold is also concealed by faulting from the vicinity of Wyatt eastward. Bordering the granite on the south side, this fault cuts the whole section of stratified rocks from Cambrian to Carboniferous, and displaces them in such manner that the formations rest consecutively against the granite. North of this fault, which extends along the strike of the rocks from the granite westward to Washita River, the rocks dip generally at low angles toward the west and southwest. On the southern side the rocks strike approximately with the trend of the fault and dip steeply toward the southwest. Northeast of Dougherty the Tishomingo anticline contracts and separates into two minor folds, the northernmost of which pitches rapidly downward toward the northwest and is lost beneath late Carboniferous conglomerate which overlaps older sediments. The second fold is the western extension of the central part of the anticline. The rocks in the axial part pitch northwestward at an angle of about 20° east of Dougherty, and rise again at about the same angle northwest of the same place. This fold continues northwestward, expanding slightly, until it also is concealed by late Carboniferous and recent river deposits.

Two to 5 miles northwest of Dougherty, and south of the western contracted end of the Tishomingo anticline, is a peculiar dome-like anticline less than a mile in width, with north-south axis. The occurrence of this local fold deflects the Tishomingo anticline slightly northward. On the northwestern and southeastern sides of this dome-like anticline there are small synclines, and their sharp north ends rise in the south side of the Tishomingo anticline. The southern part of this dome-like anticline is concealed by the sand and silt deposits in the valley of Washita River.

Washita syncline.—Just south of the Tishomingo anticline, near the point where Mill Creek crosses the large fault, is a faulted southern limb of a syncline. It is also a part of the northern limb of a narrow anticline which trends toward the northwest and approaches and is cut by the fault east of the center of T. 5

S., R. 4 E. This broken anticline is probably a part of the Arbuckle anticline described below. A local narrow synclinal fold occurs on the northern side of the same fault in sec. 2, T. 3 S., R. 3 E., and its southern limb is faulted downward and concealed. These two parts of synclines are similarly related to the Tishomingo anticline and trend in the same direction, but the fault conceals their true relations. The second small syncline rises toward the west and then descends near the western side of T. 2 S., R. 3 E., becoming a part of the deep Washita syncline, which lies beneath the valley of Washita River northwest of the gorge in the Arbuckle Mountains.

The southern limb of the Washita syncline is steeply upturned. The beds exposed south of the river valley dip toward the northeast at angles varying between 40° and 70°. In the northeastern side of the fold, east of the dome-like anticline described in connection with the Tishomingo anticline, the rocks are inclined toward the southwest at angles of about 30°. Northwest of the dome-like fold the dips are steeper. It is believed that the southern extension of the dome-like anticline does not pass beyond the axis of the syncline, since the exposed rocks in the southern limb show no indication of transverse stresses.

The sand and silt deposits of Washita River conceal the axial part of the fold, which contains a thick section of Carboniferous shale. The northwestward extension and probably a large part of the Washita syncline is covered by overlap of late Carboniferous conglomerate, which conceals the westward extension of all the large folds of the Arbuckle uplift.

Arbuckle anticline.—South and west of Washita River is a broad and steep-sided anticline which is occupied by the Arbuckle Mountains proper. The fold converges practically to a point east of Washita River, and pitches steeply eastward between converging faults. Northwestward the fold expands until it reaches a width of 15 miles at the western end of the mountains, where the rocks involved in the folding are overlapped and concealed by Pennsylvanian and "Red Beds" conglomerate. Section AB on the map (Pl. I), drawn across the west end of the fold, illustrates the character of the structure.

The rocks near the northern and southern borders dip at angles of 30° to 70°, while in the axial part of the fold, especially through the broader western portion, the inclination of the thick Cambro-Ordovician rocks is usually much lower, though locally variable. In the eastern part, near the Washita River gorge, the folding has been more intense. Only the general features of the structure have been worked out and shown on the accompanying small-scale map.

In the axial part of the anticline, near the center and the western end, are two unsymmetrical dome-like structures in which pre-Cambrian igneous rocks are exposed. The rocks in the northeastern sides of these domes are more steeply inclined, besides being faulted. The more easterly of these elevations, known locally as the East Wooded Hills, is the smaller, and is bounded on the northeast by a curved fault, giving the igneous area a rudely crescent-shaped outline. The massive Cambrian limestone on the east side dips away from the igneous mass in the direction of the downward displacement.

The more westerly dome-like elevation of the strata in the Arbuckle anticline, known locally as the West Wooded Hills, is broken on the northern side by a number of faults which have approximately the same direction as the trend of the fold, and on the southwestern side by a single fault near the western end. Four faults have been located on the northeastern side. The two faults which border the granite are gently curved or fluted and the Cambrian limestone is displaced downward toward the north. The vertical throw can not be accurately estimated, but it is probably not less than 500 feet where the Reagan sandstone is concealed. The second two faults have caused greater displacement of the strata. They are near together, are nearly parallel, and converge at the western side of sec. 12, T. 1 S., R. 1 W. Between these faults a narrow wedge of the Simpson formation is thrown down between massive strata in the lower part of the Arbuckle limestone. A fault in the strike and southeast of the depressed wedge of Simpson limestone cuts the southeastern lobe of the igneous mass, throwing the Cambrian limestone down on the southwestern side of a tongue of porphyry. It is presumed that this is the southwestward extension of the more northerly of the two faults above referred to. The fault on the southwestern side of the West Wooded Hills has a more easterly bearing than those on the northeastern side. Toward the east it enters the granite and is lost to view. Toward the west it passes into the thick Cambro-Ordovician limestone and probably beneath the overlapping Carboniferous conglomerate. The bearing of this fault is oblique to the strike of the rocks, and the displacement of the strata is downward toward the south, concealing the Reagan sandstone. The beds on each side, especially those near the base of the section, strike against the fault at high angles.

Local folding and faulting have occurred near the border of the Carboniferous conglomerate east of the West Wooded Hills. A strike fault in this district separates the Viola limestone from older formations on the west. It is evident that the displacement of the rocks on the northeast side is downward with respect to those on the opposite side. Southeastward the fault passes beneath an area of Carboniferous limestone conglomerate, which was deposited on eroded edges of the Cambrian and Ordovician rocks after the folding and faulting in this district occurred. Farther toward the southeast and extending to Washita River it is believed that the same fault continues in the strike of the Simpson formation. Its exact location, however, is difficult to determine. The displacement appears to increase southeastward, since the Simpson formation becomes gradually thinner in this direction by the loss of lower beds, until only a remnant of its thickness is present where its outcrop approaches Washita River. In the river valley the fault cuts across the Washita syncline, bringing successively Silurian, Devonian, and Carboniferous rocks in contact with the Cambro-Ordovician Arbuckle formation. East of Washita River the throw decreases, and practically ceases near the southeast corner of sec. 29, T. 2 S., R. 3 E. From approximately the same place a fault already described extends through the south limb of the Tishomingo anticline. The displacement of the rocks of this fault, however, is downward toward the south.

A second fault occurs in the rocks north of the East Wooded Hills. It joins the first near the western side of sec. 24, T. 1 S., R. 1 E., and bears toward the west, with downthrow toward the south. Thus between the two faults there is an obtuse wedge of older rocks which has been elevated with respect to the formations that occur on opposite sides of the faults.

It has been explained that the Arbuckle anticline near the crossing of Washita River and beyond toward the southeast is much contracted and strongly folded and faulted on both sides. The faults on the northern side have been described. On the southern side the disturbances are more complex and are difficult to interpret. Two and possibly more faults cross Washita River nearly in the trend of the folding, and converge toward the southeast near the southern side of sec. 31, T. 2 S., R. 3 E. The resulting displacement, when they converge, is such that Carboniferous shales are thrown down on the south and brought in contact with Ordovician limestones. In sections 32 and 33 of this township the same shales are faulted against Ordovician rocks, but on the northern side. A fault transects the fold obliquely to its trend, bearing southeast from the northern side, and approaches and seems to join the above-named converging faults near the southeast corner of section 32. Here it turns eastward in the south side of the narrow pitching end of the Arbuckle anticline, dividing Carboniferous rocks lying on the north from Ordovician limestone on the south.

Near the southern side of section 34 a narrow fragment of massive Arbuckle limestone a half mile in length is apparently projected into the Mississippian shales. The limestones are steeply upturned and the shales in exposures near by are intimately crumpled and slickensided. An attempt at explanation of the forces which produced the disturbances of the rocks would not be satisfactory without further detailed work, but it appears that there have been movements of the strata along the fault planes in the trend of the folding and that the long and narrow wedge of limestone referred to above has been thrust into the Carboniferous shales.

The rocks in the southern limb of the Arbuckle anticline have been crumpled to a small extent, apparently by forces acting in the direction of the trend of the fold. Local transverse folds occur in the strongly tilted southern limb of the anticline, and two of these are faulted. One instance was noted near Woodford and the other 6 miles east. The trend of the one is toward the northeast, while that of the other is toward the northwest. In each case the faults are traceable from the Carboniferous shales on the south into the thick Ordovician limestones on the north by means of the discordant contacts and local crumpling of the strata, due to the lateral drag on either side. Between these faults, which approach each other almost at right angles, the triangular block of strata has moved southward, or upward, with respect to the rocks on the opposite sides of the faults.

NOTES ON THE OCCURRENCE OF ORE DEPOSITS OR PRECIOUS METALS IN THE ARBUCKLE MOUNTAINS.

It has been shown in the discussion of the stratigraphy of the Arbuckle Mountains that all of the igneous rocks, including the dikes, were formed in early Cambrian or pre-Cambrian time, and that they probably suffered long erosion before the oldest sedimentary rocks were deposited. The various classes of igneous rocks, including the dikes, show no indication of faulting, fissuring, or shearing along their contacts with one another. On the contrary, there is every indication that the intrusions of granite-porphyry, aplite, or diabase as now exposed occurred at great depths, and that no occasion has been given for the passage of meteoric waters which would cause replacement or mineralization of the rocks along their contacts.

It is true that the igneous rocks, as well as the stratified rocks, of the Arbuckle region have been extensively faulted, but these faults occurred long since the formation of the igneous rocks, and they have nothing to do with the relations of the different kinds of igneous rocks with one another. All the fault contacts between the igneous and stratified rocks have been carefully traced, but no indication of the mineralization of the rocks or the occurrence of ore deposits of any consequence along them have been noted. There is nothing in the topography to aid one in tracing lines of faulting in the igneous rocks, and they are so deeply weathered or concealed by soil or surficial sand that a structural feature can not be traced for any considerable distance.

Many of the dikes, chiefly those of diabase cutting the granite, have been prospected at various times for the precious metals without any show of profit, and the sum of all information obtainable gives no assurance that ore or metal deposits of any value can be found in the region.

NOTES ON THE GEOLOGY OF THE CRINER HILLS.

Fifteen miles south of the Arbuckle Mountains and 6 miles southwest of Ardmore is a small uplift, locally known as the Criner Hills, in which are exposed all the formations occurring in the Arbuckle uplift except the pre-Cambrian igneous mass, the Reagan sandstone, and the lower part of the Arbuckle limestone.

STRATIGRAPHY.

The formations occurring in the Criner Hills include a complete section from near the top of the Cambrian up to the Carboniferous, and they are found to contain in all respects the characters appearing in the same formations in the Arbuckle Mountains, described above. A detailed description of their lithology, therefore, is not considered necessary in this place. The location and areal extent of the formations may be seen on the map.

TOPOGRAPHY.

Physiographically the Criner Hills are the Arbuckle Mountains in miniature. Composed of the same formations steeply folded and exposed to erosion in early Cretaceous time, the district was reduced to a low plain and submerged. In comparatively recent geologic time the Cretaceous deposits were removed, again exposing the older rocks to the action of erosion. It will be observed that the Criner Hills lie in an angle formed by Hickory Creek and its tributaries, and are bounded on the northeast and southwest by Cretaceous sand, the base of which, if continuous, would fall practically in a plain cutting the crests of the hills. In fact, a remnant of the Cretaceous sand may yet be seen on Carboniferous rocks at the southeast end of Criner Hills. Since the removal of the Cretaceous sand erosion has gone on more actively in the soft Carboniferous rocks than in the older and harder rocks, thereby developing the hills.

The plain at the base of the Cretaceous which falls in the crests of the Criner Hills is the same as that which marks the high levels of the Arbuckle Mountains. It was produced by the base-leveling erosion which advanced northward with the sea across the region in early Cretaceous time.

Like the larger streams in the Arbuckle region, Hickory Creek and its larger tributaries in the vicinity of the Criner Hills were imposed on the older and variably hard rocks from formerly established drainage channels in the more homogeneous southeastwardly inclined Cretaceous strata. Thus, like Washita River in the Arbuckle Mountains, Hickory Creek cut into the rocks of the Criner Hills, and is still deepening its gorge across the hard Ordovician limestones as erosion of the softer strata of the surrounding region continues to lower its surface below the plain of the Criner Hills.

The minor details of Criner Hills topography depend upon the character of the rocks composing the exposed formations. As in the Arbuckle Mountains, the Arbuckle limestone, being a massive and comparatively homogeneous formation, makes irregular stony hills, while the Viola and Hunton limestones, consisting of thinner though comparatively harder beds, make oval and smooth hills and ridges. The Sylvan shale is invariably in valleys or swales, and the Simpson formation, which is in large part composed of soft rocks, is usually occupied by valleys and lower hill slopes.

STRUCTURE OF CRINER HILLS.

The relations of the Pennsylvanian beds to the older rocks are essentially the same as in the Arbuckle Mountains, so far as could be determined by a general survey. The Sycamore limestone and Caney shale of the Mississippian occur infolded with the older rocks, and it seems evident that in this area, as elsewhere in the Arbuckle Mountain region, active disturbances of the rocks did not occur until about mid-Carboniferous time. Sufficient fossils, however, were not obtained to determine the position of the lowest Pennsylvanian beds exposed in the district.

There is a pronounced unconformity at the base of the Coal Measures strata across the northwestern end, in a large portion of the northeastern side, and at the southeastern end, of the hills. The lowest exposed beds of the Coal Measures consist of gritty siliceous limestone, sandstone, and shale interbedded, and coarse limestone conglomerates. The entire southwestern side, however, and a part of the northeastern side are marked by faults. The extent of displacement on the southeastern side is not determinable. The older rocks of the hills end abruptly in a definite but low escarpment, at the base of which a number of large springs issue. As shown by the exposures, the rocks in contact at the base of the escarpment consists of Coal Measures shales, calcareous grits, and sandstones, and dip usually toward the southwest. In the area west of Hickory Creek, except that part bordering the stream, a flat, fertile plain extends to the base of the escarpment.

The rocks of the Criner Hills structurally compose parts of four folds. All these folds are intersected by faults and are bounded on one or more sides by an overlap of Carboniferous deposits.

The larger of these folds includes the northwestern half of the hills and is a northeastward-dipping monocline or the broken southern limb of a syncline. Along and near the southwestern side the lowest exposed beds of the Arbuckle limestone are nearly flat and are locally deflected downward at low angles toward the fault which bounds the hills. It is interpreted that this local southwestward deflection of the rocks is due to the drag in the downward displacement on the opposite side of the fault. There are no means by which the extent of displacement of the strata along the southwest side of this fold can be determined. It is reasonable, however, to consider that the throw is not so great as the discordance in strata now in contact at the fault would indicate, but that it is, in part at least, due to an unconformable overlap of Carboniferous upon the folded and eroded older rocks before the faulting occurred.

A fault also bounds the northeastern side of this fold. It bears S. 25° to 30° E. from the northwest corner of the hills, oblique to the strike of the rocks and to the trend of the hills. The strata on the east side of the fault have been thrown down with respect to those on the west side. The axial part of a syncline occurs east of this fault, near the north end of the hills. The lowest rocks exposed here are Devonian (Woodford) cherty shales, which occur in contact with Ordovician (Viola) limestone on the opposite side of the fault. Near the north side of sec. 22, T. 5 S., R. 1 E., the fault crosses the axis of this syncline, and toward the southeast successively lower formations approach the fault on each side. This fault joins that in the southern boundary of the hills near the crossing of Hickory Creek. The downward displacements of these faults are in opposite directions, and it is evident that in the latter fault the displacement is greater, since it continues downward toward the southwest, beyond the junction of the faults, and to the southeast end of the hills. From Hickory Creek southeastward the inclination of the older rocks of the hills is 45° to 50° NE., while the Carboniferous rocks dip 25° to 30° SW.

East of the above-described fault, which cuts the hills diagonally, the older rocks comprise a remnant of an anticlinal fold, which trends approximately N. 20° W. The upper part of the Simpson formation is exposed in places both east and west of Hickory Creek, and the succeeding Viola limestone outcrops in large bodies on each side, making the southeastern part of the Criner Hills. Still higher formations, the Sylvan shale and the Hunton limestone, occur at the northwestern and southeastern ends of this broken fold. In the northwestern end they are terminated by faulting and overlap of the Carboniferous conglomerate, and at the opposite end apparently only by overlap. Faulting has occurred in the axial part of this fold also. At the crossing of Hickory Creek, in the SW. ¼ sec. 35, T. 6 S., R. 2 E., the Simpson formation is exposed only in the southern limb of the fold. It appears that the fault follows approximately the strike of the fold, and that the eastern limb has been thrown down with respect to the other. The dip of the rocks in the Simpson formation here is 80° SW., while on the opposite side the Viola limestone is nearly as steeply inclined in the opposite direction. In the eastern half of sec. 36, T. 5 S., R. 2 E., there is a small area of Silurian, Devonian, and Mississippian rocks, surrounded unconformably by Coal Measures strata. It appears to be a part of the northern limb of the anticline above described. The rocks dip toward the northeast, and are nearly in strike with the same formations at the southeastern end of the Criner Hills.

The Carboniferous rocks on the northeast side of this anticline have suffered folding, and near the contact with the older rocks are generally steeply inclined and dip toward the northeast. East of Hickory Creek dips of Carboniferous rocks at and near the contact vary from 25° to 40°, while the older rocks dip at greater angles and in places in different or opposite directions, indicating a great unconformity. Immediately east of the road at its crossing of Hickory Creek, near the west side of sec. 35, T. 5 S., R. 2 E., the contact is evidently upon a fault. At this place the Simpson formation dips toward the southwest, while the dip of the Carboniferous is 40° in the opposite direction. Farther southeast, and in the opposite side of the axis of the fold, the Viola, Sylvan, and Hunton formations dip northeast, in the same direction as, but at higher angles than, do the overlying Carboniferous strata. West of Hickory Creek, at the base of the Coal Measures deposits, is a strong unconformity which is probably in part due to faulting. The beds near the base are variable in character along this contact. In some places they appear to be chiefly shale, while in others, especially in sections 22 and 27, are coarse limestone conglomerates consisting of pebbles of the same nature as the limestones of the Criner Hills.

ARDMORE BASIN.

The region between the Criner Hills and Arbuckle Mountains may be characterized as the Ardmore trough or basin. The rocks consist of shale, limestone, limestone conglomerate, and sandstone, of Coal Measures age, and have been strongly folded. The trend of the folds is northwest and southeast, generally parallel with the Arbuckle and Criner Hills axes.

The details of the folding have not been worked out, but sufficient observations have been made to determine that the rocks have been crumpled into many folds, which together constitute a deep corrugated syncline or trough.

Like the Arbuckle Mountain and Criner Hills uplifts, the Ardmore trough is overlapped and concealed toward the northwest by Pennsylvanian or "Red Beds" deposits, and on the southeast by early Cretaceous sand. Toward the south the Carboniferous rocks are also concealed by Cretaceous deposits separating them from rocks of the same age in the north Texas coal field.

GEOLOGY OF THE WICHITA MOUNTAINS.

PREFATORY REMARKS.

PREVIOUS WORK.

The Wichita Mountain region was first visited by scientific observers in 1852, when Dr. George G. Shumard, who was physician to the expedition, commanded by Capt. R. B. Marcy, that explored the North Fork of Red River,[a] noted the occurrence of the igneous rocks of the mountains and the stratified sediments of the surrounding plains. The expedition touched many points along the southern side and crossed the northwestern and southeastern ends of the range. Captain Marcy mapped a part of the range, his map indicating that the range had a northeast-southwest direction, when in fact it trends southeast and northwest. The mountains and streams with one exception, still retain the names then applied. Tepe Creek was designated Spring Creek, and Tepe Mountain is evidently the eminence named Mount Webster by Captain McClellan. The names now locally used for this stream and mountain are too well established to admit change. Doctor Shumard noted that the sandstones and red clay surrounding the mountains were horizontal, and that the sandstone beds, where they approached the mountains, contained fragmental igneous materials. He also observed that the granite and porphyry were widespread in the mountains and that they contained "veins" of greenstone and quartz.

In 1899 Dr. T. B. Comstock and Mr. W. F. Cummins made a reconnaissance of a part of the Wichita Mountains.[b] Doctor Comstock had recently surveyed the "Central Mineral Region" of Texas, in which the older igneous and Paleozoic rocks occur, and his interpretations of structure and geologic relations made there were extended to the Wichita region. He assumed that the geology of the central Texas region—200 miles distant from the Wichita Range and separated from it by little distorted Carboniferous and Permian strata—was a key to its geologic interpretation. In the igneous masses of the Wichita Mountains post-Cretaceous structures were apparently recognized corresponding with those which were claimed to occur in the Texas region, where undisturbed Permian

[a] Senate Ex. Doc. No. 54, 32d Cong., 2d sess., Washington, 1853. Appendix D.

[b] First Ann. Rept. Texas Geol. Survey, 1889, pp. 319–328.

strata surrounds the mountains and no Cretaceous rocks are known. Doctor Comstock classed the granite-porphyries of the Carlton Mountains, the gabbro, and the diabase as lavas representing stages of eruption, and stated that there were flows and remnants of volcanic craters. He correctly noted the occurrence of older stratified rocks which were involved in the Wichita uplift, but failed to see that the diabase dikes which penetrate the gabbro and granite-porphyry as well as the granite are older than the oldest stratified rocks, which are of middle Cambrian age. Doctor Comstock named many of the mountains, locating them by numbers on his sketch map. Of these only Carlton, Cummins, Quana, and Navajoe can be definitely located.

In 1891 Mr. R. T. Hill made some general observations on the nature of the Wichita Mountains,[a] attempting to connect them structurally with the Ouachita Mountains of eastern Indian Territory. He notes the peculiar topographic features of the mountains and concludes "that their age is not determined," but that they are post-Silurian and have developed in part since the deposition of the "Red Beds."

In the fall of 1896 Mr. T. Wayland Vaughan, in making a reconnaissance of parts of Kansas and Oklahoma, investigated the older Paleozoic strata on the northern side of the range and made a collection of specimens representing the principal types of igneous rocks of the Wichita Range. These collections were studied and reported upon by Dr. A. C. Spencer.[b] Fossils were collected from certain limestones northeast of Tymate Mountain, which proved to be of Ordovician age. No effort was made by Mr. Vaughan to segregate or map the classes of igneous rocks, but his collections enlarged greatly the species of igneous rocks before known to occur in the region. Doctor Spencer recognized gabbro, granite, granite-porphyry, anorthosite, and troctolite. With the aid of a local surveyor Mr. Vaughan was able to locate, by reference to land surveys, practically all the mountains of the region which had been named, but none were mapped.

In the spring of 1899 Dr. H. F. Bain devoted a month's time to a reconnaissance of the Wichita Mountains, giving attention chiefly to a study of the mineral resources. His report[c] on the general geology is more complete than previous publications of the region. Doctor Bain differentiated and described the main classes of igneous rock, including the quartz veins, which in one instance he found were cut by greenstone (diabase) dikes. He considered that the granite was erupted through the porphyry and affected the Cambrian and Ordovician strata. This conclusion seems to have originated from a misinterpretation of structural con-

[a] Notes on a reconnaissance of the Ouachita mountain system in Indian Territory: Am. Jour. Sci., 3d ser., vol. 42 1891, pp. 122–123.

[b] 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. Geol., vol. 24, 1899, pp. 44–55.

[c] Geology of the Wichita Mountains: Bull. Geol. Soc. America, vol. 11, 1900, pp. 127–144.

ditions in Blue Creek Canyon. In this canyon the limestone is faulted against the granite-porphyry instead of being cut by a dike of similar rock. Cambrian rocks are recognized besides the sequence of succeeding Ordovician limestones of great thickness. The classification is substantiated by fossil determinations. Certain conglomerates composed of granite, porphyry, and limestone interbedded with shales and succeeded by shale and sandy limestone near the eastern end of the Wichita Mountains are correctly classed in age as "later than the Trenton," but instead of being older than the "Red Beds" (Permian) deposits they are evidently contemporaneous with them and form their near-shore phase. Likewise the conglomerates of limestone and various igneous rocks in the large valleys and along the borders of the Wichita and Quana groups of mountains are Permian, if the "Red Beds" are to be so classed. Beneath a zone of weathering these deposits are partially consolidated and in places associated with red clays and grits, as explained in the discussion of Permian rocks in the pages following. Along the south side of Quana Mountain, in the valleys of the larger streams, are recent surficial deposits of gravel and sand, worked over in part from the "Red Beds" conglomerate, which may be mistaken for the conglomerates in a general reconnaissance.

WORK OF THE UNITED STATES GEOLOGICAL SURVEY.

The writer, assisted by Mr. C. N. Gould and Mr. E. O. Ulrich, mapped the geology of the Wichita Mountain region in the latter part of the season of 1901. The land had been cleared of all improvements, except the occasional inclosures on the allotments to the Indians, preparatory to the opening of the country to homestead settlers. It was devoid of inhabitants outside of the few small towns, except occasional Indians and prospectors. Recently the quarter-section and section corners had been reestablished for the purpose of ready location of homesteads. This region, outside of the mountains, is an open and practically featureless plain, and the mountains are almost bare, so that conditions for rapid and accurate geologic mapping were very satisfactory.

With the assistance of Mr. Gould all the known igneous areas and the contacts between the igneous masses and the formations of stratified rocks were mapped by traverse surveys, checked by locations on section and quarter-section corner stones.

Mr. Ulrich devoted his time to a study of the Cambrian and Ordovician rocks. An abundant collection of fossils gave means by which the rocks were correctly classified, as well as correlated with the Cambrian and Ordovician formations of the Arbuckle Mountains. The lithologic similarity of these rocks to the formations of the Arbuckle region, and the duplication of fossil remains, are so nearly complete that faunal lists of the Cambrian and Ordovician of the Wichita Mountains are not considered necessary.

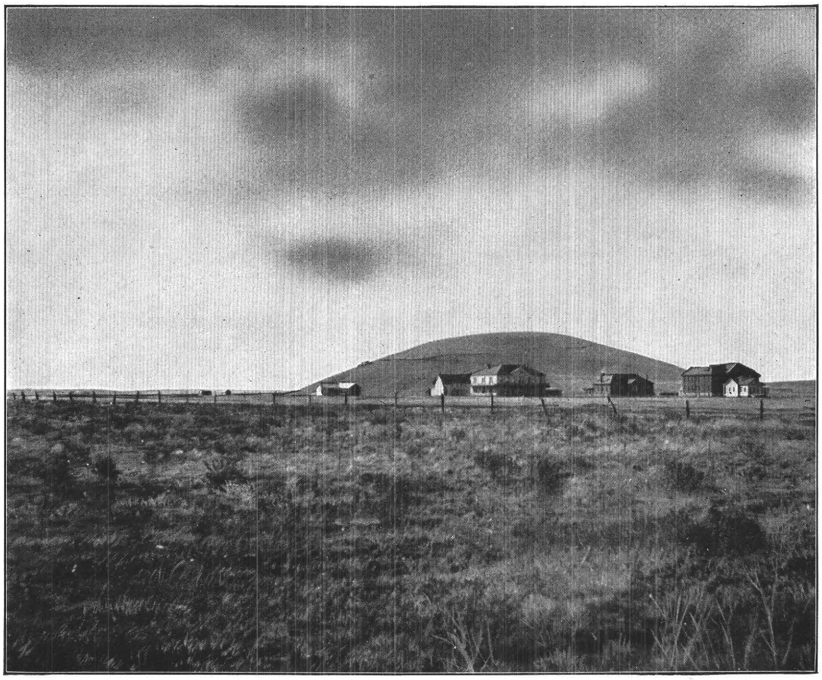
PHYSIOGRAPHY OF WICHITA MOUNTAIN REGION.

The Wichita Mountain region consists of collections of mountains, hills, and knobs extending from Fort Sill, in the Apache Indian Reservation, northwestward to beyond Granite, in Greer County, Okla., a distance of 65 miles. From the vicinity of Fort Sill the northern and southern limits of this peculiar collection of mountains diverge until, near the center, the outlying knobs upon each side are 30 miles apart. Continuing northwestward the range gradually contracts and ends in small collections of low mountains or knobs northwest of the town of Granite. The region is thus symmetrical in general outline, but not so in the arrangement, size, and form of the mountains which constitute the range, or, more properly speaking, the groups of mountains. The groups of mountains composing the range with one exception, many of the individual mountains, and numerous knobs and points of granite and other igneous rocks are surrounded and separated by the nearly level and smooth plain of the "Red Beds" which extends southward across Oklahoma into western Texas.

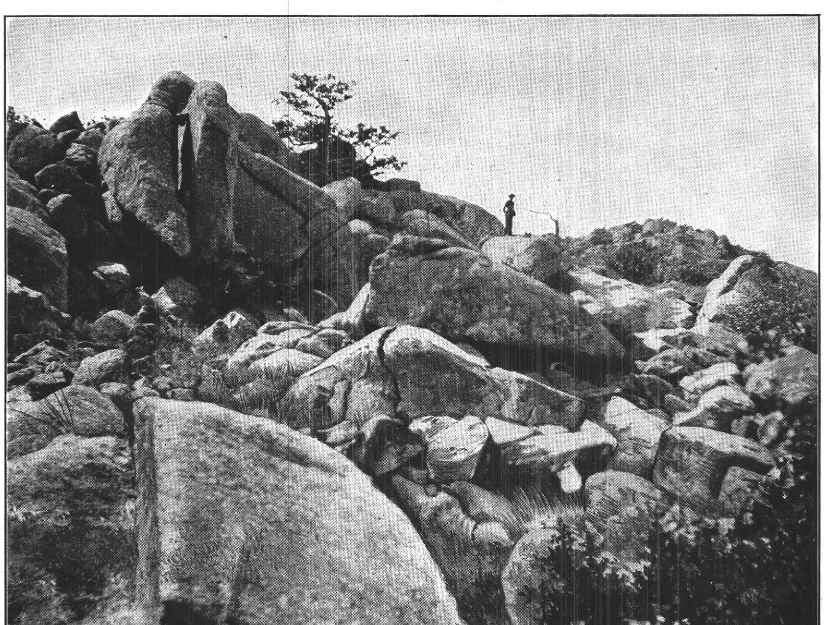
WICHITA MOUNTAIN GROUP

The largest of the groups of mountains that compose the Wichita Range is the Wichita group, from which the range has received its name. It extends from near the northwest corner of the Apache Reservation northwestward about 25 miles, and consists of many rugged and irregular granite mountains, the most prominent of which are Mounts Scott and Baker, near the southeastern and northwestern ends, respectively. On Pl. III is a view of the southeastern part of this group from the plain of Medicine Creek, looking toward the southwest, and showing Mounts Scott and Sheridan. Mount Sheridan is about 4 miles west of Mount Scott. Between Mount Sheridan and Mount Baker and Haystack Mountain, at the west end of the group, are many unnamed mountains and peaks of sharp outline, separated by narrow, rugged passes. On Pl. IV, *B*, is a view of the northwestern end of the Wichita group, showing the sharp, serrated outline of the mountain crest. Near the source of Medicine Creek an arm of the Wichitas extends northward, ending in Saddle Mountain. Saddle Mountain is separated from the main Wichita group by a low pass, which is traversed by one of the large branches of Medicine Creek. Though the highest peaks in this group rise to elevations not exceeding 1,500 feet above the bordering plain, they are difficult of ascent because of the steep and rugged slopes, which are strewn with large angular granite bowlders.

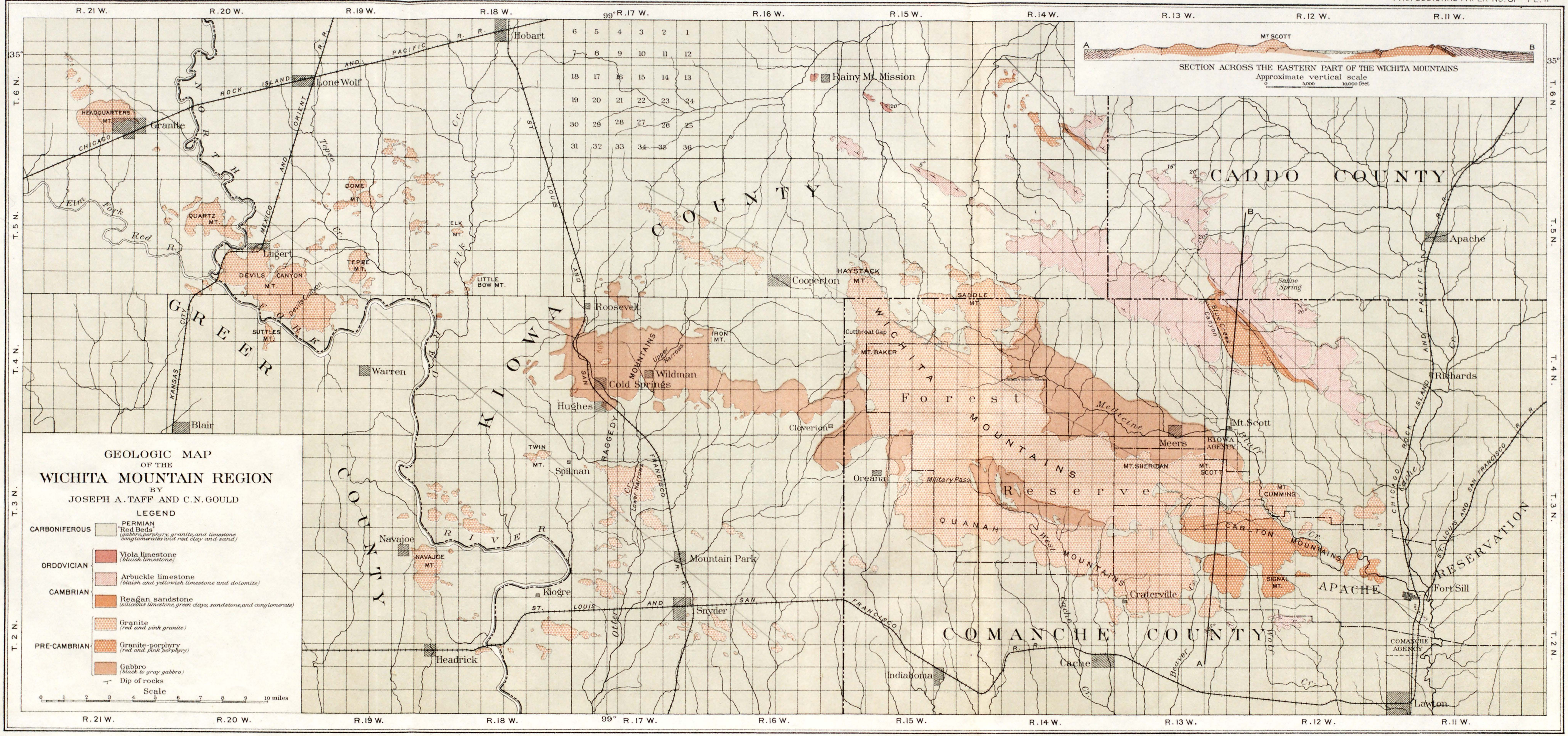
The Wichita group of mountains is separated from the Quana Mountains on the south by a wide, plain-like valley, which descends with very easy grade from Military Pass, 2 miles east of Oriana, to the western end of the Carlton Mountains,



A. RAINY MOUNTAIN, AN ORDOVICIAN LIMESTONE KNOB IN THE "RED BEDS" PLAIN.



B. GRANITE BOWLDERS IN THE EAST SLOPE OF MOUNT SCOTT.



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where it divides, the northern arm passing down a branch of Medicine Creek between Carlton Mountains and Mount Scott, while the southern arm extends to the plain down Beaver Creek. The sources of West Cache Creek occupy the western half of this valley and flow southward through gorges near the middle of the Quana Mountains.

This intermontane valley, like most other valleys of large size in the Wichita Mountain region, was formed during the deposition of the "Red Beds," of presumably Permian age, and has been resurrected and to some extent modified by more recent degradation. Many remnants of the "Red Beds" conglomerate yet remain in this valley between the present shallow drainageways from Military Pass at the head of the valley and the plain to the east upon each side of Carlton Mountains. From the same pass a wide embayment, partially filled with conglomerate and red clay deposits, opens southwestward, descending 200 feet or more to the general level of the plain about Oriana.

QUANA MOUNTAIN GROUP.

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

CARLTON MOUNTAIN GROUP.

The Carlton group consists of low mountains and peaks which lie between the east ends of the Wichita and Quana groups and extend eastward to within a mile of Fort Sill. The topographic features of the Carlton Mountains are markedly different from those of the Wichita and Quana mountains. The Carlton Mountains consist of granite-porphyries and old rhyolites, which, unlike the granite, break into small angular bowlders and fragments upon weathering, giving rounded and comparatively smooth topographic forms. The general effect is like that produced by a topographically young region composed of homogeneous soft rocks—mountains composed of numerous ridges and spurs separated by V-shaped valleys.

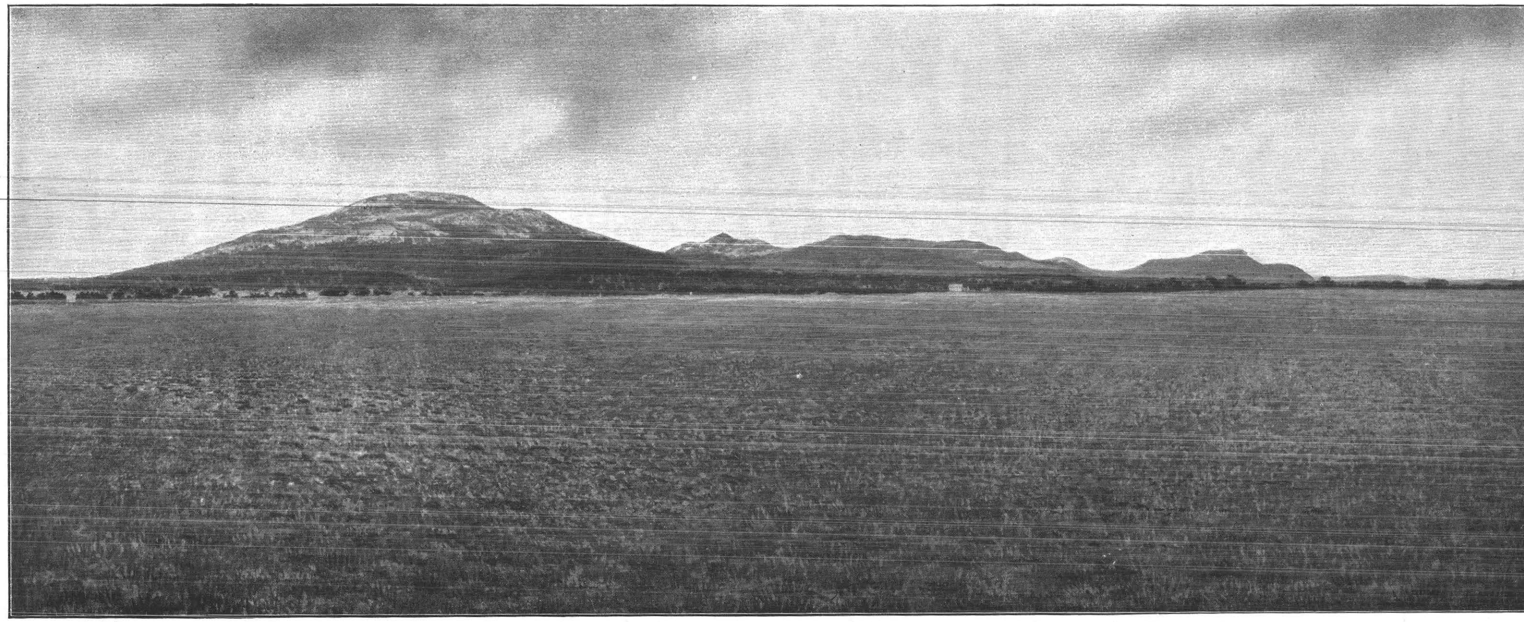
The outline of this group, as well as of its separated members, like that of all the other groups of the region, was established by marine degradation at a time when the Permian sea stood with its shores at the approximate position of the "Red Beds" and porphyry contact.

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

RAGGEDY MOUNTAINS.

West of the Wichita and Quana mountains and extending southwest to Navajoe, in the valley of the North Fork of Red River, is a scattered group of mountains and hills, the individuals of which are separated by the "Red Beds" plain. To this group the name of Raggedy Mountains has been applied. Twin and Navajoe mountains, in the southwestern part of the group, are the only mountains to which names had been given when the region was surveyed in the fall of 1901. Contrary to the arrangement of the Wichita, Quana, and Carlton groups, which have northeast-southwest bearings governed in a measure by the structure, the Raggedy Mountains are longest north and south, an arrangement which seems to be accidental. Between the Wichita-Quana group and the Raggedy Mountains the flat plain is unobstructed. While gabbro rocks come to the surface across this plain and connect the gabbro of the central mass of the Raggedy group with the Wichita, they were completely worn down and submerged in Permian time and stand now in the level of the smooth "Red Beds" plain. Southwest from the Quana Mountains there is a broken string of granite knobs and hills connecting with the south end of the Raggedy group.

The central mass of the Raggedy Mountains is composed of gabbro, and is the only area of this rock exposed in the region which has not been reduced almost to the present level of the "Red Beds" plain. These mountains of gabbro lie east and southeast of Roosevelt, on both sides of Otter Creek. That part of the gabbro area of the Raggedy group south of Roosevelt and a fringe around the more mountainous part are practically in the level of the plain and contain thin patches of the "Red Beds" deposits, a remnant of the strata which once extended over the whole reduced portion. Here and there in the reduced gabbro area are mounds and low rounded knobs which have not been affected by recent active



NORTHEASTERN FACE OF THE WICHITA MOUNTAINS.

Showing Mounts Scott and Sheridan.

erosion. The highest gabbro mountains lie on each side of the Upper Narrows and rise to elevations of 600 to 800 feet above the level of the plain. Iron Mountain is a knob in an arm of gabbro extending northeast of the Upper Narrows and is cut off from the mountain mass by a wide, flat divide. The detached elongated area east of Roosevelt makes low rounded hills 100 to 200 feet in height.

On disintegrating the gabbro breaks into bowlders in a manner similar to the granite, but they are generally smaller and rounded and give rotund topographic forms similar to the porphyry topography of the Carlton Mountains.

The northern and southern parts of the Raggedy group are composed of isolated granite mountains and knobs set in the smooth "Red Beds" plain. Many of the smaller ones rise abruptly 100 feet, more or less, above the red sediments of the plain, with evenly curved boundaries and steep sides, and have the appearance of nearly submerged peaks. In fact, they were islands in Permian time, and many—probably all—were submerged. There is no reason to doubt that these isolated areas, as well as mountain groups of igneous rocks, are connected beneath the "Red Beds" and formed peaks and knobs of a single broad range which were partly or wholly submerged and separated by the Permian sediments.

A peculiar feature of the Raggedy Mountains is that Otter Creek flows across the central part of the group and has cut through the more rugged gabbro and granite mountains, making narrow, sharp gorges known as the Upper and Lower Narrows. One of the large branches of this creek rises in the northernmost group of granite hills and flows across the gently rolling plain and passes the sharp gorges of the Narrows, 100 to 200 feet in depth, cut in wider divides which separate the higher knobs or peaks of the mountains. The only inference apparent at this time concerning the peculiar course of Otter Creek through the Raggedy group is that it occupied practically its present location at a time when the surface of the "Red Beds" plain stood above the divides between higher knobs of the igneous mountains in which the gorges of the Upper and Lower Narrows are cut. At that time the plain was nearly 200 feet above its present position, and as general degradation of the land progressed, Otter Creek was imposed upon the gabbro and granite masses which constitute the present Raggedy Mountains.

DEVILS CANYON GROUP.

The watershed between Elk and Otter creeks is a low and almost imperceptible swell in the plain. This divide separates the Raggedy Mountain group from the considerable collection of granite mountains and hills, including Little Bow, Elk, Dome, Teepee, Quartz, Suttles, and Devils Canyon mountains, besides many unnamed mountains and hills, which may be known as the Devils Canyon group.

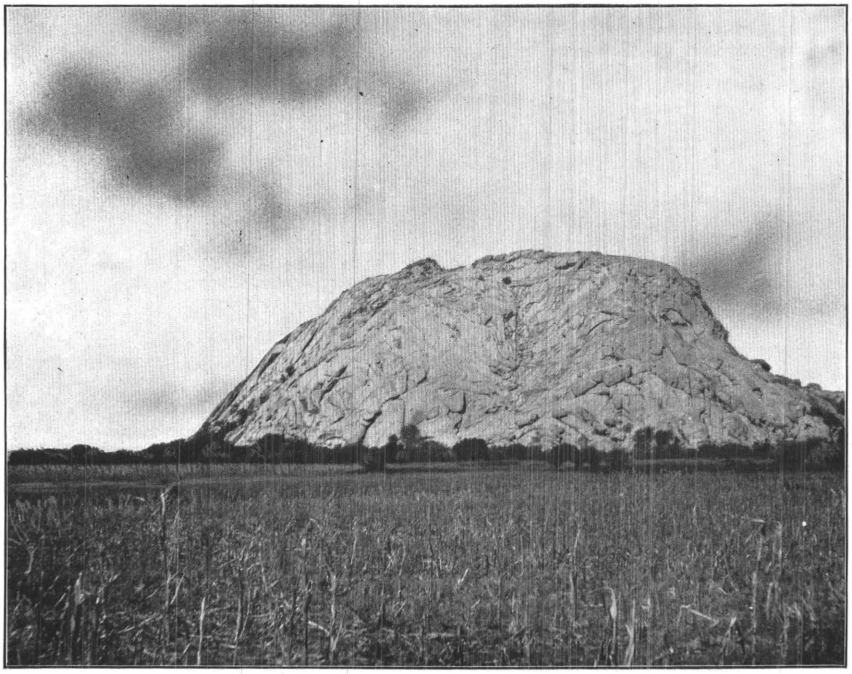
These mountains lie in the valley of the North Fork of Red River, and the channel of the river meanders among them, touching a number of the larger ones. The Devils Canyon group is composed almost entirely of granite, which protrudes through the "Red Beds." The rock is the same kind as that of the Wichita and Quana mountains and presents the same topographic forms. The smaller mountains and isolated knobs rise abruptly from the plain, their steep slopes being strewn with angular bowlders. The larger masses of granite, such as Quartz, Dome, and Devils Canyon mountains, contain many rounded knobs and peaks, rising 600 to 800 feet above the plain and separated by rugged gulches or divides. Many of these crests are dome shaped. This form was especially noted in Teepee and Dome mountains. In Dome Mountain the dome-shaped knob of the crest, 100 feet or more in height, sits 300 to 400 feet above the plain on a wide terrace or table of the mountain. On Pl. IV, *A*, is a view of the southwestern peak of Quartz Mountain, illustrating the abrupt ascent from the level plain and the forms of the isolated knobs in the western part of the Wichita region.

HEADQUARTERS MOUNTAIN GROUP.

At the extreme northwestern end of the Wichita Range is a small group of granite mountains which lie entirely west of Red River and northwest of the town of Granite. The largest of these is Headquarters Mountain, which covers an area of nearly 3 square miles and rises steeply to an oval crest about 600 feet above the plain. These mountains are composed of red granite similar to that of the Wichita group, but the mountain peaks and knobs have a rounded form, though the slopes are strewn with large bowlders.

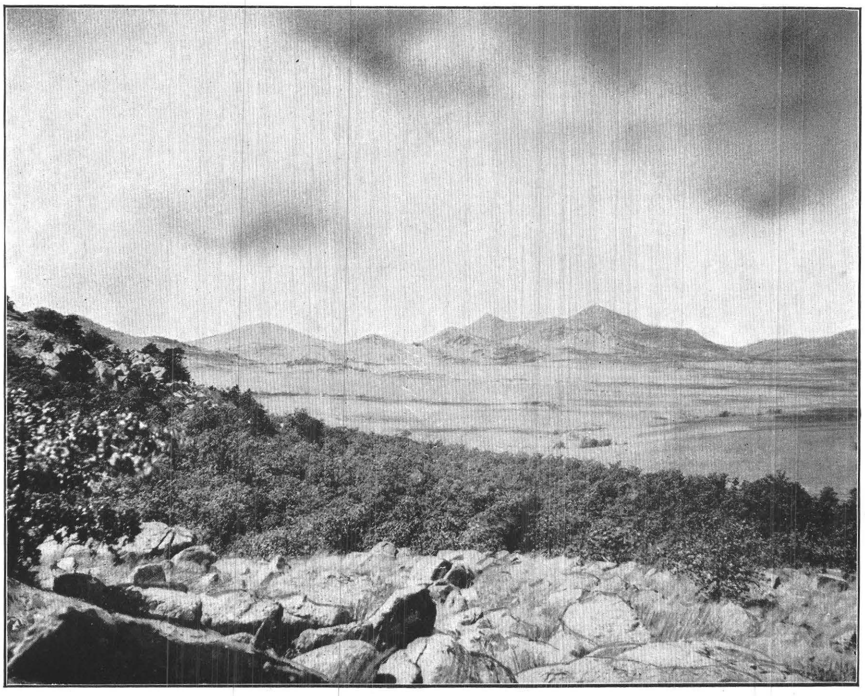
LIMESTONE HILLS.

Another mountain group of the Wichita region is the elongated collection of limestone and porphyry hills and low mountains which lies northeast of the Wichita group and is separated from it by a long strip of rolling plain 2 to 6 miles in width. This group, which has received no adequate name, extends from a point 7 miles north of Fort Sill northwestward, with the general strike of the rocks, to Rainy Mountain at Rainy Mountain Mission. It gradually expands in a rudely triangular form and reaches a width of about 7 miles in the central part. Near the middle, north of Mount Scott, the compact mass of hills is divided into two portions by a broad, flat inlet of the "Red Beds" deposit of the plain. Each of these arms is broken northeast of Saddle Mountain into numerous low mountains or hills, which are oriented generally northwest–southeast, with the trend or strike of the rocks. The northern arm contains a number of porphyry hills. A mass of porphyry also occurs between the limestone hills north of



A. SOUTHWESTERN KNOB OF QUARTZ MOUNTAIN.

Showing abrupt ascent of granite from the level plain.



B. NORTHWEST END OF THE WICHITA MOUNTAINS.

Showing sharp mountain crests and embayment of "Red Beds."

Mount Scott. The detached masses of limestone and porphyry are surrounded throughout this region by the open and level "Red Beds" plain.

The topographic details of the porphyry hills in this group are of the same character as in the porphyry hills composing the Carlton Mountains. The surface is broken and cut by many gulches and sharp defiles, but the hills are generally smooth crested and have rounded or oval forms.

The limestone hills have the same topographic features as the porphyry hills, and many of their crests are now 400 to 600 feet above the plain. Pl. V, *A*, shows a typical knob of Ordovician limestone near Rainy Mountain Mission, at the extreme western end of the limestone hills, known as Rainy Mountain.

Like all the other mountains of the region, the location, general plan, and contour of the hills are due to a cycle of degradation culminating in Permian time and to later minor modifications. The larger valleys descending from the more prominent limestone and porphyry hills, as well as the broader level passes of the plain which separate them, are not always occupied or followed by the principal drainage lines. These larger valleys and passes do not contain extensive deposits of recent local conglomerates, which might be supposed to extend as fans or sheets out from the mouths of the valley. The deposits of conglomerate descend or extend into the plain, blending with the red grits and clays and forming parts of the plains materials. The partly consolidated gravel, sand, and clay which filled the old valleys are softer than the crystalline limestone and porphyry now making the hills, and they were therefore more rapidly eroded and the old valleys were resurrected and are perpetuated. Many of the streams are small, but when established in their positions in the once submerged and filled valleys, as the general degradation of the land progressed, they cut downward without regard to the older and harder rocks. Thus many of the streams once flowing in the softer rocks became imposed upon the spurs and slopes of hard limestone bordering the old valleys. Marked instances of such superimposed drainage occur in Tps. 4 and 5 N., R. 12 W., where small streams, flowing in the wide resurrected valleys whose floors are filled with "Red Beds" deposits, cut through sharp spurs projecting from the limestone hills, while the level plain upon soft rocks was opened for their passage.

STRATIGRAPHY OF WICHITA MOUNTAINS.

IGNEOUS ROCKS.

In the general survey of the Wichita Mountains only sufficient time was available to study the salient features of the igneous rocks. The kinds of igneous rocks which occur abundantly or in large masses were distinguished, classified in respect to age as far as conditions would permit, and mapped. Local variations of the larger masses and various phases of the dike rocks were noted and specimens collected, but a study of their relations in detail was not attempted. The rocks collected were submitted to Mr. Ernest Howe, of the Geological Survey, for study, and the petrographic descriptions are from his report.

The igneous rocks of the Wichita Mountains are separated into four general classes, distinguished by their large mass or abundant occurrence, and also by their age relations. These, in order of apparent age, are, gabbro and related anorthosite, granite and related aplites, granite-porphyry and associated aporhyolite, and diabase dike rocks.

GABBRO AND RELATED ANORTHOSITE.

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

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

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

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

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

GRANITE AND ASSOCIATED APLITE.

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

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

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

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

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

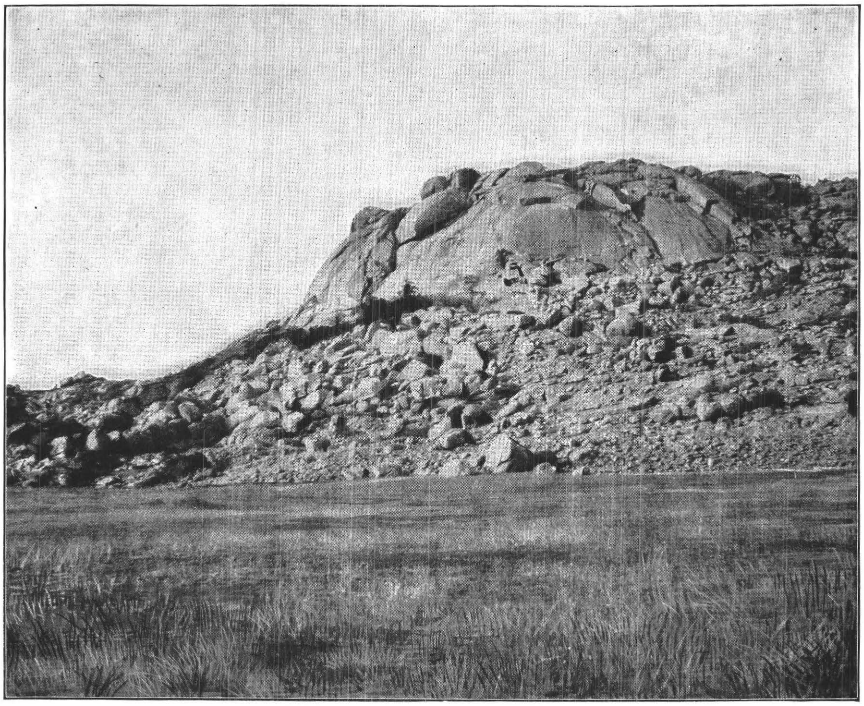
Variations of the granite from the average type are found chiefly near its contact with the gabbro. A particular instance was noted in the SE. ¼ sec. 21, T. 4 N., R. 14 W., where the granite mass rests against the gabbro. Hand specimens show the rock to be strongly porphyritic, and it may be called spherulitic granite-porphyry. A similar contact phase of the granite with gabbro occurs near the center of the south side of sec. 16, T. 4 N., R. 14 W.

The dikes which extend from the granite and cut the gabbro range from massive bodies 40 feet and more in thickness to thin sheet and stringers. Usually the rock of the thicker dikes is coarser and is more nearly related to typical granite than the rock of the thin dikes. A dike, 40 feet in width, cutting the gabbro in the SE. ¼ sec. 4, T. 4 N., R. 13 W., is characterized as an augite-hornblende-granite. The dikes generally, however, are best described as aplites. They are fine-grained rocks, in gray, pink, and lighter colors. Quartz and feldspar occur in the usual fine mosaic characteristic of aplites. The feldspar is predominantly orthoclase, plagioclase being present only in very small amounts. Augite, hornblende, and biotite occur, but never prominently; muscovite is rarely present, and the usual accessories of granite, magnetite, titanite, apatite, and zircon are generally found in small amounts.

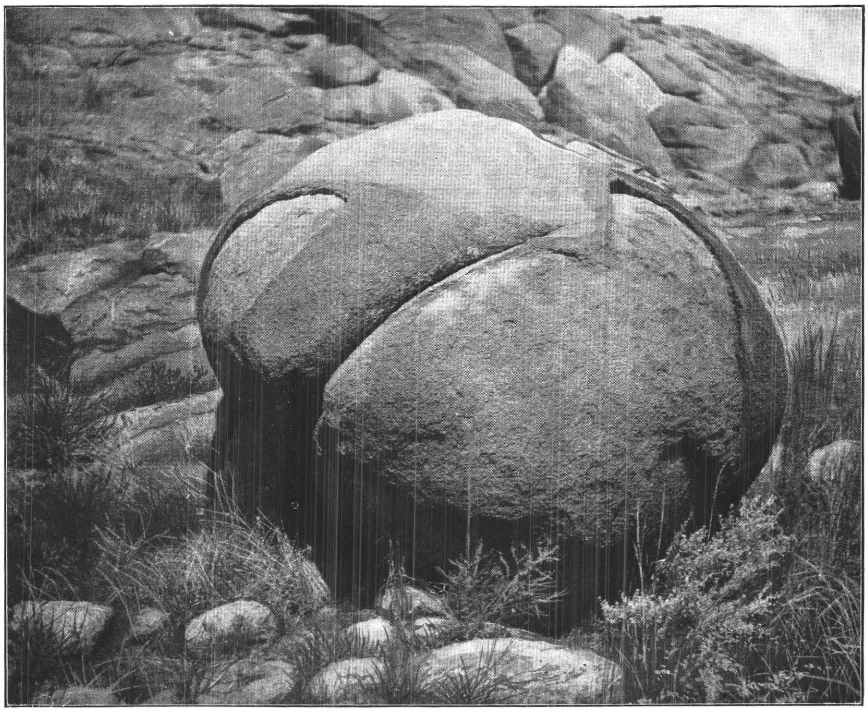
The contact between the granite and granite-porphyry is exposed south of Mount Scott for a few miles. To the west, across secs. 22 and 23, T. 3 N., R. 13 W., the contact between the granite and porphyry can be traced, although the contrast in the rocks on each side is not strong, as the two rocks are practically the same in color and in granular texture. Apparently, also, there is a gradation through a short space from the granite to the granite-porphyry. Along the eastern part of the contact, in parts of sec. 24, T. 3 N., R. 13 W., and farther east, a wide band of finely granular aplite occurs between the granite and the granite-porphyry.

In the description of the structure of the Wichita Range it was observed that there are zones of fracturing and jointing in the granite. In such localities the rock on weathering breaks up into relatively small, angular bowlders. The prevailing surface features of the granite, however, are coarse and rugged, the rocks having broken deeply into large angular bowlders between widely set joints, and become rounded on long weathering. The slopes of Mount Scott are typical of the granite surface of large masses. (See Pl. V, *B*.) The lower slopes of the knobs and mountains are strewn with immense bowlders, many of which descend to the borders of the plain. The large bowlders become well rounded on long surface exposure, and some of these in old age are reduced by exfoliation. A typical example of this peculiar mode of weathering occurs at the southern side of Quartz Mountain, and is shown in Pl. VI, *B*.

In the western part of the Wichita Range many of the low mountains and



A. EXFOLIATE WEATHERING OF GRANITE MOUNTAIN 3 MILES NORTHWEST OF SNYDER.



B. EXFOLIATE WEATHERING OF GRANITE BOWLDER, SOUTH SIDE OF QUARTZ MOUNTAIN.

knobs have dome-shaped or oval crests. The centers of some of these show large masses of granite but little broken. A typical knob of this character may be seen in one of the crests of the granite mountains of the Raggedy group in sec. 22, T. 3 N., R. 17 W. On long exposure the massive granite knob has assumed exfoliation on a large scale. From the plain on the southwestern side large segments of granite, many feet thick, may be seen becoming detached from a spheroidal dome. This view is illustrated on Pl. VI, *A*.

GRANITE-PORPHYRY AND ASSOCIATED APORHYOLITE.

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

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

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

Another porphyry, distinct from that just described, is found in the east end of the Carlton Hills, at the east end of Medicine Bluff. It is a dull-pink rock, with phenocrysts of feldspar and quartz, in a dense or finely granular groundmass. The feldspar phenocrysts are all orthoclase, frequently twinned according to the Carlsbad law, and from 3 to 4 millimeters in length. The groundmass, largely feldspathic, and in part possibly micropegmatitic, is now very much decomposed, and looks not unlike the devitrified base of a surface glassy flow. With the exception of a little doubtful hornblende there are no dark silicates to be made out. The feldspars are all charged with a fine reddish dust, probably hematite.

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

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

On weathering the porphyry breaks into small bowlders and fragments, and the hills composing it have distinctly rounded forms. At Medicine Bluff, 1½ miles northwest of Fort Sill, the granite-porphyry is exposed in a vertical cliff 100 to 400 feet high, showing rude columnar structure, doubtless due to close parallel and cross jointing. Pl. VII is a view of Medicine Bluff showing this peculiar jointing. The distinct, closely placed parallel joints may be seen a considerable distance extending nearly vertically from the top of the bluff to the bed of Medicine Creek. Whether this structure is common in other parts of the granite-porphyry of the Wichita Mountains can not be determined on account of the mantle of weathered surface rock. It is presumed that similar structural conditions occur, since the characteristic weathering of the porphyry into small angular blocks is universal.

DIABASE.

The gabbro, granite, and granite-porphyry, the only igneous rocks in the Wichita region which are known to occur in large masses, are cut by great numbers of diabase dikes. These dikes range in thickness from several feet to thin stringers. They cross the contact between the granite and the gabbro and intersect the granite dikes in the gabbro.

These diabase dikes extend in various directions, but sufficient time was not given to their study to determine whether they conform to any system of arrangement. Dikes of the same texture and color penetrate one another at various angles, but whether they are of one or more generations was not ascertained.

The diabase ranges from a moderately fine-grained dark-gray to fine-textured bluish-black rock. As a rule, the larger the dikes the coarser the texture. A thick and apparently neck-like dike in the granite-porphyry of Blue Creek Canyon has a texture approaching that of the average gabbro.

Petrographically these dike rocks have the typical structure and mineral composition of diabase. One specimen, from a dike 18 inches wide cutting both gabbro and granite, contains, in addition to labradorite, augite, and magnetite, a considerable amount of a brownish-yellow mineral which is evidently an alteration product, but which possesses the optical characters of serpentine, and was probably derived from olivine, as outlines of olivine crystals are still to be made out. The ophitic structure of the rock is emphasized by this mineral, for it partly surrounds the laths of labradorite after the manner of the augite.

A number of diabase dikes were noted intruding the granite-porphyry of the Blue Creek Canyon area near the Cambrian contact, and pebbles, both of granite-porphyry and of diabase, make conglomerate beds in the Reagan formation, which is the oldest sedimentary deposit of the region, being middle Cambrian in age. Thus all the evidence of the age of the igneous rocks so far obtainable indicates that they are older than middle Cambrian, and, since granites form only at considerable depths or under great pressure, the inference is that they are much older than middle Cambrian.

QUARTZ-MONZONITE.

Certain rocks occurring in association with granite-porphyry, granite, or gabbro, and in the field considered to be phases of these rocks, on microscopic study were found to be quartz-monzonite. The rock associated with granite-porphyry was found at the western bank of Medicine Creek, in the NW. ¼ sec. 35, T. 3 N., R. 12 W. It is dense, rather fine grained, porphyritic, deep red in color, and has a general physical resemblance to much of the granite-porphyry of the region. Near the center of sec. 25, T. 3 N., R. 14 W., a granular gray rock was found in the wall of a narrow mineralized zone in which galena is disseminated in small quantity. The country rock here is the ordinary granite of the region, and the specimen collected was considered to be a phase of the same. Two specimens of finely granular gray rock were obtained near the center of sec. 13 and in the NW. ¼ sec. 17, T. 4 N., R. 17 W. They occur in the large gabbro area of the Raggedy Mountains and near granitic intrusions, which cut also the ordinary coarsely crystalline gabbro. The specimens of finely granular rock are all more or less decomposed, so that exact determinations were not possible.

The predominant constituents of the monzonite are orthoclase and some plagioclase feldspar, which is difficult to determine on account of its decomposed condition. In a few cases there is an indication of oligoclase, and in one the plagioclase seemed to be as basic as labradorite. The relations of the two feldspars vary somewhat, but orthoclase is generally slightly in excess. In all specimens quartz occurs, but never in great abundance. It is usually in the form of pegmatitic intergrowths with orthoclase. Hornblende and accessory biotite, though seldom fresh, are present in all the rocks, frequently in abundance. Accessory minerals are inconspicuous.

QUARTZ VEINS OR DIKES.

The large igneous masses above described contain here and there veins or dikes of white quartz. Probably the most extensive deposits of quartz occur in nearly east-west leads in the central part of the gabbro area of the Raggedy Mountain group. Quartz bands were noted by Dr. H. F. Bain in the granite of the Quana Mountains in the valley of the stream which flows south through sec. 35, T. 3 N., R. 14 W. Quartz bands were found also in a small gabbro hill in the southeast corner of sec. 6, T. 4 N., R. 18 W., near a large granitic dike which cuts the gabbro in an east-west direction. Like the diabase dikes, the quartz bodies extend both across and in the direction of the trend of the Wichita Range. It has been reported by Doctor Bain[a] that some of the quartz veins are granular and contain mica, and that a large one cutting the granite-porphyry of the Carlton Mountains at Medicine Bluff is intersected by a diabase dike.

It has been shown that the granite-porphyry and the diabase dikes which intrude it were formed prior to middle Cambrian time. The relations of quartz bodies and diabase dikes in the Carlton Mountains and the granular structure of the quartz suggest strongly that at least one of the quartz bodies is a true dike and not a vein deposit.

GRORUDITE.

Two dikes of peculiar nature, cutting gabbro, were located, one in the SE. ¼ sec. 4, T. 3 N., R. 15 W., and the other near the center of sec. 9 of the same township. The first is 4 to 6 inches thick and cuts a large gabbro mass near the contact with the granite, toward which it bears. The other is 18 inches to 2 feet thick and occurs in the same gabbro area, but at a point where the gabbro is less than one-fourth of a mile in width and is bounded on each side by granite. As in the first instance, the dike bears across the gabbro and toward the granite. In neither case, however, could the dikes be traced into or connected with the granite on account of the disintegrated and bowldery nature of the latter near the bases of the hills at the contact with the gabbro. While the general bearing of the larger dike is east-west, it appears to have been folded or distorted. It curves in different directions, and inclines at various angles, from nearly flat to a vertical position.

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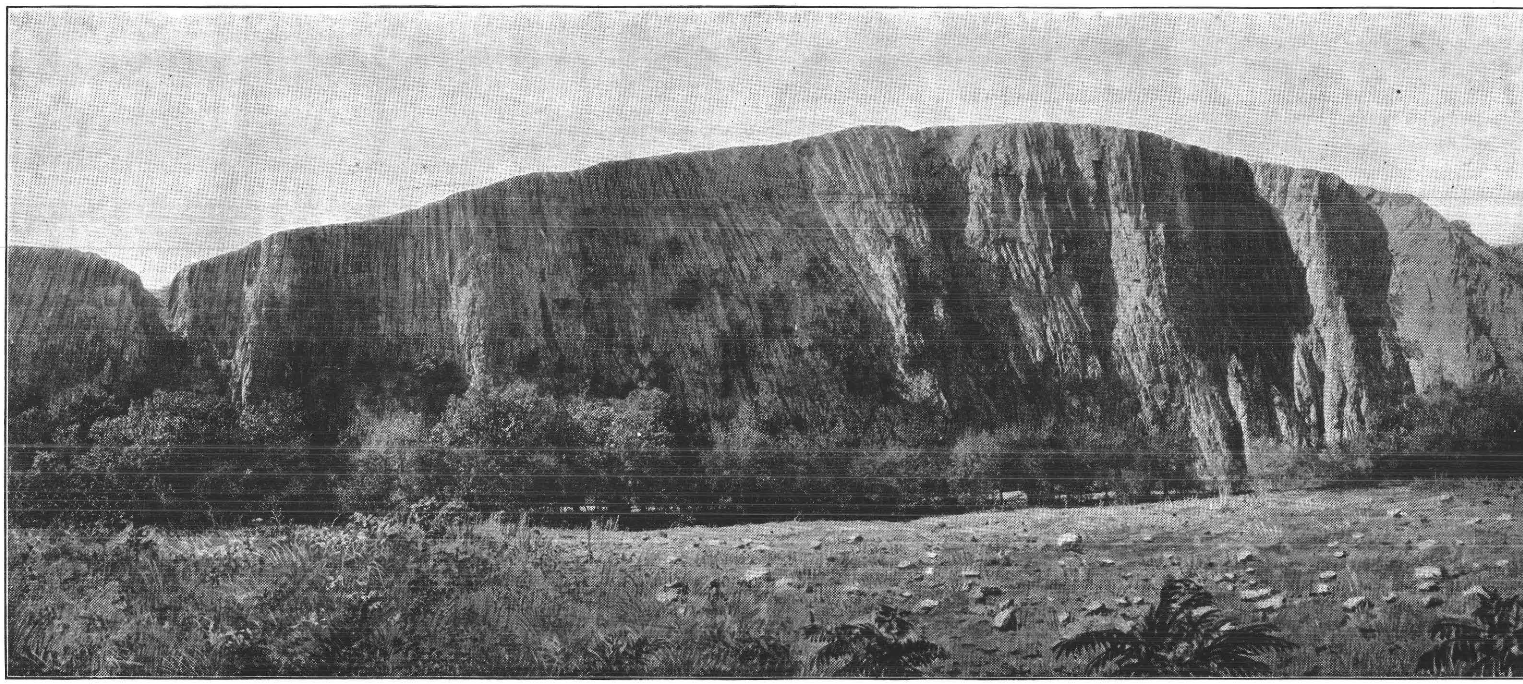
[a] Geology of the Wichita Mountains: Bull. Geol. Soc. America, vol. 2, 1900, pp. 127–144.



MEDICINE BLUFF, NORTH SIDE OF CARLTON MOUNTAINS.

This dike rock is reddish to greenish gray, and granular in texture. Usually on each side near the contact it is coarsely crystalline and resembles pegmatite in structure, while toward the center it becomes by degrees finely granular; and with the variation in structure there is a gradation from light to dark colors, giving the dike a rudely banded, vein-like appearance.

On microscopic examination it is found that a large amount of quartz and feldspar in irregular masses is penetrated by elongated crystals of a nearly black ægirite. There is a rapid transition between the coarse border and the interior, which is very fine textured and in which individual crystals can not be distinguished by the unaided eye. The prevailing color of the interior is dull green. Another portion in an intermediate position is a little less finely grained, and individual crystals can be made out in hand specimens. This has a slightly different composition from the rest, and the relation of the two is not clear. Under the microscope the rock is found to be composed of quartz, feldspar, and ægirite. The different occurrences show slight variation in the character of the feldspar, but the average is orthoclase and microperthite or microcline-microperthite in nearly equal proportions, with albite and some anorthoclase. Quartz follows the feldspars in the importance of its occurrence. Ægirite is abundant, and is fresh and typical in appearance. It occurs in crystals one-half to three-fourths of an inch long in the border zone, and in fine acicular needles or mesh-like aggregates surrounding the grains of feldspar and quartz in the interior of the dike. It has the appearance of having been developed later than the feldspars. As well as can be determined from a microscopic examination, the rock is practically the same as the grorudite described by Brögger.[a]

A few specimens from different parts of the same dike would probably have nearly the same chemical composition as the rock described, but the soda-rich pyroxene appears in very subordinate amounts and its place has been largely taken by arfvedsonite. In other details the rock is also different from the grorudite. Albite in irregular laths is the most prominent feldspar, and with it is associated microperthite, but little or no orthoclase. Quartz is abundant, and the arfvedsonite, often intergrown with ægirite, is a most striking constituent. Ægirite is also found free from arfvedsonite, in needles and larger masses, but it is a distinctly subordinate mineral.

SEDIMENTARY ROCKS.

In the Wichita region and the Arbuckle Mountain region the formations below the "Red Beds" agree in all essentials, both in lithologic characters and in age, in so far as they are exposed, and are of essentially the same thickness.

[a] Zeitschr. für Kryst., vol. 16, 1890, pp. 65–69; Eruptivgest. d. Kristianiageb., I, Grorudit-Tinguait Serie, pp. 46–48, Kristiania, 1894.

Therefore the classification and the formation names employed for the Arbuckle region are used also for the Wichita Mountains.

CAMBRIAN ROCKS.

Reagan sandstone.—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 formation is known to outcrop in this region in but four areas. The largest of these lies on the northeastern side of the large mass of porphyry east of Blue Creek Canyon and is beneath the thick section of Cambro-Ordovician limestone, which follows in regular stratigraphic succession. The other three areas are near the northwestern end of the group of limestone hills, 8 to 12 miles northwest of and in the strike of the large area near Blue Creek Canyon. The same granite-porphyry either is exposed near by or is in contact beneath the Reagan sandstone and the Cambro-Ordovician limestones. Between these smaller outcrops of the Reagan sandstone, as well as in many other places where the succeeding limestone indicates that it should occur, the Reagan sandstone is concealed by the widespread "Red Beds" deposits. In all the occurrences cited the Reagan sandstone dips in a northeasterly direction and is so aligned in strike as to show, without doubt, that it is continuous beneath the "Red Beds."

In a part of the larger area east of Blue Creek Canyon the Reagan sandstone is repeated in parallel belts by faulting. The fault approaches the stratified rocks in the porphyry from beneath the "Red Beds," bearing nearly due northwest. The downthrow is toward the southwest, giving sufficient displacement to bring the whole section of the Reagan sandstone against the belt of porphyry which occurs between the duplicate outcrops of the sandstone. The displacement due to faulting decreases toward the northwest and comes to an end near the northwest corner of sec. 1, T. 4 N., R. 13 W. The normal dip of the rocks is toward the northeast, varying from a few degrees to about 25°. Next to the fault on the southwest or downthrown side there is a reverse dip, due to the upward flexing of the strata in the faulting, which is sufficient to produce a narrow synclinal fold a mile or more in length, ending in a spoon-like form, with porphyry upon each side and beneath. The Reagan sandstone is softer than either the porphyry beneath it or the succeeding Arbuckle limestone. In consequence it forms the base and northeast side of valleys, and forms bluffs and steep slopes in which the rocks are admirably exposed. The section accompanying the map illustrates the relations and structure of the rocks, including the Reagan sandstone, across the northeast corner of T. 4 N., R. 13 W. Pl. VIII, *A*, is a view of the Reagan sandstone and associated rocks in the NE. ¼ sec. 12, T. 4 N., R. 13 W., looking northwest. The porphyry upon which the Reagan sandstone rests is on the left, and the Arbuckle above the sandstone caps the mountain on the right.

The Reagan sandstone is approximately 300 feet thick and is composed of hard and soft sandstone, grit, conglomerate, shales, and siliceous shell limestones. The section of the formation is essentially the same as in the western end of the Arbuckle Mountains. In each case porphyry is beneath it, and the limestone which overlies the Reagan is of the same nature and contains the same fossil fauna. In both localities the Reagan formation is made up of conglomerate composed of porphyry pebbles and included basic rocks, gritty light-brown to gray and greenish sandstones, greenish clay shales, and siliceous limestones, interstratified. The limy layers contain many species of Cambrian fossils, which were carefully collected, but which have not yet been thoroughly studied. 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.

From Blue Creek Canyon northwest toward Rainy Mountain Mission the Reagan formation should occur, in the natural order of succession, beneath the "Red Beds" plain, between the igneous rocks of the Wichita Mountain group and the limestone of the long ridges to the northeast. Southeastward of Blue Creek Canyon, beneath Fort Sill, and westward from Fort Sill, its stratigraphic position is between the porphyry of the Carlton Mountains and the limestone of the hills. These limestones are in the lower part of the Ordovician, and their southward dips indicate that the Reagan sandstone is concealed unconformably beneath the "Red Beds." The basal "Red Beds" grits outcropping at the eastern end of the Carlton Mountains resemble parts of the Reagan formation occurring east of Blue Creek Canyon. As the "Red Beds" grit is composed of porphyry material, and is for the most part a local beach deposit like the Cambrian sandstone, it is necessary to determine the relations of the individual beds to the succeeding strata in order to classify them.

CAMBRO-ORDOVICIAN ROCKS.

Arbuckle limestone.—Above the Reagan formation in conformable succession is a great limestone section essentially the same as the Arbuckle formation in the Arbuckle Mountains, where the lower part, practically the lower third, was found to be Cambrian, and the upper two-thirds Ordovician in age. Near the transition zone, between the rocks of the two periods, very few fossils have been found, so that precise distinctions as to age can not be made at the present time. The same conditions of deposition seem to have occurred in the Wichita region as in the Arbuckles, and the rocks must be classified in the same manner. There seems to be no reason to doubt that the formation is continuous from one region to the other beneath "Red Beds" deposits.

With the exception of three small areas near Rainy Mountain Mission, all the limestones found in the area mapped belong to the Arbuckle formation. There are certain thin limy strata in the "Red Beds" which do not resemble the older limestones and have not been mapped. The Arbuckle limestone is composed of a practically continuous succession of limestone beds, usually less that 5 feet in thickness and aggregating 4,000 to 6,000 feet. The individual beds vary from dense, fine-grained, white limestone to cream-colored dolomitic limestones interstratified with slightly argillaceous and siliceous lime beds, which are usually not so hard. Occasional cherty limestones, and more rarely thin beds of chert, occur. As a result of the variable hardness of the beds, the more resistant ones have a relief which rarely exceeds 5 or 6 feet. A complete section of the formation is not exposed in the region. The thickest exposure found is northeast of Blue Creek Canyon, where the rocks outcrop in regular succession from the base upward for nearly 3 miles. The dip is approximately 20° NE., and approximately 4,000 feet of this limestone are exposed. It is estimated that the same thickness is exposed in the long arm of limestone hills outcropping northwestward from Blue Creek Canyon. Neither the top nor the base of the limestone, has been found in the hills west of Blue Creek Canyon. The lowest limestones exposed beneath the "Red Beds" at the southwestern side, however, are near the base and those of the northeastern side are toward the top.

The elongated limestone hills at the northeastern part of T. 5 N., R. 15 W., and in the southwestern portion of T. 6 N., R. 15 W., belong most likely below the middle of the section, as determined by the abundant fossil remains and by the position in the strike of the central part of the section exposed in the large limestone mass toward the southeast. Likewise the limestones occurring at the quarries southeast of Fort Sill, south of Signal Mountain, and farther west at the eastern end of the Quana Mountains, belong below the middle of the Arbuckle formation. The limestone in the hills south of Signal Mountain and farther west yields an abundant fauna of upper Cambrian and lower Ordovician age, closely related to that of the quarries at Fort Sill and of the limestone hills 3 to 6 miles southeast of Rainy Mountain Mission. The Arbuckle limestone north and east of the porphyry in T. 6 N., R. 14 W., is in the lower and middle part of the formation and belongs to the Cambrian and lower Ordovician parts of the section.

ORDOVICIAN ROCKS.

In the Arbuckle Mountains there is a formation 1,500 to 1,800 feet thick, composed of limestone, shale, and sandstone, known as the Simpson formation, which occurs between the Arbuckle and Viola limestones. The rocks of this formation are for the most part softer than the contiguous limestone upon each side, and are therefore more easily degraded and usually form low lands or valleys. In the Wichita region this formation, if it occurs, is entirely concealed by the "Red Beds" deposits which surround the Arbuckle and Viola limestone exposures. As far as can be determined from the exposures of the rocks which elsewhere occur above and below it, the Simpson formation, if the "Red Beds" were removed, would outcrop in an area extending northwestward from the north end of Blue Creek Canyon, passing just south of the porphyry areas in T. 6 N., R. 14 W., and the three Viola limestone hills south of Rainy Mountain Mission, in an area east of the group of limestone hills bearing northwestward from the vicinity of Richards switch; and in an area south of the isolated limestone hills west of Fort Sill. These references as to location are given because along the streams in some of these areas the "Red Beds" may have been eroded to a sufficient depth to expose the Simpson formation.

Viola limestone.—This formation, which occurs in full exposures throughout the Arbuckle Mountain region, is found here in three isolated areas, which form small rounded hills rising from the level of the "Red Beds" plain in the vicinity of Rainy Mountain Mission. They are in alignment, and extend northwest-southeast, in the general strike of the limestones of this region. The thickness of the formation, where it is known in the Arbuckle region, is 500 to 700 feet; but in the Wichita region only 200 to 300 feet of the middle portion are exposed. The formation is composed entirely of limestones, with occasional thin lentil-like bands and nodules of chert. Its lithologic character, including the chert, and the abundant Ordovician fauna, are practically the same here as in the Arbuckle Mountain country. According to its position in the section this limestone should occur beneath the "Red Beds" northeast of the group of limestone hills bearing northwestward from the vicinity of Richards, and also south of the eastern end of the Arbuckle limestone south and southwest of Fort Sill. The Viola formation is thinner and more easily eroded than the Arbuckle limestone, and as a result has been generally worn down to lower levels and concealed by the "Red Beds" deposits. Most likely it will not be found in the region beyond the limited areas near Rainy Mountain Mission.

In the Arbuckle Mountains the Viola limestone is succeeded by a soft, greenish shale formation termed the Sylvan shale. This is at the base of the Silurian, and is followed in turn by the Hunton limestone, which reaches to the Devonian. Above the Silurian is Devonian chert, which is succeeded by a very thick section of Carboniferous rocks. In the Wichita region all these rocks, so far as known, are concealed by "Red Beds" deposits. So far as can be judged from the structure of the Wichita uplift, the Silurian, Devonian, and Carboniferous rocks should occur successively farther away from the axial part of the range beyond the outcrop of the Ordovician strata.

CARBONIFEROUS ROCKS.

PERMIAN.

"*Red Beds.*"—In discussing the stratigraphy of the Arbuckle Mountains it has been stated that the "Red Beds" lap across the western end of the Arbuckle uplift unconformably, concealing the westward continuation of the folded strata, including Ordovician, Devonian, and Carboniferous rocks. From the western end of the Arbuckle uplift these "Red Beds" deposits are continuous westward to and around the Wichita Mountains, also northwestward into northern Oklahoma and Kansas, and southwestward into Texas.

From the Arbuckle Mountains westward, midway to the Wichita Mountains, the "Red Beds" dip slightly (less than 5°) toward the west. Still farther west, to and around the Wichita Mountains, the rocks are practically flat. In and near the Wichita Mountains the "Red Beds" have local variable but low dips away from the mountains, which were the old Permian land areas. These local structures are considered to be due to deposition of the sediments upon the sloping near-shore sea bottom rather than to post-Permian orogenic movements.

In the earlier part of the season of 1901 and at other times Dr. George I. Adams made some stratigraphic investigations concerning the age of the "Red Beds" in northwestern Indian Territory and eastern Oklahoma north of Canadian River. He observed[a] that the red color transgressed the strata diagonally from the upper part of the Pennsylvanian into the Permian. No indications of unconformity between the Pennsylvanian and Permian, or between other stratigraphic horizons, were noted by Doctor Adams. If there is no unconformity at the base of the "Red Beds" north of Canadian River, and if Doctor Adams's observations concerning the color of the strata are correct, the stratigraphic unconformity of the "Red Beds" across the Arbuckle uplift is local, though the uplift was profound and the erosion great from the beginning of the uplift through a large part of "Red Beds" time.

In this discussion no attempt will be made to distinguish by names or classify the various deposits which make the "Red Beds" except as to order of succession, since they were studied only across the western end of the Arbuckle uplift, along the section between the Arbuckle and Wichita Mountain regions, and in proximity to the pre-Permian rocks of the Wichitas, and since no fossils, except a few small fragments of bones which were not determinable, were found in them. The base of the "Red Beds" was traced across the upturned and eroded beds of Ordovician, Silurian, Devonian, and Carboniferous strata from the northern side of the Arbuckle Mountains southward nearly 30 miles. The "Red Beds" were observed to dip westward regularly at low angles. It has been explained that in the

[a] The Carboniferous and Permian age of the Red Beds of eastern Oklahoma from stratigraphic evidence: Am. Jour. Sci., 4th ser., vol. 12, 1901, pp. 383-386.

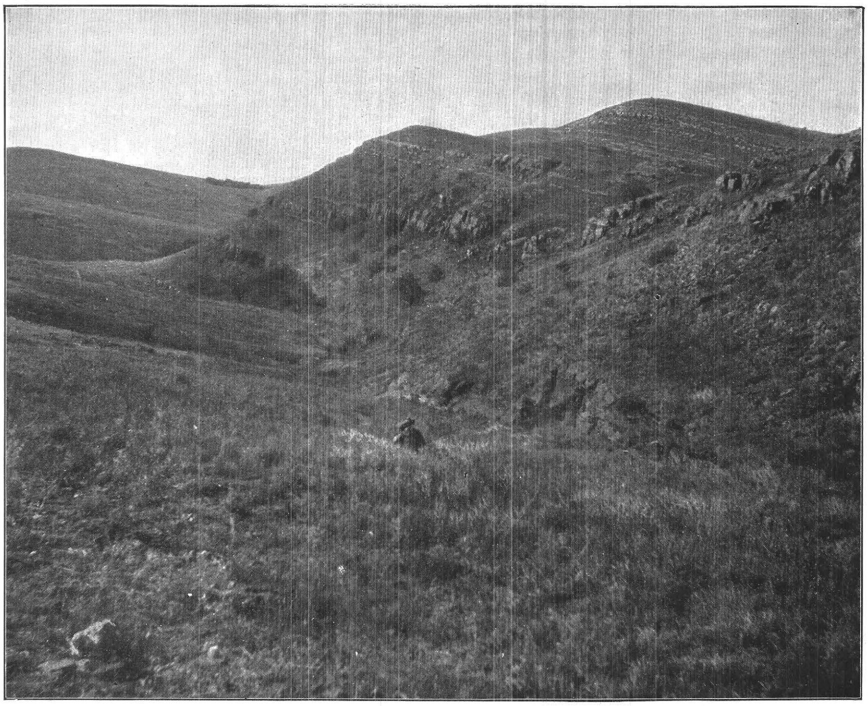
Arbuckle Mountain region the older rocks above the Cambrian dip steeply and at various angles toward both the north and the south, with strikes generally northwest and southeast.

In the section from the Arbuckle Mountains westward the "Red Beds" are naturally divided into three members, formations, or divisions, the extent of which toward the north and south has not been determined. The basal member, resting upon the upturned and eroded older rocks, varies in composition along the strike according to the character of the older rocks in the vicinity from which it was in large part derived. At the western end of the axial portion of the Arbuckle uplift, where limestones appear in contact with the "Red Beds," the basal conglomerate is composed chiefly of limestone pebbles derived directly from the degraded older Paleozoic rocks. These limestone conglomerates are interstratified with grits, greenish and red shales, and siliceous fragmental limestones, or fine limestone conglomerates, which have a total thickness of probably 200 feet. South of the axial portion of the Arbuckle uplift, where the "Red Beds" approach outcrops of Devonian chert and Carboniferous sandstone, the basal member is composed chiefly of cherty conglomerates interstratified with the greenish and reddish clays and soft sandstones. Still farther south, where the basal member rests only upon the Coal Measures sandstones and shales it is composed chiefly of soft sandstones and shales, with a minor amount of conglomerate. Above Carboniferous rocks these sandstones and shales of the "Red Beds" usually contain less red color than above the limestones and shales of the Ordovician and Silurian. As these coarse strata near the base of the "Red Beds" are followed westward they are found to continue for several miles before disappearing beneath higher sediments. In their extention westward the conglomerate element is found to decrease, the limestone conglomerates giving place to argillaceous tough limestone beds associated with the same green and red shales, grits, and soft sandstones.

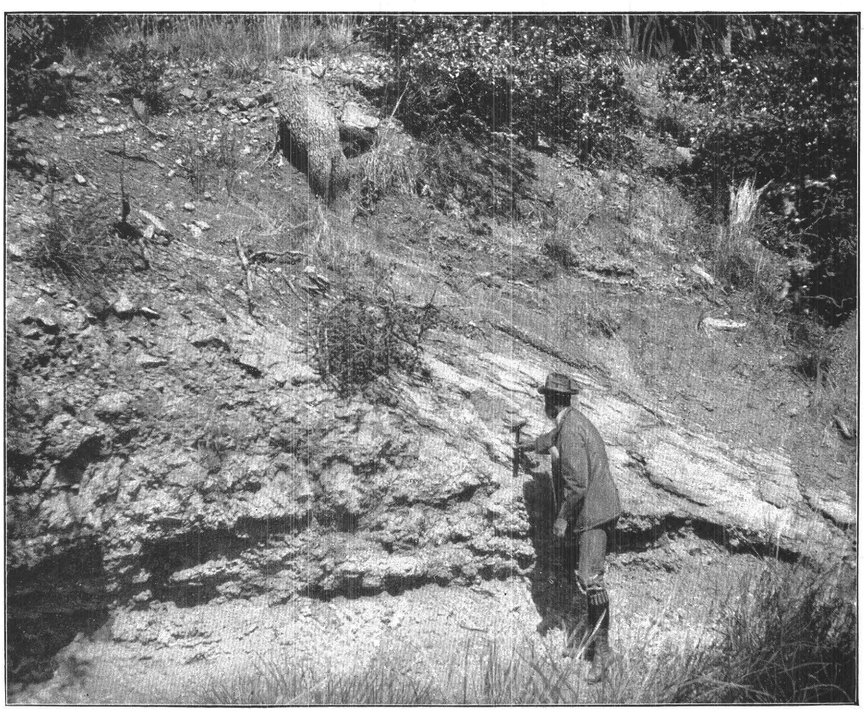
Succeeding the basal conglomerate series are extensive deposits of friable sandstones dipping very slightly toward the west. The outcrop is about 10 miles wide, extending westward from near the western line of the Ardmore quadrangle to the vicinity of Velma. These sandstones contain local deposits of grit and fine conglomerate composed chiefly of foreign quartzitic material consisting of smooth white, red, and blackish pebbles. This sandy formation is so friable that it breaks down readily and forms deep sandy soil, so that fresh exposures of the rocks are of rare occurrence. The main topographic features of this sandstone are low rounded hills and generally wide smooth valleys, which are covered by a sparse growth of scrubby oak timber with thick scrubby underbrush or shin oak. In places the sandstone and grit is indurated and occurs at the surface in large rounded bowlders which weather usually to a brick-red color. The thickness of these sandy deposits can only be estimated, since so few exposures of the rock occur that dips can not be determined. It is probable, however, that it does not exceed 200 feet.

Above the sandy member and continuing from the vicinity of Velma westward to the Wichita Mountains are deposits of bluish, greenish, and red shales, with some grit, thin cross-bedded sandstone, and siliceous limestone. The shales predominate over the other associated deposits to such an extent as to give the topographic appearance and general character of a clay formation. From Velma to Fort Sill the surface is generally smooth and occupied by prairie except in the immediate valleys of the larger streams. Here and there are low buttes and terraces capped by thin sandstone and limestone beds which are interbedded with the shales. So far as observations could be made, these shale beds are practically flat.

Near Fort Sill the sediments undergo certain changes due to their proximity to the Wichita Mountains, which were land masses during a great part if not all of the time in which the "Red Beds" were deposited. In the east side of Cache Creek Valley, southeast of Fort Sill, 60 to 100 feet of the "Red Beds" are exposed in the bluffs, deep gullies, and slopes. Here the deposits consist of red and greenish clays, thin strata of grit and fine conglomerate, and argillaceous limestone. The greenish and red clays in part contain numerous calcareous nodular concretions, which seem to owe their origin, to a certain extent at least, to the segregation of the calcareous matter in the clays during their disintegration. The fresher exposures of the rocks seem to contain fewer of these concretions than appear in the weathered surfaces. Other exposures occur along the eastern side of Cache Creek Valley east and northeast of Fort Sill. On ascending Medicine Creek from its mouth, toward Carlton Mountains, one finds that the conglomerate and sandy beds become more pronounced, many layers being composed of coarse igneous material in a matrix of grit and sand and interstratified with blue clays. Naturally the coarser and more durable beds are best exposed and little can be seen of the clay deposits. At the eastern end of Carlton Mountains, immediately west of the Rifle Range, these conglomerate beds rise at low angles and come in contact with the porphyry. From round and subangular pebbles the material changes westward to angular breccia in the contact with the porphyry. Pl. VIII, *B*, illustrates the contact phenomena in a small gulch entering Medicine Creek at the extreme eastern end of the Carlton Mountains. In the bluff above and upon the east side of the gulch shaly and gritty beds succeed the contact breccia and conglomerate. Wherever the stratified rocks are exposed near the porphyry masses the conglomerate beds are found to be composed chiefly of porphyry materials, though granite bowlders and pebbles are found. Excellent exposures of the conglomerate and grit occur in the deep gullies between the



A. CAMBRIAN SANDSTONE ON GRANITE-PORPHYRY EAST OF BLUE CREEK CANYON.



B. "RED BEDS" CONGLOMERATE ON GRANITE-PORPHYRY AT EAST END OF CARLTON MOUNTAINS.

two easternmost hills of the Carlton Mountains, south of Medicine Creek, and 2 miles west of Fort Sill. Farther up Medicine Creek, south of Mount Cummins, the present stream is found to be located in an old valley which is still partially filled by the "Red Beds" conglomerate. Southeast of Mount Cummins the conglomerate is exposed in numerous places along the bluffs of the creek, and is noted to be composed chiefly of coarse granite conglomerate with occasional bowlders and pebbles of gabbro and diabase dike rocks, the latter of which is found penetrating the gabbro, granite, and porphyry. The mountains upon either side in this vicinity are composed of granite. The gabbro occurs farther up the valley north of Mount Scott.

It has been explained in discussing the geography that the plan and general configuration of the mountains and hills composed of the older rocks originated in Permian time. The contact of the later sediments with these old rocks represents or locates the shore line of the sea at certain stages in Permian time. Since the land masses at that time were not large the conglomerates and associated sediments laid down in contact with them are limited in area and represent materials degraded chiefly by the action of the waves upon the shores. North of Medicine Bluff the porphyry conglomerate gives place to sediments of red clays in the plain, which farther north change to grits and then to coarse limestone conglomerates in contact with Cambrian and Ordovician limestone. Farther northwest, 6 miles north of Mount Cummins, the composition of the contact conglomerate changes from limestone along the strike of the beds to chiefly of porphyry against the porphyry hills. In Blue Creek Canyon 5 miles north of Mount Scott low hills of "Red Beds" conglomerate composed of mixed limestone and porphyry materials are found in the old Permian valley. Similar conditions prevail in all the larger valleys in the limestone hills where the present streams are cutting into and removing the "Red Beds" conglomerates. In the resurrected Permian valley now occupied by a tributary of Cache Creek, which flows across T. 4 N., R. 12 W., the coarse limestone conglomerate is especially well exposed.

All of the streams at the present time flowing from the mountains of the Wichita region are small, and are not degrading the harder rocks with sufficient power to remove coarse materials. Upon entering the "Red Beds" deposits the streams cut into and transport the conglomerate and associated sediments without depositing, as fans or overwash deposits, the fine materials brought down from the igneous and older stratified rocks. The tributaries of Medicine Creek flowing south from the limestone hills in T. 4 N., Rs. 13 and 14 W., cut deeply into the conglomerate and expose the older Ordovician limestones, and make rough low hilly country at the border of the "Red Beds" plain. In the plain between the Wichita Mountains and the limestone hills, and in the wide embayment of the "Red Beds" deposits northwest of Blue Creek Canyon, the relations between the contact conglomerate and red-clay sediments are well shown. In the immediate valleys of the streams flowing south across and from the Quana Mountains the relations between the granite conglomerate and red sediments are the same as between the limestone conglomerates and red sediments above described. In some places especially noted, near Quana Parker's house, in the NE. ¼ sec. 2, T. 2 N., R. 14 W., and in sec. 16, T. 3 N., R. 15 W., the granitic conglomerates occur in a matrix of red, calcareous, gritty clays.

The gabbro of the Wichita region is a hard rock, but it is more easily disintegrated and degraded by erosive agents than either the granite or the porphyry. As a consequence the rocks of the gabbro areas were worn down to lower levels during the transgression of the Permian sea than were the granites and porphyries or even the harder limestones. On account of the nature of the gabbro rocks the contact sediments of the "Red Beds" are composed of finer materials. Coarse gabbro conglomerates have not been found in the "Red Beds." On the contrary, red clays interstratified with calcareous, slightly indurated, gritty beds of red color have been noted to occur in contact with the gabbro. Such sediments were noted especially in the valley of Otter Creek immediately north of the Upper Narrows; also in contact with the small gabbro hill on the banks of Red River in the southeast corner of sec. 6, T. 4 N., R. 18 W. Some of the coarser contact material from the gabbro is slightly angular, and the rock somewhat resembles a tuff.

As the igneous and limestone areas were reduced to small size, isolated and almost submerged during Permian time, no coarse materials were brought into the sea by stream erosion. In consequence the contact sediments of the "Red Beds" in such cases were composed of disintegrated materials in situ. At the present time, therefore, fine sandy sediments of the "Red Beds" are in contact with the small igneous and limestone areas. They are usually surrounded by the level plain, so that recent erosion of streams rarely exposes the sediments in contact with the older rocks.

QUATERNARY ROCKS.

Pleistocene (?) gravels.—In relatively recent geologic times certain gravel and pebble deposits of quartz and quartzites were introduced into the region of the Wichita Mountains and now occupy the high levels of certain divides as well as terraces cut in the igneous rocks associated with some of the larger streams 100 to 200 feet above the general level of the plains. These gravels are well rounded, smooth, and are composed of quartz and quartzitic material of various colors, chiefly of light and dark shades. The gravels were noted especially on the divide east of Fort Sill, near the east line of the present Apache Reservation. They occur simply scattered upon the surface or as a very thin mantle.

Gravels of similar nature were noted also upon the granite mass at the north end of the Lower Narrows, about 6 miles northwest of Snyder. Gravels in this instance occur upon a terrace in the granite representing an old level of Otter Creek before cutting its present narrow and sharp channel. No original materials of the nature of these gravels have been found in the region of the present drainage of Otter Creek, and their occurrence here indicates that they were introduced into the region by a system of drainage and under conditions not now in existence.

STRUCTURE OF THE WICHITA MOUNTAINS.

The Wichita Mountain range, except the group of outlying ridges on the northeastern side and some low detached hills on the southern side, near the eastern end, is composed entirely of igneous rocks. These igneous rocks are separated into more than 250 detached areas, and form mountains and hills which range from closely connected groups of 150 square miles in area to isolated, sharp knobs which rise above the plains like islands. The numerous small igneous mountains and hills in the western half of the range are especially broken and disconnected. All these groups and mountains are surrounded by the nearly horizontal "Red Beds" deposits which extend on all sides of the range for long distances. They conceal the rocks of the Wichita Mountains to such a degree that no adequate conception can be had of the extent of the Wichita uplift. The archipelago-like arrangement of the granite mountains and peaks in the plain leaves one to assume that only a small part of the igneous core of the Wichita uplift is now exposed.

EVIDENCE OF DISTURBANCE IN THE IGNEOUS ROCKS.

These igneous masses of the Wichita Mountains possess certain general, yet pronounced, structural features. The granite has been intruded through the gabbro in part at least, and spread out in a broad way upon it. Where the erosion of Permian and more recent times has uncovered the gabbro in what is now the generally level plain, the gabbro areas are found to be oriented in a direction approximately N. 60° to 70° W., as would be the case if the gabbro had been arched in the axial part of an uplift. The larger areas of granite, especially in the Wichita and Quana mountain groups, and also a great number of the smaller ones, are found to be oriented in the same general northwest-southeast direction.

In the strike of the principal ridges and lines of peaks and hills there are marked zones of fracture or of major jointing. These lines of jointing are especially pronounced in the western part of the Wichita group, south of Mount

Baker. The same structures were also noted near the eastern end of this group, east of Mount Cummins, and in the porphyry of Carlton Mountains. In the western part of the range the major joints are generally nearly vertical, while in the eastern part they are inclined toward the south at an angle of 30° to 40°. This inclined jointing is so marked in the eastern end of the Carlton Mountains, and in the granite east of Mount Cummins, that at a distance it resembles pronounced stratification. Such structures, causing variable weaknesses in the igneous rocks, were emphasized to a marked degree by agents of degradation before the present drainage system was established. Especially pronounced instances are found in the large resurrected Permian valley leading southeastward from Military Pass between the Wichita and Quana mountain groups. Other instances of less pronounced character occur in the southern part of the Wichitas, south of Mount Baker, where the ridges and valleys are oriented in the general strike of the range. These major structural lines would naturally be concealed to a greater extent in the large area of isolated mountains and hills making the western half of the range. Many of these mountains, however, and even some of the smaller ones, show pronounced major joints in zones of crushed rocks bearing in northwesterly directions. Such occur in Elk Mountain and are especially marked in Twin Mountains. Aside from the major jointing, it will be observed by reference to the map that with a few exceptions these igneous mountains and even small hills have their longer axes arranged in directions generally northeast and southwest. This is doubtless due to the survival of the more resistant zones of the igneous mass parallel with the lines of weakness. Conspicuous jointing occurs in other directions than northwest and southeast, the most pronounced being north and south, across the trend of the range.

FOLDING AND FAULTING OF THE STRATIFIED ROCKS.

In the stratified rocks on the northeastern side and near the eastern end of the range the structures are more pronounced and easily interpreted. These rocks occur in a small part of the Wichita Range, and, as explained above, are probably but a small part of the uplift. The Ordovician limestone, which forms part of the thick Arbuckle formation, occurs upon the northern and southern sides of the Wichita Mountains near the eastern end, showing that this part of the range is anticlinal. On the southern side of the range, south and southwest of Signal Mountain, the remnants of the Arbuckle limestone occur in low hills dipping south and southwest. One-half mile southeast of Fort Sill the same limestones dip toward the southeast. Beginning north of Fort Sill and extending northwestward to Rainy Mountain Mission the whole Cambrian section and a large part of the Ordovician are exposed in a group of straggling, low mountains and hills. Local foldings occur in these limestone hills, and there are repetitions in the section due to faulting, but throughout the exposed section of 4,000 to 6,000 feet the general direction of the dip is toward the northeast. This shows, without doubt, that these separated limestone hills are parts of the northern limb of a great anticlinal fold which encompassed at least the eastern part of the Wichita Range. The diverging strikes of the rocks on each side of the eastern end of the range indicate that the uplift became broader and probably more elevated toward the northwest.

The Reagan sandstone, the lowest Cambrian formation in the region, lies upon the porphyry east of Blue Creek Canyon and dips northeast. In the strike of these rocks toward the northwest the same formation occurs in three small areas near the northwestern end of the group of hills, dipping in the same northeastern direction. Below it is the same kind of porphyry as at Blue Creek Canyon, and above it the limestone occurs, dipping in order toward the northeast. Between these small areas, and separating them from the larger limestone mass east of Blue Creek Canyon, the "Red Beds" conceal all the older strata. The regularity of the dip and strike of the Reagan sandstone and succeeding limestones indicates, without much doubt, that they occur and continue without break beneath the "Red Beds" deposits.

Blue Creek faults.—In the vicinity of Blue Creek Canyon, about 7 miles north of Mount Scott, there are two lines of pronounced faulting. One of these faults follows the canyon and bears nearly N. 20° W., while the other is a mile east of the canyon and strikes N. 40° W. In each case the throw is downward and toward the southwest, and the displacement of the canyon fault is greater than the other. As a result of the displacements due to these faults the porphyry mass has been elevated with respect to the stratified rocks on the northeastern and southwestern sides. The Blue Creek fault extends toward the northwest and separates the limestone and porphyry areas upon the northeast from limestones of the same character and age upon the southwest. Excepting along Blue Creek Canyon the extensive deposits of "Red Beds" conceal the fault contact. The limestones southwest of the porphyry belong to the same formations as those upon the northeast, and in each area the dips are in the same general northeastward direction, exposing the limestone section to a thickness of 4,000 to 5,000 feet.

The lowest rocks exposed on the southwestern side of this group of limestone hills are below the middle of the Arbuckle formation and belong to the upper part of the Cambrian or the lower part of the Ordovician, the Reagan sandstones being here concealed by the "Red Beds," so that there is no positive connection, except as indicated by the structure, between the igneous mass of the Wichitas and the limestones. The structure section accompanying the map of the Wichita Mountains shows the succession of stratified rocks and their relations to the igneous masses.

AGE OF THE WICHITA MOUNTAIN UPLIFT.

In the discussion of the stratigraphy it was shown that the igneous rocks of the region are pre-Cambrian. The succeeding Cambrian and Ordovician strata, representing approximately 6,000 feet of strata, bear no evidence that they were either folded or uplifted into land at any time during their deposition. The rock section exposed in this region is an almost exact repetition, both in stratigraphy and in structure, of that of the Arbuckle Mountain uplift. As already explained, the Arbuckle uplift began near the middle and culminated near the close of Pennsylvanian time, previous to the deposition of the "Red Beds," which occur now undisturbed between the Arbuckle and Wichita mountains. It has been shown that there is no record to indicate that the rocks of the Wichita Mountain region were disturbed during the deposition of the Cambrian or Ordovician rocks, nor since the formation of the "Red Beds;" therefore the deformation of the rocks occurred between Ordovician and Permian time. The Arbuckle and Wichita mountains occur near together, have the same general form of uplift and structural trends, and show identical stratigraphic sections and igneous cores of similar character and age, which are good reasons for supposing that their uplifting and folding occurred during the latter part of the Carboniferous period. Moreover, since these uplifts are in alignment it is natural to presume that they belong to the same uplift, being separated by deposits which were laid down since the folding occurred.

NOTES ON THE OCCURRENCE OF ORE DEPOSITS IN THE WICHITA MOUNTAINS.

With two exceptions, which include the gabbro, the oldest igneous rock, and a local and very limited dike of grorudite in the gabbro, all the igneous rocks as well as the quartz veins or dikes of the Wichita Mountains are duplicated in the Arbuckle region. The texture of the granites varies in an unimportant degree, but the granite-porphyries, aporhyolites, diabase, and quartz are essentially identical in the two regions. Moreover, they have the same age relations, and all, with the possible exception of some of the quartz, are, without any reasonable doubt, of pre-Cambrian origin.

When the writer made a survey of the Wichita region in 1901, the lands of the Kiowa and Comanche reservations which include it had just been opened to settlers. Practically every dike and igneous rock where it came in contact with another showing contrast in texture or color had been prospected, besides Permian "Red Beds" and Cambrian sandstone and limestone. The light-colored granite or aplite dikes in the gabbro and the points of intersection of such dikes with the diabase dikes, also the quartz bodies and grorudite dike, proved especially attractive to the prospector, and it was easy enough to get favorable reports of the occurrence of gold and silver in samples submitted to some assayers.

As in the Arbuckle region, the contact phenomena between the various classes of igneous rocks, including the dikes, seen by the writer, gave no encouragement to a belief that mineral deposits of value could be found. It is possible, though not considered probable, that the precious metals or their ores may occur in small quantities as original constituents in these igneous rocks.

Following the settlement of the lands of the Wichita region in the spring of 1902, prospecting for the precious metals became more aggressive; the occurrence of rich ores of gold and silver were reported, and at some places mining operations were begun. These activities resulted in civil disturbances between prospectors and homestead owners and made necessary a thorough investigation of the reported ore deposits. The appended report of Doctor Bain is conclusive as to the occurrence of ore deposits of any value in the Wichita Mountains.

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REPORTED ORE DEPOSITS OF THE WICHITA MOUNTAINS.

By H. Foster Bain.

INTRODUCTION.

For many years rumors of the occurrence of gold and other ores in the mountains have been rife, and even previous to the opening of the country to settlement considerable prospecting had been done. When the reservation was thrown open to settlement many mining claims were staked out, and repeated announcement of the discovery of ore has stimulated prospecting throughout a wide territory. Local assayers have constantly reported gold and silver values, and occasionally assayers outside the district have found values in ores from these mountains, or reported to be from them. On the basis of these reports a large number of people have located in the territory and attempted its development. There have been numerous conflicts as to title, and much litigation has arisen.

The Wichita Mountains have been visited by a number of geologists, but in all cases their investigations were either hurried reconnaissances or were directed to general problems of geology rather than the study of the reported ores. Under the circumstances it was thought advisable to make a special investigation of the ores, and this was accordingly done by the author in the month of October, 1903.

The important mining camps in the area extending from Lawton to Lugart were visited and samples were taken from the leading mines in each camp. In every instance the effort was made to get samples from the prospects upon which the most work had been done, or where the most encouraging results were reported. It was felt that if even some of these prospects had a demonstrable value, others might reasonably be considered as worthy of further effort, but that if the best prospects had no value, the less encouraging ones were not likely to yield any profit.

MODE OF OCCURRENCE.

The geology of the region has already been discussed in considerable detail by Mr. Taff. It is sufficient for present purposes to recall the fact that the mountains consist of a core of crystalline rocks, including granite,[a] gabbro, granite-porphyry, and certain diabase dikes, the whole partially encircled by a fringe of Paleozoic limestones. The gabbro and the granite-porphyry at least are pre-Cambrian. The granite and the dikes, which include certain rare and petrographically interesting types, are eruptive through the older crystallines.

Prospecting has been confined in general to the area of crystalline rocks. Within that area it was found that rocks in five modes of occurrence were being prospected: (1) Certain well-defined quartz veins which cut both granite and gabbro. (2) Diabase dikes which apparently cut indiscriminately all other igneous rocks. (3) Contact of the granite and gabbro, particularly where, as often happens, the granite sends off into the gabbro long apophyses, or dikes, usually assuming an aplitic phase. (4) Disintegration products of the gabbro. (5) Along simple shear zones in the granite.

It will be at once apparent that, of the classes of occurrences above enumerated, some were of the sort which, in view of the relations of the rocks, might well be expected to warrant prospecting. For example, quartz veins very commonly carry gold and other metals in sufficient amount to make the material an ore, though it is also true that many of the largest and best-defined quartz veins known carry either no values or such low ones as to preclude the working of the vein. Shear zones in granite, on the other hand, very seldom have been found to carry ore, and then only in the immediate neighborhood of well-recognized ore bodies of other types and of considerable richness. Since, however, the miners reported assays to show values in all the sorts of occurrence noted above, samples were taken from both probable and improbable occurrences; and in many cases, as noted below, where no reason was seen for suspecting the presence of any values, the owner or person in charge was invited to select samples of what he considered his richest material. In all cases where the workings were accessible samples were carefully taken across the entire vein. Occasionally these were taken in duplicate, and usually, with hand specimens of the wall rock, specimens of any horses present, etc., so that the occurrence of the ore might, if necessary, be studied in detail. Having in mind the disappointment which has so often come from incomplete or inaccurate sampling, the utmost care was taken to get fair samples of the material which, in case mining was carried on, would be shipped. As already suggested, where any bias was introduced it was in the direction favorable to the miner, and arose from taking picked samples of the better grade rather than average samples of the vein. Whenever possible, with reasonable

[a] In an earlier reconnaissance trip through the Wichita Mountains, made in 1899, the author studied this granite, and found, as he thought, sufficient evidence for considering it eruptive and post-Ordovician in age. (Bull. Geol. Soc. America, vol. 11, pp. 127-144.) Mr. Taff's fuller studies lead him to believe that the rock is pre-Cambrian. The author believes that the matter is still open to reasonable doubt, but with present knowledge is quite disposed to accept Mr. Taff's determination as probably correct.

expenditure of time, the owner or his representative was invited to be present while the samples were being collected. All the usual precautions were taken to prevent possible mixing or salting of samples, and each package was personally opened and identified by the author in the Survey laboratory. In all, over 300 pounds of samples were taken, and 71 assays were made, as detailed below, without in any case showing gold.

LIST OF SAMPLES.

MARY MACLANE MINE.

The Mary Maclane mine is near Meers, a small mining camp on the north of Mount Sheridan. It represents apparently a basic dike cutting through the gabbro. This mine was full of water, and it was impossible to collect any other than the dump sample.

W–1. Sample of vein material collected from dump.

GOLD BLOSSOM MINE.

The Gold Blossom mine is located in the NW. ¼ sec. 11, T. 3 N., R. 13 W. It is known occasionally as the Campbell mine. The workings include a shaft about 65 feet deep, with a tunnel at the bottom driven west a reported distance of 30 feet. As the lower tunnel was full of water it was impossible to collect samples of the vein, except in the short drift about 40 feet below the surface. In the case of each sample the surface was first picked clean and then material was chipped from the whole exposure of the rock. The material thus obtained was quartered down to about 5 pounds weight.

W–2. The sample represents an average across a streak of granitic material cutting the gabbro country rock. It lies next to a north-south dike of some basic rock from which the next sample was taken.

W–3. Sample of basic dike from crosscut noted above.

BUCKHORN MINE.

The Buckhorn mine, in sec. 2, T. 3 N., R. 13 W., shows the usual gabbro country rock cut by a thin sheet or dike of an acid rock, probably related to the granite which forms the main mass of Mount Scott. In the gabbro near the contact with the acid dike are small crystals of pyrites and chalcopyrite. As the mine was full of water it was impossible to collect samples from the face of the workings, and a picked sample was accordingly taken from the best material found on the dump.

W–6. Picked sample of pyrite- and chalcopyrite-bearing rock from the Buckhorn dump.

ROSEDALE MINE.

The Rosedale mine is located in sec. 3, T. 3 N., R. 13 W., and the material being worked represents the clays formed by the distintegration of the gabbro country rock. This material is known locally as a volcanic ash, but has nothing to warrant the designation, as it is simply residual material.

W–8. Average sample from stock pile at Rosedale mine.

THREE BOYS CLAIM.

This claim is in sec. 33, T. 4 N., R. 13 W., immediately east of Meers post-office, on a dike of fine-grained dark greenstone about 3 feet thick, cutting through the ordinary gabbro plain. There are three small shafts along this dike, and assay values have been reported from all of them.

W–10. An average sample of the material of the dike rock, Three Boys claim.

KECK BROTHERS MINE.

This mine is situated near the Three Boys claim, on a cross dike. It shows on the dump shattered greenstone material cemented somewhat by calcite. There is also present a darker, bronze-colored rock which is said to carry values.

W-11. Greenstone recemented by calcite.

W-12. Bronze-colored dike rock.

WILLIE HINTON MINE.

This mine is near the Keck Brothers mine, and is somewhat similar.

W-14. Sample of best appearing ore.

BLACK LODE.

This mine is situated in sec. 34, T. 4 N., R. 13 W. Apparently a big boss of granite in the gabbro country rock.

W-15. An average sample across the face of the granite exposure.

GEORGE WASHINGTON CLAIM.

This claim is located in a saddle on Mount Sheridan. The general country rock is the normal red granite of the region. In the saddle is a dark, coarse-grained gabbro, which is itself said to carry values. It is somewhat cracked and jointed and carries a small amount of quartz in the seams. It is cut by a dike of diabase about 12 inches thick, along the edges of which there has been some contact metamorphism, with the development of a red facies. At one point on this contact is a small vug, which, on careful examination, proved to be entirely calcite. This was pointed out as the rock from which was broken a beautiful specimen of white quartz showing leaf gold. Samples 16, 18, and 19 are from this claim.

W-16. Average sample of coarse-grained rock.

W-18. Sample of contact facies of dike rock.

W-19. Sample of calcite from the vug mentioned above.

MAUD S MINE.

This mine is located in the gabbro plain, immediately south of Meers post-office.

W-20. Micaceous dike rock.

SHAWNEE MINING COMPANY.

The Shawnee Mining Company has a large group of claims located about 1½ to 2 miles south of Meers. These include the Lost Lead, Joe Dandy, Teddy, the Compton, Big Four, and several others. They have been under development for some time, and at the Lost Lead there is a shaft 72 feet deep, well timbered, and fully equipped with all necessary machinery for sinking and general development work. The other mines show prospecting shafts of various slight depths. The claims are located within the gabbro plain, upon various dikes which cut through the gabbro.

W-21. Average sample across the east wall of the Lost Lead at the bottom of the shaft.

W-22. Average sample across the Lost Lead from the west wall at the bottom of the shaft.

W-23. Average sample across the east wall of the Lost Lead about 15 feet above the bottom of the shaft.

W-24. Joe Dandy. Sample of best material, picked from dump by Dr. S. I. Hardin, manager of the property.

W–25. Teddy mine. Sample of best material, picked from dump as above.

W–26. Bismuth mine. Sample of best material, picked from wall of lead by Doctor Hardin. This material has been reported to carry bismuth, but upon examination in the laboratory fails to show any metallic element.

W–27. Big Four mine. Sample of best material, picked from dump by Doctor Hardin.

W–30. John A. Logan mine, of the Madison Creek Mining Company, near the Shawnee mines. Sample from the wall, showing small quantity of molybdenite. Apparently not much material is present, although it is possible that additional work might develop more.

CACHE MINING AND REDUCTION COMPANY, MONTE CRISTO MINE.

This mine is situated in NW. ¼ sec. 18, T. 2 N., R. 13 W. At this point there are three small shafts located in the midst of the red granite country rock. The granite is at this point cut by joints and seams, but not noticeably more so than at many other points in the district. Very small quantities of common pyrite can be found by careful examination. The samples were taken under the direction of the superintendent, and from places which he pointed out as representing the best ore.

W–32. Sample across the south wall at the bottom of the shaft, including about 4 feet in width and showing only the normal granite.

W–33. Sample of soft gouge about 3 inches wide occurring in the southwest corner of the shaft.

W–34. Gouge from the cracked granite, about 5 inches thick, in the northwest corner of the shaft, sampled about 4 feet from the bottom.

W–35. Sample picked from the dump as representing the best ore from the mine.

FLORENCE MINE AT CRATERVILLE.

This mine, which is equipped with a small whim and whose shaft is said to be 100 feet deep, is located upon a greenstone dike cutting across the normal granite country rock. The shaft was partly full of water, and it was impossible to collect samples from the bottom. A sample was taken from the material found in the shaft house and reported by the superintendent to represent ore from the bottom of the shaft. It shows small stringers of quartz with a total thickness of perhaps 2½ inches. This material is reported to have assayed irregularly, but to have occasionally given rather high values.

W–39. Sample of vein material from the Florence, as above noted.

ALBERTA MINING COMPANY.

This mine is situated a short distance northwest of Craterville. The claim is located upon the greenstone dike cutting through the granite, and itself cut by some small veins of quartz having a maximum thickness of three-eighths of an inch.

W–40. Sample across the vein at the bottom of prospecting shaft.

PARKER MINE.

This mine is located not far from the edge of the granite area lying north of Quana Parker's, in the granite country. There is no evidence of a vein. The granite shows small pieces of chalcopyrite sprinkled through the rock, but not in quantity.

W–41. Sample of picked material from dump showing the most chalcopyrite. The assay of this sample gave 0.14 ounce silver to the ton, an amount not commercially important.

LEAD LODE.

This claim is in sec. 22, T. 3 N., R. 14 W. It is located on a granitic dike cutting across the gabbro. The sample was taken from the bottom of an assessment hole, at a depth of 10 feet. This material from the same point is said to have yielded $8 in gold upon assay.

W–42. Sample across the vein as above.

GEM MINE.

This mine is located in sec. 16, T. 3 N., R. 14 W. The working is located upon a greenstone dike, 4½ feet across, sheeted and cemented with white quartz, and itself cutting through the normal granite country rock.

W–43. Sample from across the vein on the west wall at the bottom of the shaft.

DIAMOND MINE.

This mine is about 300 feet east of the Gem, and supposed to be located on the same vein. At this point it shows a noticeable development of quartz on both foot and hanging walls.

W–44. Sample of foot-wall quartz streak, average width 6 inches.

W–45. Sample near hanging wall, shattered greenstone including one streak of quartz.

CLARK AND BENNETT MINE.

This is also known as the Galena mine. It is located a short distance northwest of the Gem and Diamond mines, and shows a greenstone dike about 2½ feet thick cutting through the red granite. This dike has been faulted and considerably broken up. There has been a development of white quartz in the interstices of the broken rock. Accompanying the quartz is galena and some chalcopyrite. The sample taken from here (W–48) was from the dump and represented the best material which could be found. It showed on assay, as noted below, no gold, 0.92 ounce of silver, and 3.63 per cent of lead. The silver value is unimportant. The lead is not enough to give the material rank as an ore. In its present form and in order to make mining pay, it would be necessary to erect concentrating machinery and produce an ore carrying a larger amount of lead. The development work so far accomplished does not show enough lead to warrant this, and while the matter is one of personal opinion, it is not believed that further development work would give any better results.

LITTLE BAR MINE OF THE BIG FOUR COMPANY.

This mine is located a short distance east of Oriana. It has attracted a great deal of attention. It was from it that a carload of ore is said to have been taken and shipped to Denver for sale to Beam & Co. It is reported that this shipment gave a net return of $11.87 per ton. The mine as now developed shows a shaft about 40 feet deep, located on a greenstone dike running through the normal granite country rock. There are no quartz stringers or other signs of mineralization except a very small amount of pyrite along certain fault planes. The dike is 4 to 5 feet wide, varying slightly at different points. It had been suggested that the vein proper pitched to the north and passed out of the shaft at a depth of about 12 feet from the surface, but an examination of the wall at that depth showed no vein or slip planes cutting the north wall, such as would be required by this hypothesis.

W–49. Sample across west wall at the bottom of the shaft.

W–50. Sample picked by the foreman from the east wall about 6 feet from the bottom and said to have assayed $48 in gold.

W–51. Sample chipped from around the entire shaft at a point from which the ore shipped is said to have been mined.

W–52. Sample picked from the dump by the foreman and the blacksmith as representing ore similar to that shipped.

BLUEBELL CLAIM.

This claim is in sec. 9, T. 3 N., R. 15 W., near Oriana.

W–54. Sample of a small quartz stringer, 1 to 2 inches thick, found in a granitic dike.

HALE MINE.

The Hale copper mine is in sec. 9, T. 3 N., R. 15 W. It is located near the contact of the granite and the gabbro, upon a granitic dike rock technically known as grorudite. This claim has been known for many years to show copper, and prior to the opening of the country was staked off and prospected. It is now in litigation, and nothing but prospecting holes a few feet in depth are open to inspection. Small pieces of native copper have been repeatedly found in the outcropping edge of the dike, and a number of them were seen at the cabin of Mr. Hale near by. Copper stains are found, and occasional small pieces of chalcopyrite. The sample taken represents the best material that could be picked up from the dump. It is probably not so good as has been obtained by others, since the showy pieces have naturally been carried away. It represents, however, in all probability, far better material than could be obtained in continuous workings of the vein, and offers, in the author's judgment, no encouragement for further development work.

W–57. Samples of best material from the dump.

MOUNTAIN PARK MINING AND DEVELOPMENT COMPANY.

The Little Lead is located in sec. 5, T. 2 N., R. 17 W. This lead is a greenstone dike dipping sharply into the red granite country rock. It is said to show free gold on panning and to have assayed from a trace to $2.40. The dike is about 3 feet wide.

W–58. Sample of dike material from east and west sides of the shaft at a depth of about 40 feet.

W–59. Red gouge and shattered rock on the hanging wall; sample both sides of the shaft 6 to 14 inches across.

W–60. General sample of the fine mine dirt for panning. This was not assayed, but repeated panning failed to show any gold.

WHITE QUARTZ LEAD.

This lead is in secs. 16 and 17, T. 4 N., R. 17 W., near Wildman. It is said to be well developed for about 4 miles in an east-west direction. The general country rock at the point where the sample was taken is gabbro. The lead is marked on the surface by a broad belt of white quartz float. In sec. 16 a shaft has been sunk upon it to a depth of 10 or 12 feet and shows that the lead is made up of several different stringers of white comb quartz penetrating the gabbro rock. Several samples were taken from this point.

W–61. Picked specimen of white quartz.

W–62. Average sample of white quartz from both sides at the bottom of the shaft.

W–63. Sample of the decomposed gabbro from between the quartz stringers.

W–64. Material from dump, said to show copper and to represent material from the extreme bottom of the shaft.

CLEMENTS MINE.

This mine is in the NW. ¼ sec. 21, T. 4 N., R. 17 W. It is located on a zone of shattered gabbro about 16 to 18 inches wide, cemented with white quartz. The development work consists of the usual assessment hole, 10 feet deep. Samples were taken from the bottom across the entire width of the vein.

W–67. Sample across north wall.

W–68. Sample across south wall.

WILLIAMS MINE.

This mine is in sec. 21, T. 4 N., R. 17 W. It is on a greenstone dike about 16 inches thick, in gabbro country rock.

W–69. Average sample across the "vein" at the west end, a few feet below the surface.

LONE STAR MINE.

The Lone Star is in the SW. ¼ sec. 14, T. 4 N., R. 17 W. Supposed to be the same lead as the "White Quartz lead" mentioned above. It is a vein in the gabbro country rock showing numerous white quartz stringers with some yellow ocher.

W–70. Sample from 8-inch streak of sheared greenstone with 2 inches of white comb quartz in the middle.

LAST DRIVE CLAIM.

This claim is in sec. 7, T. 4 N., R. 16 W. It is located out on the plain between Wildman and Cooperton. The development work consists of a small pit in a pasture, about 3 feet deep It shows disintegrated gabbro in the bottom of the pit, with an iron capping, having a maximum thickness of 2 feet at the east end of the pit. There is no sign of a vein or lead of any kind. The sample was taken by Colonel Meers and the material is said to have run on local assay $14 in gold and copper.

W–71. Picked specimen as above.

BLACK DIAMOND MINE.

Supposed to be on the same lead with the Last Drive and in similar material. Prospect hole 10 to 12 feet wide.

W–72. Sample picked from dump by Colonel Meers and said to show both gold and copper on local assay.

KIOWA COPPER COMPANY.

This prospect is in the SE. ¼ sec. 7, T. 4 N., R. 16 W. It is located on the open plain, lying northeast of the Upper Narrows of Otter Creek and in an area of decayed gabbro country rock. The shaft itself was full of water, and the samples were taken from sacked material which had been prepared for shipment by hand sorting. An examination of this material made it clear that the ore proper was included within a streak from one-half to 1½ inches in thickness, which agrees with measurements given by D. A. Bressman, the land owner. While the assay shows a considerable amount of copper to be present, and small pieces of metallic copper have been found in the material, it is believed that the thinness of the vein as indicated by the samples seen precludes the possibility of the mine being profitable.

W–73. Sample of hand-sorted material from sacks as above.

HOMESTAKE MINE.

The Homestake mine is in the NW. ¼ sec. 18, T. 4 N., R. 16 W. This claim is in the gabbro country, and there are no indications of any vein material.

W–74. Picked sample from dump, said to represent the last bucket of material taken from bottom.

TENDERFOOT MINE.

On same quarter section with the Homestake. The development work consists of an assessment hole 10 feet deep. The material shown in the walls of the hole is a weathered greenstone with some white streaks of feldspathic material. In the southeast corner of the shaft there is a body of hard greenstone from which samples are said to have been taken which yielded as high as 4.40 ounces of gold and 5.44 ounces of silver.

W–75. Sample from the hard greenstone noted above.

OAKS MINE.

This claim is in the NW. ¼ sec. 23, T. 4. N., R. 17 W. It is located on a very fine-grained, glassy, dark rock, forming a dike and cutting through the usual gabbro. There is a development of white quartz along the contact.

W–78. Average sample of dike across the bottom.

W–79. Average sample of white quartz from bottom of shaft.

BONANZA MINE.

The Bonanza mine is in the NE. ¼ sec. 27, T. 4 N., R. 17 W. It is located on white quartz veins cutting the gabbro. Near the surface there are two separate quartz veins, which come together at the bottom.

W–80. Average sample across the bottom on the south side.

TWIN ROSE MINE.

This is on the same land as the Bonanza mine. It is located on white quartz cutting the gabbro. At the surface separate stringers extend through a width of about 10 feet. At the bottom of the prospect shaft, about 20 feet in depth, the thickness is about 2½ fe

W–81. Sample across the vein at the bottom.

FELAND MINE.

This claim is in sec. 11, T. 4 N., R. 17 W. It is located in the gabbro plain, east of the Narrows. The vein shows in the shaft an average thickness of 3 to 3½ feet. It includes several stringers of white quartz cutting through the gabbro.

W–82. Average sample across face, east side, at a depth of 16 feet.

CREYCRAFT MINE.

This claim is three-quarters of a mile northeast of Wildman. It is located on a greenstone dike cutting through the gabbro.

W–83. Sample of material picked by owner.

JOSHUA LODE.

This lode is in the SW. ¼ sec. 15, T. 4 N., R. 17 W. It consists of thin quartz streaks cutting through the gabbro, with a total thickness of 4 inches at the bottom, spreading apart to 6 inches at the top. The sample was taken from both sides of the assessment hole and from top to bottom.

W–84. Sample quartz vein as above.

ARKANSA MINE.

This claim is in the SW. ¼ sec. 17, T. 4 N., R. 17 W., on a well-defined greenstone dike, 4 feet wide, cutting through the gabbro.

W–85. Average sample across dike at bottom of assessment hole.

GLEN RAVEN MINE.

This claim is in sec. 12, T. 4 N., R. 18 W. It is located within the gabbro area and upon the greenstone dike cutting through the gabbro. Near both foot and hanging walls there is a development of pink feldspathic rock.

W–86. Average sample across dike.

SNOW BIRD MINE.

This mine is on the same land as the Glen Raven. It is located on a quartz lead cutting through the gabbro. The sample was taken from the bottom of a 10-foot hole and across a width of 3½ feet, showing quartz and pinkish decayed feldspar developed along the contact of a fine-grained intrusive rock cutting the gabbro.

W–87. Average sample across face.

LUGART MINING COMPANY.

The Lugart Mining Company is engaged in the development of a number of properties lying near Lugart post-office and known as the Devils Canyon District. These include the Grubstake claim, from which ordinary blue bottom-land clay is being taken and treated by a new secret leaching process which is supposed to yield "from 20 to 30 per cent more than is shown by fire assay." The average yield of treatment so far is represented to be about $60 to the ton. Samples were taken from the face of the cut in the presence of the assayer and inventor of the process, C. F. Lawrence, and were considered by him to represent a fair average of the material treated. On the same claim a shear zone in the granite is being worked. On the Black Diamond claim, near by, is a big dike of greenstone about 8 feet across and running through the granite in a north-south direction. Higher up the hill is a development of pegmatite and a small cave showing quartz crystals.

W–90. Average sample taken from the face of pit and showing blue clay with occasional small balls of pyrites.

W–91. Duplicate sample taken from same pit.

W–92. Sample of sheared granite from assessment hole on Grubstake claim.

W–93. Average sample across the south wall of assessment hole made on the greenstone dike.

W–94. Sample picked by W. J. Gilbreath, superintendent of the company, and representing the best material from the Black Diamond claim. This material is reported to have yielded, in assays made by Lawrence, $3,300 to the ton.

W–95. Sample from the pegmatite dike, picked by Mr. Gilbreath and including crystals of quartz.

REPORT OF ASSAYS FOR GOLD, SILVER, COPPER, AND LEAD.

By E. T. ALLEN.

Gold assays were made of 71 samples, numbered as follows: 1, 2, 3, 6, 8, 10, 11, 12, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 30, 32, 33, 34, 35, 39, 40, 41, 42, 43, 44, 45, 48, 49, 50, 51, 52, 54, 57, 58, 59, 61, 62, 63, 64, 67, 68, 69, 70, 71, 72, 73, 74, 75, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 90, 91, 92, 93, 94, and 95. Most of the samples were granite, quartz, or other siliceous material, which was readily fluxed by the charge, which was as follows:

1 assay ton ore.
1 assay ton sodium bicarbonate.
2.5 assay tons litharge.
0.5 assay ton borax.
1.5–2.0 grams argol.
Salt cover.

A few milligrams of silver were also added to the charge in order to collect the gold, except where silver was sought.

Although the prescribed charge gave satisfactory fusions with most of the samples, it was modified wherever the composition of the material required; e. g., No. 19, being nearly pure calcite, required a large quantity of borax, and Nos. 67 and 72, which were for the most part oxide of iron, required about 2 assay tons of borax and 4 grams argol.

After the usual cupellation and parting, gold was looked for most carefully, but not a trace was found in any of the samples.

Ten of the above samples were examined for silver as prescribed for gold, except, of course, that the silver was omitted from the charge, but no silver was found except in Nos. 41 and 48, which showed 0.14 and 0.92 ounce per ton, respectively.

Nos. 57 and 73 were also assayed for copper, and No. 48 for lead.

No. 57 gave 0.35 per cent copper; No. 73 gave 10.81 per cent copper; No. 48 yielded 3.63 per cent lead.

CONCLUSIONS.

In view of the precautions taken in collecting the samples, and the great care with which they were assayed, the absolutely uniform absence of even a trace of gold and only the occasional presence of a small quantity of silver, copper, or lead allows but one conclusion to be drawn, namely, that none of the prospects examined shows any ore in the proper sense of the term, nor does any one of them have any present or probable future value. The possible exceptions in the case of copper and lead have already been discussed in detail.

Whether future prospecting may reveal other occurrences which do have value can not, it is true, be stated. It is believed, however, that the prospects examined were fully representative and have, in many cases at least, been developed enough to allow a proper judgment as to their value to be made, and in no case do they offer any encouragement whatever for additional prospecting.

In the granite mountains near Lugart there are certain coarse pegmatites showing crystals of quartz 3 inches or more in length. With the quartz crystals are some small, black, semivitreous crystals recognized by Doctor Hillebrand as belonging to the columbite-tantalite group. It is hoped that further investigations may show the presence of some of the rare earths.

While the results of the investigations were disappointing in so far as they failed to show the presence of the expected ore bodies, the region is one of other valuable resources. The granite, which is so abundant, is suitable for building purposes, and is at many points excellently situated for quarrying. The limestones are available for the manufacture of lime, and are of suitable composition for the manufacture of Portland cement if fuel and industrial conditions ever change so as to warrant investment in that industry. The small asphalt springs found near the east end of the Fort Sill Reservation are possibly indicative of larger deposits of oil or gas, and the excellent soil of the prairies and valleys, combined with good water resources, afford the basis for a large and thriving population.

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PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Professional Paper No. 31.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the fortieth in Series B and the sixty-seventh in Series C, the complete lists of which follow. (PP=Professional Paper, B=Bulletin, WS=Water-Supply Paper.)

SERIES B, DESCRIPTIVE GEOLOGY.

B 23. Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 124 pp., 17 pls. (Out of stock.)

B 33. Notes on geology of northern California, by J. S. Diller. 1886. 23 pp. (Out of stock.)

B 39. The upper beaches and deltas of Glacial Lake Agassiz, by Warren Upham. 1887. 84 pp., 1 pl. (Out of stock.)

B 40. Changes in river courses in Washington Territory due to glaciation, by Bailey Willis. 1887. 10 pp., 4 pls. (Out of stock.)

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