"Little Canyon" of the Washita river, Arbuckle Mountains, four miles south of Davis, Okla.

OKLAHOMA GEOLOGICAL SURVEY

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BULLETIN No. 3

A REPORT ON THE GEOLOGICAL AND MINERAL RESOURCES OF THE ARBUCKLE MOUNTAINS, OKLAHOMA

BY

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NORMAN
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A REPORT ON THE GEOLOGY AND MINERAL RESOURCES OF THE ARBUCKLE MOUNTAINS, OKLAHOMA.

(By Chester A. Reeds.)

Introduction: This report deals with the physiography, the stratigraphy, the structure and the mineral resources of the Arbuckle Mountains. These mountains cover portions of Murray, Johnson, Coal and Pontotoc counties in the south central portion of Oklahoma.

Physiographically the Arbuckle Mountain region consists of a moderately dissected plateau which is gently inclined to the southeast from 1300 feet above sea in the north and west to 750 feet in the southeast portion. They are not high mountains with serrated ridges and snow capped peaks like the Rocky Mountains, since they are of far greater age and have been worn down to lower levels than the Rockies. The agents of erosion have not only reduced them to one base level producing a Cretaceous peneplain but have made two successive attempts, following as many uplifts, during Eocene and Pliocene times. The first cycle of erosion was complete but the second and third were interrupted cycles.

Stratigraphically the Arbuckle Mountains consist of approximately 10,000 feet of Paleozoic sediments, chiefly limestones, which rest unconformably upon Pre-Cambrian granite and porphyry. The nine formations which appear in the plateau are variable in thickness and extent. This variation is accounted for by differential erosion and deposition during Paleozoic times.

The structure of the Arbuckle Mountains is complex. It consists of two series of pitching anticlines and synclines which are distributed almost at right angles to each other and also of a minor number of domes and basins. The folds have not only been truncated by erosion but they have been affected considerably by normal faulting. The period of chief uplift, folding and erosion occurred during Pennsylvanian time, previous to the deposition of the Permian sediments across the western border of the uplift.

The minerals of the Arbuckle Mountains which occur in paying quantities are non-metallic. Those of chief economic value are asphalt, glass sand, cement materials and building stone.

The classification of the formations as established by Taff and others in the Atoka and Tishomingo folios and Professional Paper No. 31 of the U. S. Geological Survey, have been followed in this report. Frequent citations have been made to these publications in the text of this bulletin.

Acknowledgements of assistance received in the preparation of this report are due the following persons:

Professor Charles N. Gould, Director of the Survey, has rendered every assistance possible within his power. It may be said, however, that funds sufficient to pay for only five weeks of field work and the cost of publication of the report have been provided by this Survey. The writer has received no compensation for the large expense entailed in the preparation and writing of the report necessary to its publication. He has, however, borne this additional expense himself in order that the report might reach interested persons.

Mr. Key Wolf of Pauls Valley served as assistant for two weeks during the prosecution of the field work.

Mr. Frank Ghartz, under the direction of the writer, made the maps and drawings which bear his name as draftsman.

Plates I, II, III, V and XI were made from protographs taken by I. W. Saunders of Davis, while those numbered XVII, XXI were photographed by H. E. Smythe of Norman, from specimens supplied by the writer. The remaining plates were made from photographs in the writer's collection.

Dr. Ruth S. Harvey of the Philadelphia High School read Chapters I and III for corrections while Miss Lucy P. Bush of New Haven, Conn., examined Chapters II and IV.

Bryn Mawr College,
Bryn Mawr, Pa.,
June 27, 1910.

CHAPTER I

PHYSIOGRAPHY

Introduction: The general features of the Arbuckle Mountains have been considered by Mr. J. A. Taff in the Atoka and Tishomingo Folios and in Professional Paper No. 31 of the U. S. Geological Survey. The following discussion is supplementary to that which has already been published and is necessarily more specific.

General Features: The Arbuckle Mountains consist of a low plateau, moderately dissected, which pitches gently southeastward from 1300 feet in the west and north to approximately 750 feet in the southeast. In plan they form a rude triangular area of 35 miles on each side, with a 20 mile arm extending westward from the southwest corner. Near the points of the triangle are the cities Ada, Wapanucka and Berwyn, while the villages, Woodford, Poolville and Hennepin skirt the arm. In elevation the mountains are highest in the narrow contracted arm west of the Washita river, while along the southeast margin the plateau plain coalesces with the bordering plain. Over the northeast and southwest edges of the plateau there are steep descents of from 200 to 400 feet.

In the following discussion the more specific and technical features of the topography are given under the headings: Stream Erosion, Alluviation, Effects of Unequal Hardness of Rocks, Erosion Cycles, Stream Piracy and Stream Adjustment.

Stream Erosion

Age of Plateau: As far as the erosion of the plateau is concerned, it is in early maturity.

DRAINAGE

General Features: The plateau is drained to the south southeast by three tributaries of Red river: the Washita, Blue and Clear Boggy river systems. They have been named in the order of their importance, which is also their order from west to east. The Washita river and its valley running from north to south dissect the plateau into two portions. (Geological Map, Plate XXIV and Plate II). The western one, the Garrison plateau, is named after Garrison Creek; the eastern one, the Pontotoc plateau, after Pontotoc, Okla. The drainage of each will be discussed separately.

Drainage of the Garrison Plateau

Drainage Systems: This plateau is drained to the south, north and notheast, by three systems, Caddo, Wildhorse, and Washita.

The first and second are large tributaries of the third. The divide between the south and north-northeast drainage is long and narrow, with elevations from 1250 to 1400 feet above sea. Since the total area of the Garrison plateau is but 140 square miles, the area of each of the three drainage systems upon the plateau is necessarily small. The Washita, which is the largest, drains 70 square miles, while the Caddo and the Wildhorse drain 57 and 29 square miles respectively. The streams of the plateau are short.

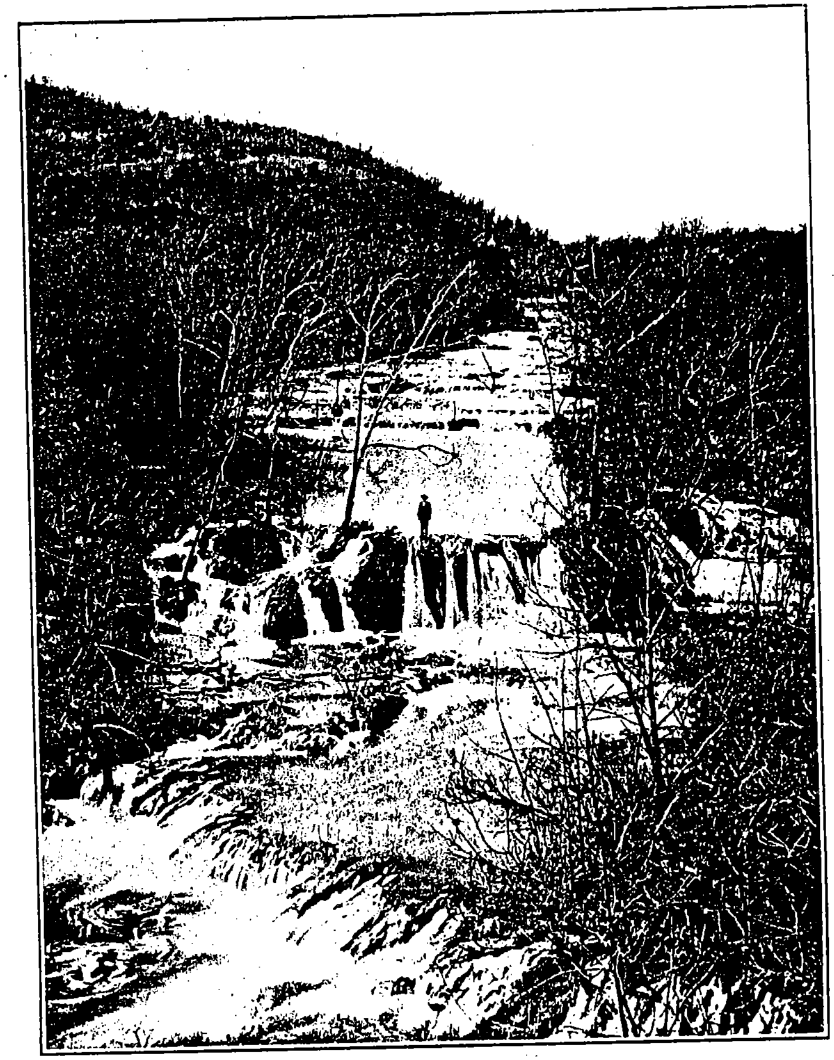
Stream Gradients: The varying character of a stream basin in the Garrison plateau has been represented graphically by drawing three profiles (1) to represent the stream gradient, (2) the country 1-4 mile distant, and (3) a divide. The profiles of Falls, Garrison, Hickory, Henry House and Honey Creeks (Fig. 1, 2, 3, 4, and 5) show that upon the plateau the gradients of these streams are steep and the streams youthful. The profile of the country 1-4 mile distant from the stream bed indicates a still more youthful stage in the tributary valleys. Of these three, the stream divide profile shows the least dissection of the former even plateau surface, the Cretaceous peneplain. The profiles indicate diagramatically the complex rock floor over which each creek flows, for the effects of erosion on rocks possessing unequal hardness and inclined position has produced in these short streams local flood plains, rapids and waterfalls. This varying hardness and structure of the rocks has also affected stream adjustment and given to the plateau its minor topographic features.

All of the streams of the Garrison plateau are intermittent except Honey, Falls and Eight Mile creeks. Each of these three streams are supplied daily with thousands of barrels of underground water from large fault springs. This water contains calcium bicarbonate in solution, since in its underground movements it has become highly charged while passing slowly through great thicknesses of limestone. In the immediate vicinity of the large springs no deposits are precipitated from solution as there is a sufficient amount of carbon dioxide present to hold the lime in solution. By the time, however, that the water has flowed a quarter of a mile down stream large quantities of the carbon dioxide have been given off into the atmosphere and calcium carbonate is deposited in the bed of the stream in the form of travertine dams. For the following few miles these travertine dams are often very numerous and of varying heights, causing pools, rapids and waterfalls. For example, forty-four were counted in the bed of Falls creek in going a mile. These varied in height from a few inches to fifteen feet. The numerous travertine falls, rapids and pools in Honey creek above Turner Falls may be seen in Plate III. It may be added that the water of these three streams is so highly charged with calcium carbonate that the stream bed is aggraded and the gradient is further affected by the deposition of the transverse travertine dams mentioned above.

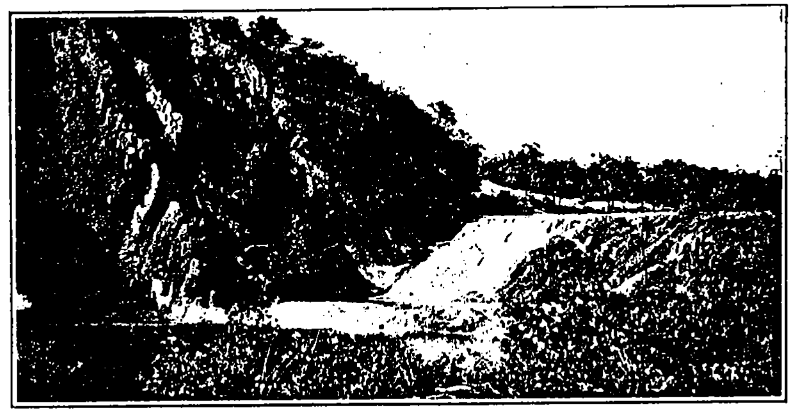
Type of Streams: Garrison and Honey creeks at first sight sug-

PLATE II

EROSION CYCLES. STREAM EROSION AND ALLUVIATION. The Washita river at Flood Time, Arbuckle



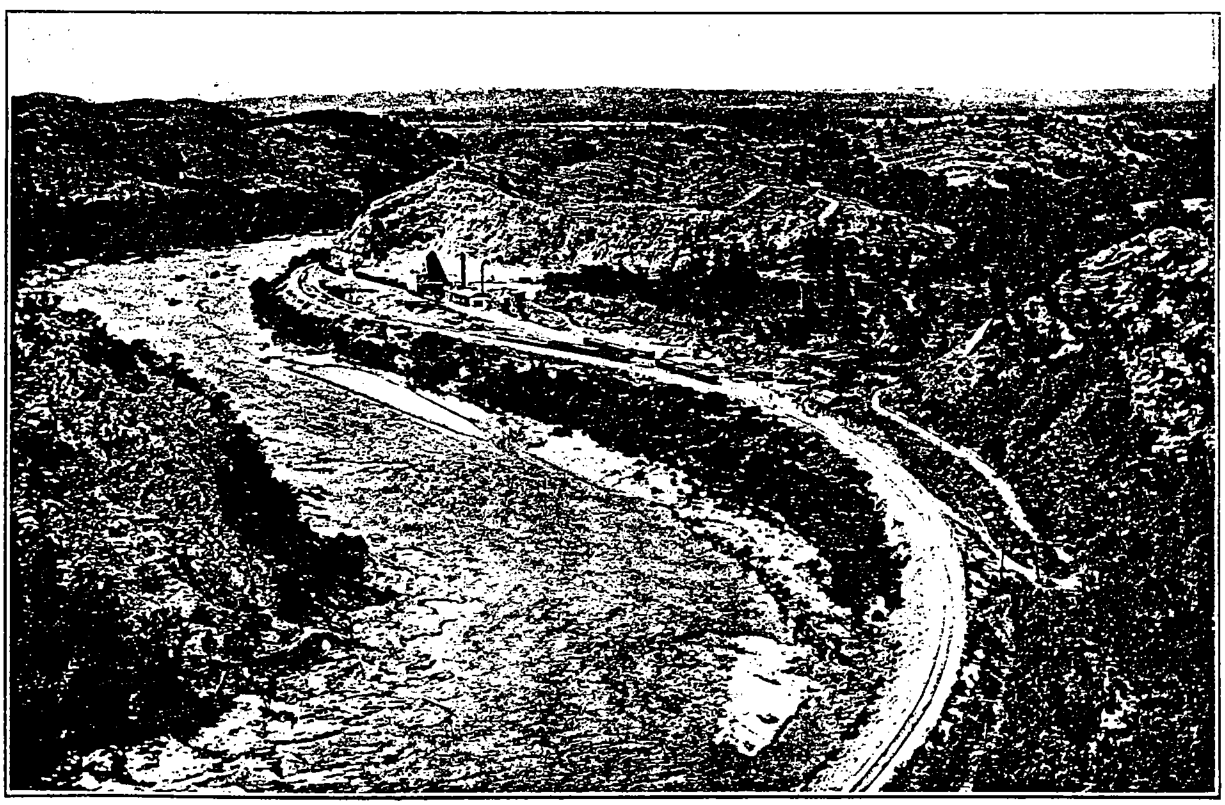
STREAM EROSION. Travertine Falls in Honey creek, Fast Timbered Hills, seven miles southwest of Davis, Oklahoma. The rounded hills on the left of the stream are of porphyry.



A. STREAM EROSION. Oil creek falls, over Viola limestone at Sylvan, Okla.

B. STREAM EROSION. Washita river at Flood time, after cutting across the neck of a meander lobe opposite Randolph, Okla., on the 'Frisco railroad, June 16, 1908.

PLATE V



STREAM EROSION. An intrenched meander. The gorge of the Washita river at Crusher, Okla.

gest antecedent streams, since they flow across centers of uplifts in which the strata have opposed dip and unequal hardness. Further analysis shows that they have probably been superimposed from more or less horizontally disposed overlying Cretaceous beds which have since been completely removed from the plateau. The even surface of the plateau when projected southward passes beneath the Cretaceous sediments to the south and east of Ardmore, approximately in the Cretaceous floor. *(1)* Furthermore, as the Trinity sands, basal Comanche, cover the southeast corner of the Pontotoc plateau at the present time, it is probable that formerly they covered the Garrison plateau. If such were the case, it would be comparatively easy to account for the northward, southeastward and southward flowing streams as consequent upon the Comanche overlap, and subsequently superimposed upon the complex plateau floor.

Age of Streams: The streams of the Garrison plateau had their birth at the close of the Comanche period, since the district then became land. Erosion was not interrupted during the Cretaceous for the sea was to the south and west of the mountains. At the beginning of the Tertiary erosion cycle the streams were rejuvenated by uplift. Before they reached maturity they received a second slight rejuvenation at the inauguration of the Pleistocene erosion cycle. The cross-sections of the valleys on the Garrison plateau show youthful stages, so that these varied events are not so well preserved as in the larger Washita river, which will be considered later. The youthful character is also attested by the steepness and variations of the gradients and by the short V shaped tributary valleys.

Drainage of the Pontotoc Plateau

Drainage Systems: There are three drainage systems, the Washita, Blue and Clear Boggy, all tributaries of Red river. As the trunk streams flow in a south-southeast direction the divide from which they arise is not a central portion as it was in the Garrison plateau, but it is a small area on Carboniferous rocks 1300 feet high along the northwest border near Roff and Fitzhugh, Okla. The drainage north into the Canadian is also from this divide.

The streams of the Washita and Blue river systems parallel one another in flowing across the plateau. Those of the Clear Boggy system which affect the plateau, flow generally in an east or northeast direction to the trunk stream. The portion of the plateau drained by the Washita system has an area of 325 square miles. The principal tributaries are Rock, Buckhorn, Oil, Sycamore, Courtney, Mill, Sand, East Rock, Pennington and Big Sandy creeks. The Blue river system is well knit together and drains 225 square miles. In the Clear Boggy river system the principal tributaries are: Delaware, Mosely, Goose, Canyon, Sheep, Big Spring, Bois d'Arc and

1 Taff, J. A., U. S. Geol. Surv. Prof. Paper No. 31, p. 16, 1904.

Jackfork. They drain 119 square miles of the plateau. The total area of the Pontotoc plateau is 669 square miles.

Stream Gradients: Blue river, Mill and Canyon creeks may be considered representative streams of the Pontotoc plateau. It may be noticed from a study of the profiles that Canyon creek, (Fig. 6), which is chosen as a representative of the creeks which flow over the northeast escarpment of the mountains, has a gradient and length comparable to the streams of the Garrison plateau. Blue river and Mill creek, however, which flow south, are of a different type. They are long streams which are nearly in the plain of the plateau slope and of the old Comanche floor. They have an average gradient of 16 feet per mile which may be considered to be the inclination of the plateau to the south-southeastward. It has the same slope as the southwardly inclined portion of the Garrison plateau when extended to meet the most northern outcrop of the Trinity sands. From a comparison of the stream gradients of the mountains it may be said that the length of the longest streams upon the Pontotoc plateau is approximately four times as great as the length of the longest creeks upon the Garrison plateau and that the ratio of their gradients approaches 1:3. Big Spring creek and Blue river have travertine dams in portions of their courses.

Type of Streams: The streams of the Pontotoc plateau have been let down upon the tilted paleozoic strata and pre-Cambrian granite from an overlying bed of Trinity sand which still overlaps the southeast corner of the plateau. Since Oil, Mill, East Rock, Pennington and Blue river are large streams whose channels are but slightly depressed below the plain of the plateau, it may be supposed that the Comanche cover has been removed but recently.

Age of Streams: The streams of the Pontotoc plateau are of the same age as those of the Garrison plateau. Since the uplifts which affected the mountains were differential, the southward flowing streams like Pennington and Mill creeks do not show in cross section the various erosion cycles to the degree that the creeks of the Garrison plateau do. Oil, Mill, East Rock and Pennington creeks are distinguished by wide shallow valleys with the exception of the lower portion of the valleys of those streams which are tributary to the Washita. Here the valleys are narrower and deeper and falls and rapids occur. (Plate IV, A.). On the eastern border of the plateau the principal tributary streams of Clear Boggy are youthful in their upper courses in the plateau but show mature characteristics after emerging upon the bordering plain of soft Carboniferous beds.

Drainage of the Bordering Plains

General Features: To the north, northeast and southwest of the mountains, bordering plains appear from 100 to 400 feet below the level of the plateau surface. To the north and south of the Pontotoc plateau the Washita river and its tributaries flow across and drain these plains. Clear Boggy creek and its tributaries drain the

northeast and east bordering plains. Blue river drains a small area southeast of the mountains between the basins of the Washita river and Clear Boggy creek. To the north of the Pontotoc plateau the drainage is tributary to the Canadian river through Sandy creek.

Type of Streams: The streams of the bordering plains, Washita and Blue rivers and Clear Boggy creek are large streams which have been superimposed upon the softer beds surrounding the mountains from a former Comanche cover of Trinity sands and other strata. Being large streams working upon soft strata they have carried vast quantities of this material away and developed plains while the smaller tributaries upon the plateau of hard paleozoic rocks have cut only narrow canyons.

Age of Streams: Since the Washita river is the most important of the bordering plain streams, and since it dissects the plateau, it may be considered first. Above and below the mountains it is a river in old age as is shown by the numerous cut offs and prominent meanders. Where it passes through the mountains, however, it shows more youthful features. Between Davis and Crusher, Okla., (Plate II), it occupies a tapering synclinal valley. Here it is in maturity for it is aggrading and widening its valley by undercutting its banks as it gently shifts from one side to the other. At the gorge (Plate V) it is in its youth, for it has rapids and is still cutting a V shaped valley. During a flood in June, 1908, (Plate II), the river covered its flood plain and stopped railroad traffic in the canyon for a week. Above and below the gorge it made new channels, cut opposite meanders and became a wide and dangerous river (Plate IV, B.).

On the bordering plain, Blue river and Clear Boggy creek are streams in old age, since the former meanders on a flood plain, while Clear Boggy meanders and has a braided channel.

Alluviation

General Features: Alluviation is taking place only in the trunk streams and lower courses of the larger tributaries. All the way across Oklahoma the Washita river is building up its large flood plain except at the water gap in the Arbuckle mountains where it is still cutting. Between Davis and Crusher the bluffs are being driven back by undercutting and the valley is being widened by lateral planation. Above the mountains Wildhorse and Rush creeks are developing flood plains in their lower courses. Below the mountains Caddo and Oil creeks have large flood plains upon soft Pennsylvanian beds. Rock creek, just east of Dougherty, has developed a large flood plain in the soft Woodford shales which fill the Dougherty basin. The bed of this stream and plain is strewn with sand and gravel derived from the Carboniferous conglomerate beds to the north of the mountains. (Plate VI, A.). Clear Boggy has a meandering and braided channel on the eastern bordering plain.

Effects of Unequal Hardness

Major Features: The most conspicuous major topographic feature of the Arbuckle Mountains is the moderately dissected plateau which rises from 200 to 400 feet above the broad floor of the Washita and Boggy drainage basins. This is due to the greater hardness of the rocks composing the plateau. The less resistant rocks which once surrounded it have been removed by erosion from the north, northeast and southeast sides, while the harder ones remained but little reduced. The valley of the Washita river is very wide both above and below the mountains, but is greatly restricted where it passes through them. In this respect it is comparable to the valleys of the Connecticut and Hudson rivers before they enter the crystalline belt.

Minor Features: The minor topographic features of the mountains are dependent upon the structure of the plateau and the effect of erosion acting on rocks of unequal hardness. The East and West Timbered Hills constitute monadnock-like prominences of pre-Cambrian porphyry upon the Garrison plateau. (Plate VII, A and B). The tilted paleozoic strata surrounding these nuclei and the Tishomingo granite of the Pontotoc plateau are composed of alternately hard and soft beds. In the anticlines (see Chapter III on Structure), the ledges of the Arbuckle, Viola, Hunton and Sycamore limestones, the second, fourth, sixth and eighth formations respectively in order of deposition, appear as long parallel ridges noted for hardness. (Plates VII, A; VI, B; VIII, A. B). The Reagan and Simpson sandstones and the Sylvan, Woodford and Caney shales, the first, third, fifth, seventh and ninth formations respectively in order of deposition, usually outcrop in long narrow timbered valleys between the harder limestone ridges. (Plates VII, A and B; VI, B; VIII, A and B).

In the more notable synclines of the mountains: Stonewall, Wapanucka, Millcreek, Dougherty and Washita, (Outline Structural Map and Geologic Map), the respective streams Bois d'Arc, Delaware, Buckhorn and Rock creeks and the Washita river have eroded the softer beds from the level of the plateau to that of the bordering plain. Sometimes, as in the Millcreek, ridges of limestone are prominent features of synclines. They arise from faulted blocks of the paleozoic sediments concerned in the uplift.

Erosion Cycles

General Features: There are three sets of levels preserved in the Arbuckle Mountains which represent cycles of erosion. It may be noted that these three cycles are the same three which affected the neighboring mountains; the Ouichita, Ozarks and the Wichitas and the far distant Appalachians. In interpreting the stratigraphy of the Gulf Coastal Plain in Arkansas and Louisiana, Veatch (1)

1 Veach, H. C., U. S. Geol. Surv. Prof. Paper No. 46, p. 16, 1906.

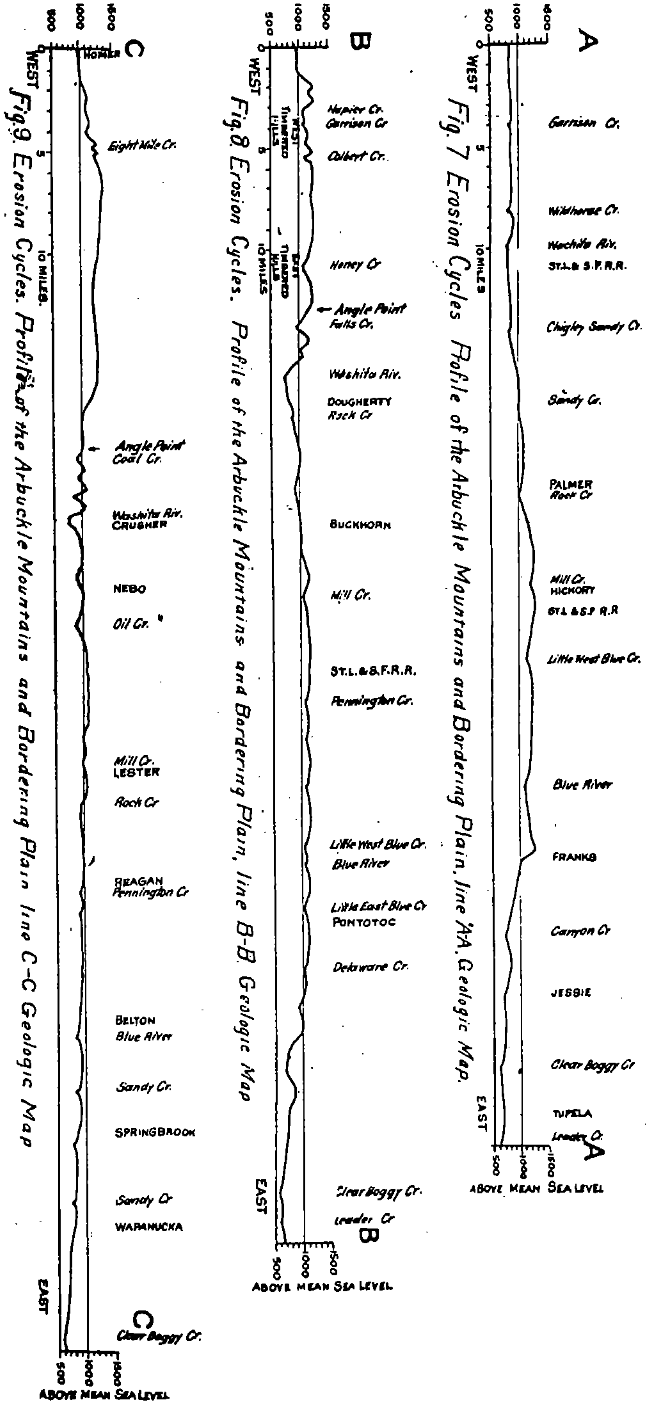


Fig. 7 Erosion Cycles Profile of the Arbuckle Mountains and Bordering Plain, line A-A, Geologic Map.

Fig. 8 Erosion Cycles. Profile of the Arbuckle Mountains and Bordering Plain, line B-B, Geologic Map

Fig. 9 Erosion Cycles. Profile of the Arbuckle Mountains and Bordering Plain line C-C Geologic Map has determined the age of these cycles to be of Cretaceous, Miocene and early Pleistocene age. They were not complete; they were interrupted or partial cycles.

Cretaceous: The Cretaceous, however, was the most complete, since all of the districts mentioned were brought nearly to base level except a portion of the southern Appalachians. *(1)* The short, broad, parallel anticlines and domes of the Arbuckle Mountains were truncated and the hard and soft beds of rocks were brought to a common level at the close of the Cretaceous cycle. The crests of the harder ledges have retained this level. From the distance they appear as a single even sky line. (Plates II, V, VI B, VIII).

Miocene: During the late Cretaceous and early Eocene periods the Arbuckle Mountain region was uplifted relative to sea level, and the streams rejuvenated. *(2)* They cut most effectively into the weaker formations surrounding the mountains. The weaker paleozoic formations of the plateau, the first, third, fifth and seventh of the plateau, were also affected but not to the same degree, since they outcrop between more resistant limestone beds. The softer beds surrounding the mountains were eroded to a peneplain which now intersects the plateau about 850 feet above sea level. The general surface at this level records a second cycle of erosion, the Miocene. It was incomplete, since the hard tilted strata of the plateau were reduced but little.

Pleistocene: During the Pliocene the region was again affected by uplift, *(3)* but it was a differential uplift, the western portion being elevated slightly higher than the eastern, with the result that the Cretaceous peneplain now slopes toward the southeast. The Miocene streams were rejuvenated and the valleys deepened during the Pliocene and Pleistocene periods, to about 200 feet below the level of the Miocene peneplain in the Washita and Boggy valleys. These valleys are broad and flat and may represent the Pleistocene cycle which has been continued into the present. "The smaller streams tributary to the large creeks and rivers have steeper grades, especially toward their sources, and occupy various levels between two peneplains." *(4)*

Levels in Profiles: To fix specifically these three levels in the Arbuckle Mountains, profiles (Figs. 7, 8, and 9) have been drawn along the lines A-A, B-B, and C-C, as indicated on the outline map. The Washita river may be especially noticed, since it and its larger tributaries have best developed the Miocene and Plestocene topographic levels. It is probable that it was not instrumental in the development of the Cretaceous peneplain, since it is regarded as a consequent stream imposed upon the hard paleozoic rocks of the plateau from a former Comanche cover. The progressively increasing gradient of the valley slopes is shown in the tapering valley as it passes from the plains country above Davis, through the narrowing Washita synclinal valley and Dougherty basin (Plate II) to the one mile, V shaped gorge, at Crusher, (Plate V). To the south of the gorge the plains of the Miocene cycle appear in the uplands, while the Pleistocene lowlands in the broad river valley are more pronounced than north of the mountains.

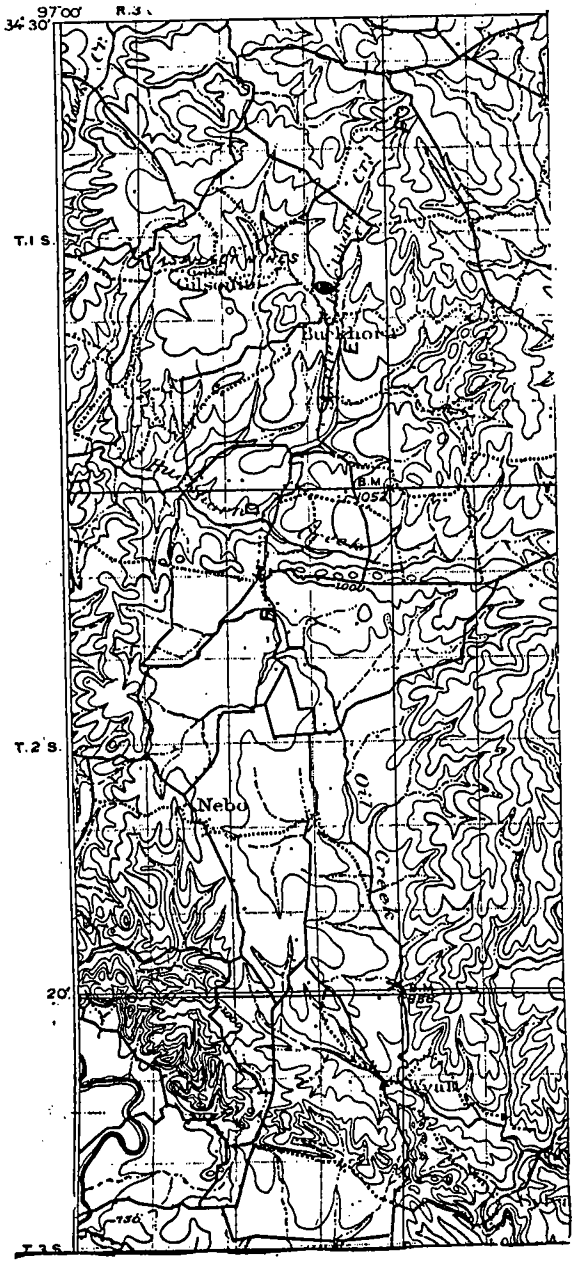
1 Hayes, C. W. and Campbell, M. R., Nat. Geol. Mag., Vol. VI, p. 104, 1894.
2 Taff, J. A., U. S. Geol. Surv. Prof. Paper No. 31, p. 16, 1904.
3 Ibid., p. 17.
4 Ibid., p. 17.

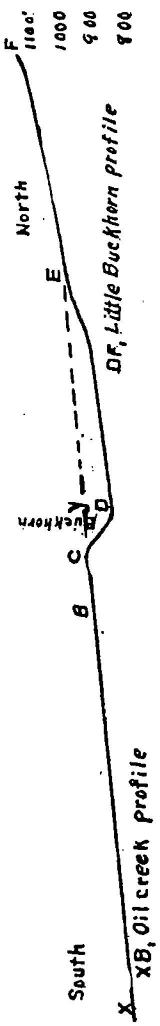
Stream Piracy

General Features: The Arbuckle Mountain region affords two notable illustrations of stream piracy. One is in Buckhorn creek, in the northwest corner of the Tishomingo sheet, and the other in Delaware creek in the northeast part of the same sheet.

Buckhorn Creek: In regard to the pirate work of Buckhorn creek, (Plate IX, A), the following points may be noted: (1) The main stream below the confluence of the two principal tributaries has a gentle gradient (10 feet per mile) and a mature valley, while Little Buckhorn creek and the other headwater tributaries have steep gradients (50 feet per mile) and comparatively youthful valleys. (2) The slight gradient and broad open valley of the headwaters of Oil creek (A-B, 20 feet per mile). (3) The prominent wind gap (at C) in the divide between Buckhorn and Oil creeks which is in line with the direction of flow of Little Buckhorn and Oil creeks. (4) The much steeper gradient from the divide to Buckhorn creek. (5) The headwater of Little Buckhorn starts southward in a broad open valley until a little above the 1000 foot contour where the valley narrows and the stream decends with a steeper grade to a little below the 950 contour where it begins to meander. (6) The fact that, if the broad valley of Buckhorn and its tributaries were filled up, there would be a declining surface with a gentle grade southward to Oil creek, and the grade between the headwaters of Little Buckhorn and Oil creeks (at B) would be altogether harmonious with the grade of the Oil creek valley below (B).

A north-south profile (F E D C B X) has been drawn to show the profile of Little Buckhorn creek, the divide, and a portion of the upper course of Oil creek (Plate IX, B.). The profile of Oil creek (X B C) when extended northward strikes the profile of Little Buckhorn creek a little above 1000 feet (at E) at the mouth of its open valley. The dotted line (C E) indicates the amount of filling that would be necessary to restore the former course of Oil creek (F E C B X). Or, in other words, the triangular area C D E represents a cross section of the vast amount of material which Buckhorn and its tributaries have eroded after tapping Oil creek at Y. The profile of Little Buckhorn creek (D E F) suggests rejuvenation. A cross section of the geology along the profile line F E D C B X (Tishomingo Folio) shows that the divide at C is stable. It also shows that Little Buckhorn in its upper course





(E F) flows across successive beds of hard and soft paleozoic rocks and is thus antecedent. The valley of Buckhorn creek (C D E) is a mature valley, while that of Oil creek (X B C) has the appearance of much greater age.

The above noted features suggest the following sequence of events: (1) The drainage of Little Buckhorn creek once went southward to Oil creek in a valley of gentle grade. No doubt it was similar to the present ones of Mill and Pennington creeks. (2) A valley tributary to Rock creek was then developed in the soft Caney shale which filled the Millcreek syncline, and by head erosion worked its way back to the eastward. (3) Presently it became a pirate by tapping Oil creek and diverting its head waters. (4) Having been successful in one venture it has continued its eastward head erosion for more than three miles and will probably in a very brief geological time tap Mill creek.

Delaware Creek: Delaware creek in the northeast part of the Tishomingo sheet (Plate X, A), has a very similar history. This is quite evident from a study of the topographic and geologic maps of the Tishomingo Folio. The following points may be noted: (1) The course of Delaware creek above Viola (now Springbrook) is in line with the present course of Sandy creek a few miles to the south of Viola. (2) The country to the north of the mouth of the Delaware canyon, Sec. 2, T. 2 S., R. 7, E., is a highly dissected table land which inclines gently southward, intersecting the divide between Delaware and Sandy creeks to the south and west of Viola. (3) A broad shallow wind gap in this divide is shown by the 900 foot contours one mile southeast of Viola. (4) The fact that, if the broad Wapanucka valley and its tributaries were filled up, there would be a declining surface of gentle grade southward to the valley of Sandy creek, and the grade between the upper Delaware and the head of that stream would be altogether harmonious with the grade of the Sandy valley below.

A north south profile (A B C D E F) (Plate X, B) has been drawn of Delaware creek to Viola, then over the divide through the water gap (at D) and then down the east prong of Sandy creek (E F) to the 750 contour. The profile of the Delaware shows rejuvenation in the creek's history. The divide (D) would be in a process of shifting were it not for the fact that the geological section (Tishomingo Folio) shows massive limestones steeply inclined against granite. The valley of the Delaware between B and C is mature, but above B it presents more youthful stages. The valleys of Sandy creek and Blue river show no rejuvenation. From A-B the creek flows across a low broad anticline, the Hunton, with the Viola and Simpson formations dipping at the low angle of 10 degrees to the east. These strata, particularly the Simpson, are composed of alternating soft and hard beds of limestone, shale and sandstone. The stream and its tributaries have cut down through these beds, forming in places canyon walls 100 feet high, while in other instances outlying buttes have been formed near the mouth of the canyon. Waterfalls and rapids are present.

The above noted features suggest the following sequence of events: (1) The drainage of the upper Delaware as far down as Viola once went southward down the east prong of Sandy creek, in a valley of gentle grade. (2) A valley tributary to Clear Boggy was then developed in the soft Carboniferous beds at a higher level than at present, possibly a little more than 800 feet, for that is the height of the Wapanucka limestone ridge between Bromide and Wapanucka, through which the creek has cut "narrows." It is very probable that the head erosion had progressed westward beyond this ridge before it was let down upon it. In the course of time it worked westward until it tapped Sandy creek at Viola and thus diverted the head waters of that stream. Since then the valley has been lowered to base level and tributaries extended to the western limit of the syncline and beyond. In fact one tributary is within less than a mile of Blue river, with only a narrow divide of a little more than 50 feet high to cut. It thus seems that in the near geological future where Mill creek will be Buckhorn's second capture, Blue river will be the Delaware's.

Stream Adjustment

General Features: The streams of the Arbuckle Mountains may be grouped into two categories: (1) unadjusted; (2) adjusted. From a study of the streams it is evident that all of the larger ones were superimposed upon the complex plateau floor of tilted beds, from an overlying formation, the Trinity, which is still present across the southeast corner of the plateau. It is probable that the streams which flowed southward on the Trinity sands were long streams, since they were extended out over a bordering coastal plain. Blue river below Wiley, Okla., is a good example of such a consequent stream. It has a broad valley, a slight gradient, and a meandering course. The early Tertiary uplift rejuvenated the streams, which uncovered and obliterated a large part of the marine Cretaceous plain northeast and southwest of the Arbuckle district. As the Pliocene uplift was differential, the plateau surface being tilted slightly to the southeast, the streams became most active in the western portion. As a result, the streams of the Garrison plateau have removed the last vestige of the Trinity cover and show adjustment to structure while those of the Pontotoc plateau are still removing the cover from the southeast border and show no adjustment to structure when superimposed upon the plateau of pre-Cambrian granite and tilted paleozoic beds.

Unadjusted Streams: The streams which show no adjustment or but little adjustment to structure are Blue river, Pennington, East Rock and Mill creeks of the Pontotoc plateau. They are large streams which flow in a southward direction across anticlinal and synclinal folds of limestone, sandstone, shale and granite, without

any regard for this varying structure. Oil and Sandy creeks had similar courses before pirate streams invaded the plateau. It would seem that the Trinity cover has been removed so recently that these streams show no adjustment or but little adjustment to the structure of the plateau.

Adjusted Streams: The streams which show adjustment to structure are numerous and are to be found in the western half and the northeastern border of the mountains. These streams illustrate (1) that they have a pronounced tendency to follow the trike where they flow through a district of tilted strata of unequal hardness, and (2) that when they do not follow the strike they flow at right angles to it. A number of the more prominent examples may be considered.

Washita River: Below Davis the Washita river follows the axis of the Washita syncline until the gorge is reached, where it cuts across the strike of steeply inclined strata of the Arbuckle anticline at right angles. (Plate XI). Below the gorge it parallels the trend of the mountains and follows the strike of the softer beds for about 25 miles to the east when it again turns to the south athwart the strike of harder rocks to the Red river.

Buckhorn and Rock Creeks: These creeks (Geologic Map, Plate XXIV), have wide valleys at right angles to one another along the axes of the Millcreek syncline and Dougherty basin, respectively. Those valleys were once filled by the comparatively soft Glenn and Woodford formations at the time of the early Tertiary uplift. Since then the streams have been very active, the Buckhorn becoming a pirate.

Oil Creek: Oil creek (Geologic Map, Plate XXIV) (and Plate IX), since decapitated by Buckhorn, has developed three small headwater tributaries on the Tishomingo anticline. They are at right angles to the trike of the beds. The trunk stream follows the strike of the Arbuckle and Simpson formations south to Wyatt, then it turns southeast along the strike of the Arbuckle limestone and a prominent fault plane, until opposite Sylvan. Then it flows south at right angles to the strike of the steeply inclined Arbuckle, Simpson, Viola, Sylvan, Woodford, and Sycamore formations until the Caney shale is reached, when it swings back to the Viola limestone and then south again, forming the finest example of intrenched meanders in the whole of the Arbuckle Mountains. Before reaching the Washita river it meanders widely across its flood plain on the soft Glenn formation.

Honey Creek: In its intermittent upper course (Geologic Map, Plate XXIV) Honey creek follows the strike except for a short distance where it is at right angles to it. Throughout the five miles of its lower course it flows directly across the strike.

Henry House: This stream (Geologic Map, Plate XXIV) follows the same habit. On the Arbuckle, Simpson and Viola formations it flows at right angles to the strike, but upon reaching the soft Sylvan shale it follows the strike for one and one-fourth miles before turning directly across the harder Hunton, Woodford, and Sycamore formations to the soft Caney and Glenn formations on the bordering plain to the south.

Cool Creek: This stream (Geologic Map, Plate XXIV) follows the strike of highly inclined Arbuckle limestone beds for a few miles, then zigzags across the Simpson to the Viola limestone, when it moves directly across the successive younger beds to the soft Glenn shale, where it follows the strike east to the Washita river.

Wildhorse and Caddo Creeks: These streams are on opposite sides of the Garrison plateau, but they have west-east courses which tend to follow the strike of the softer beds. Their shorter, more vigorous tributaries from the plateau enter at right angles.

Clear Boggy: This stream, which is some five miles off the northeast escarpment of the mountains, follows the strike of the soft Pennsylvanian beds to the southeast. The prominent tributaries which rise upon the plateau to the west generally flow across the strike of the beds and join the main stream at right angles. The captured headwaters of Delaware creek follow the strike.

The History of the Physiographic Features

General Features: The structure and the plateau surface indicate that great orogenic movements and profound erosion have affected the Arbuckle Mountains. The present plateau boundaries mark only in part the limits of the uplift. Near the beginning of Pennsylvanian time the western part of the mountains emerged and was uplifted to mountainous altitudes. The paleozoic sediments, Cambrian to Mississippian in age, 8,000 to 10,000 feet in thickness, were successively exposed to erosion. Degradation occurred to such a degree in Pennsylvanian time that extensive limestone conglomerates were deposited in the vicinity of Sulphur, Roff, and Franks, together with sand and shaly sediments in the adjoining sea. Before the close of the Pennsylvanian period the Arbuckle uplift either by erosion or subsidence or both was submerged in part at least and late Pennsylvanian conglomerates deposited across it upon the eroded edges of older strata. Following the deposition of the conglomerate both folding and faulting occurred since the Pennsylvanian section is involved in parts of the uplift, both within and upon its borders. The folding and faulting had ceased by Permian times since the Permian strata rest unconformably and undisturbed across the western end of the mountains.

During Jura-Trias time the mountains were reduced to a peneplain previous to the encroachment of the Comanche sea in which were deposited the Trinity and possibly other beds which covered the plateau. The deformative movements which brought the Comanche period to a close uplifted the region into land. Degradation affected the region during the Cretaceous period. At the close

of the Cretaceous or beginning of the Eocene regional uplift occurred and the streams were rejuvenated. This was the inauguration of the erosion cycle which produced a partial base level in Miocene times. It was interrupted, however, by another uplift during the Pliocene which was differential, the western part being raised the higher. The streams of the west portion were rejuvenated and the broad valley of the Washita river was developed by Pleistocene time. This activity has continued into the present.

CHAPTER II

STRATIGRAPHY

Introduction: Previous to 1901 little had been published concerning the geography and geology of the Arbuckle Mountains. The first mention of a part of the mountains was in 1858, when Jules Marcou, *(1)* traveling along the old trail from Fort Smith to Fort Washita, called the few long limestone ridges and detached buttes in the beautiful valley of Delaware creek *(2)* "The Delaware Mountains," and referred them to the "Sub-Carboniferous or Mountain Limestone." These features are easily recognizable today in that part of the Arbuckle Mountains which lies in the Wapanucka syncline and constitutes the north limb of the Hunton anticline. They will be discussed later under Simpson and Viola formations.

In 1883, the Arbuckle Mountains were regarded as an undefined mass of the Ouachita Mountain System and referred to as the "Potato Hills of the Chickashaw Nation." *(3)*

In 1889, Hill *(4)* refers to them again as a "string of small knolls," the "Potato Hills of Indian Territory."

In 1891, Hill, *(5)* in a paper: "Notes on a reconnaissance of the Ouachita Mountain System in Indian Territory," speaks of the Arbuckle Mountains as the "Central or Chickasaw Division." He considers this division under three sub-headings: 2a. The Wapanucka Sub-division, 2b. The Tishomingo Granite, and 2c. The Arbuckle Mountains and Washita Water Gap. From the crude outline map and the discussion, it may be noted that the part west of the Washita river is called the Arbuckle Mountains, after old Fort Arbuckle, near the base line and Indian Meridian, and that little was known about the eastern portion except the Tishomingo granite area and the limestone and sandstone exposures in the Delaware valley, near Bromide. Nothing is said about the extensive area reaching northward past Roff and Franks to the vicinity of Lawrence. A section across Indian Territory from south to north, along the Gulf, Colorado and Santa Fe Railway, gives in a very general way the relation of the mountains to the bordering rocks.

In the light of present knowledge, the foregoing paper is of interest only from a historical standpoint.

In 1898, in a "Preliminary Report on Paleozoic Invertebrate Fossils from the region of the McAlester Coal field, Indian Territory," Dr. Girty *(1)* identified and described fossils of Lower Helderberg, Niagara and Ordovician age from the Arbuckle Mountains. Two small collections were made by Mr. J. A. Taff and party in 1897, and a later one, with profile, by Mr. F. E. Matthes, of the United States Geological Survey. The collections were made in the northwest corner of the Atoka quadrangle, in the vicinity of Hunton.

1 Marcou, Jules., Geology of North America, 1858.
2 Hill, R. T., Am. Jour. Sci., 3d Series, Vol. XVII, p. 118, 1891.
3 Hill, R. T., Arkansas Geol. Surv., Vol. II, p. 175, 1888.
4 Hill, R. T., Am. Jour. Sci., 3d Series, Vol. XXXVII, p. 283, 1889.
5 Hill, R. T., Am. Jour. Sci., 3d Series, Vol. XLII, pp. 111-124, 1891.

In 1899, Vaughan *(2)* published some very brief reconnaissance notes on the "Arbuckle Hills." Frequent citations were made to Mr. Hill's paper, *(3)* but very little was added to the knowledge of the Arbuckle Mountains. Eight or ten miles above Stonewall, however, an exposure of Lower Silurian (Ordovician) in the form of low hills on the south side of Boggy creek is of interest, since this represents the first mention of rocks in the northern extension of the Arbuckle Mountains. Mr. Vaughan defines the rock as "a hard gray or bluish, coarse grained limestone containing fossils, *Orthis fontalis* White, *Asaphus* sp., *Bellerophon* sp.," and states that "these strata can be referred to the lower portion of the Ordovician," since "*Orthis fontalis* was described from strata of the age of the Quebec group." In view of the present knowledge of the Reagan and Woodford formations, it is interesting to note that at that time no positive data had been accumulated concerning the existence of Cambrian and Devonian sediments in this region.

The Arbuckle Mountains were called a range, and their present limits defined for the first time, by Taff *(4)* in 1901. During that same year the Coalgate *(5)* folio, Indian Territory, appeared. This represents the first detailed geologic mapping that was done in what is now Oklahoma. The Arbuckle uplift and the normal drop faulting in the Arbuckle region are mentioned in this folio. The Atoka Folio, No. 79, followed in 1902. It describes geographic and topographic features, and the geologic structure; as a nearly complete geologic section of the rocks of the Arbuckle Mountains appears in the northwest part of the area covered by this sheet, the various formations are described as Tishomingo granite, Arbuckle limestone, Simpson formation, Viola limestone, Sylvan shale, Hunton limestone, Woodford chert, and Caney shale. Under Mineral Resources, the Tishomingo granite is considered as a building or ornamental stone. The adaptability of the Arbuckle, Viola, and Hunton limestones as building stones is also mentioned. In 1903, the Tishomingo Folio, No. 98, was published. The northern half of this folio is upon the Arbuckle plateau. It describes geography, physiography, general relations, pre-Cambrian igneous rocks, Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Cretaceous

1 Girty, G. H., U. S. G. S., 19th Ann. Rept., Part III, pp. 539-600, 1897-98.
2 Vaughan, T. W., Am. Geol., Vol. 24, pp. 51-55, 1899.
3 Hill, R. T., Am. Jour. Sci., 3d Series, Vol. XLII, pp. 111-124, 1891.
4 Taff, J. A., Abstract, Science, New Series, Vol. 13, p. 271, 1901.
5 Taff, J. A., U. S. Geol. Surv., Atlas of U. S. folio, No. 74, 1901.

sedimentary rocks and Quaternary deposits, geologic structure of the Arbuckle Mountain region, and the mineral resources.

The succeeding and last report on this region is entitled: "A Preliminary Report on the Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma." *(1)* It describes the physiographic features and history of the region, the occurrence, character, and relations of pre-Cambrian igneous rocks, and Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Cretaceous sedimentatry rocks, with the geologic structure of the Arbuckle and Wichita Mountains. It is the first report on the entire area of these mountains.

In examining the literature pertaining to the Arbuckle Mountains, it will be seen (1) that it is all of comparatively recent date; (2) previous to 1901 the publications are quite preliminary, since geologists were few, and there were no base maps; and (3) that with the advent of the topographic map and the trained geologist the reports are strikingly accurate. Owing to the careful work of Taff and his assistants, in the Atoka and Tishomingo Folios and Professional Paper, No. 31, of the United States Geological Survey, much has been added to the knowledge of the geology of the Arbuckle Mountains.

Description of the Rocks

General: The formations of the Arbuckle Mountains consist of igneous and sedimentary rocks. The igneous rocks are less extensive in area, occupying approximately 155 square miles, while the sedimentaries cover 654 square miles. Of the 155 square miles in the igneous mass, 148 are Tishomingo granite and 7 Colbert porphyry of the East and West Timbered Hills. The sedimentary formations are known as Reagan, Arbuckle, Simpson, Viola, Sylvan, Hunton, Woodford, Sycamore, Caney, and Franks. The location of these formations is shown on the large map, (Plate XXIV), while a generalized columnar section for the northern part of the Tishomingo Folio appears in Plate XII.

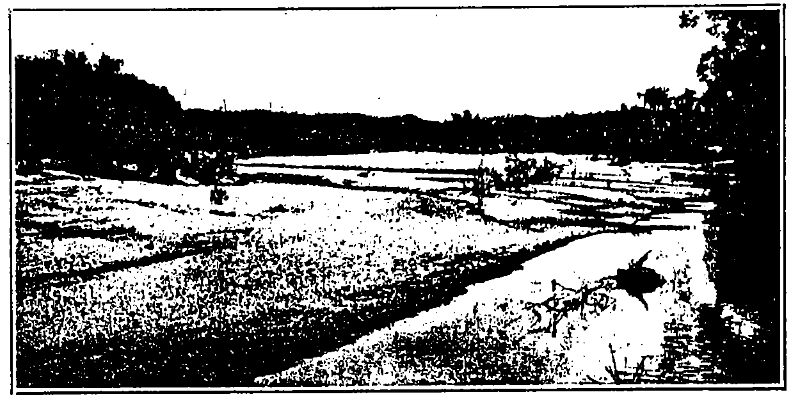
Igneous Rocks

Tishomingo Granite: The largest of the three igneous areas in the mountains has been called the Tishomingo granite, from Tishomingo, Okla., formerly the principal town of the Chickasaw Nation. This granite is excellently exposed at numerous places along the Frisco Railroad, between Millcreek and Ravia, also between Ravia and Tishomingo, south and southwest of Wapanucka, and particularly in Pennington, Rock, and Mill creek valleys, near Tishomingo.

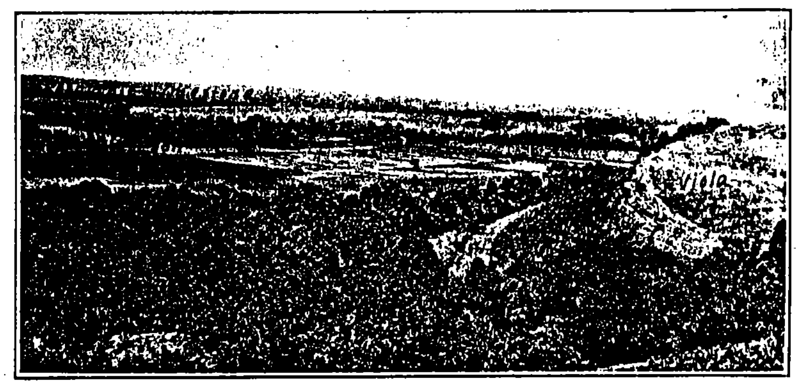
This mass of granite occupies the southeastern part of the Arbuckle Mountains. It occurs in a rudely triangular area, with the

1. Taff, J. A., U. S. Geol. Surv., Professional Paper, No. 31, pp. 11-81, 8 pls., 1 fig., 1904.

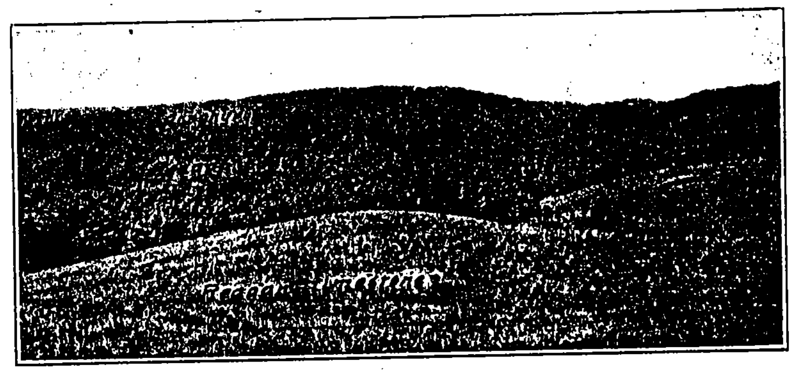
PLATE VI



A. ALLUVIATION. Bed of Rock creek, two miles northeast of Dougherty, Okla.

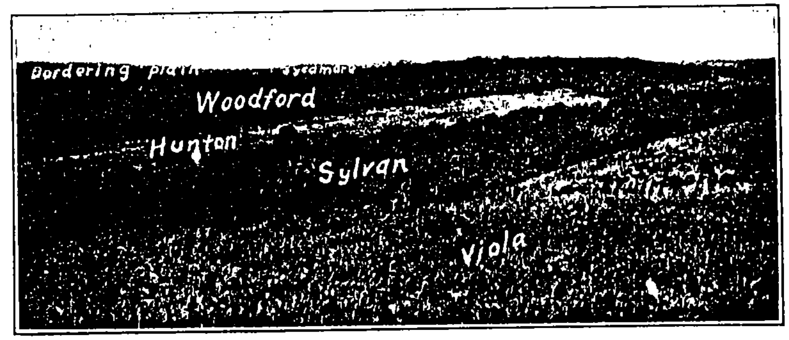


B. UNEQUAL HARDNESS. Valley of Hickory creek on the Simpson formation, two miles north of Woodword, Okla.



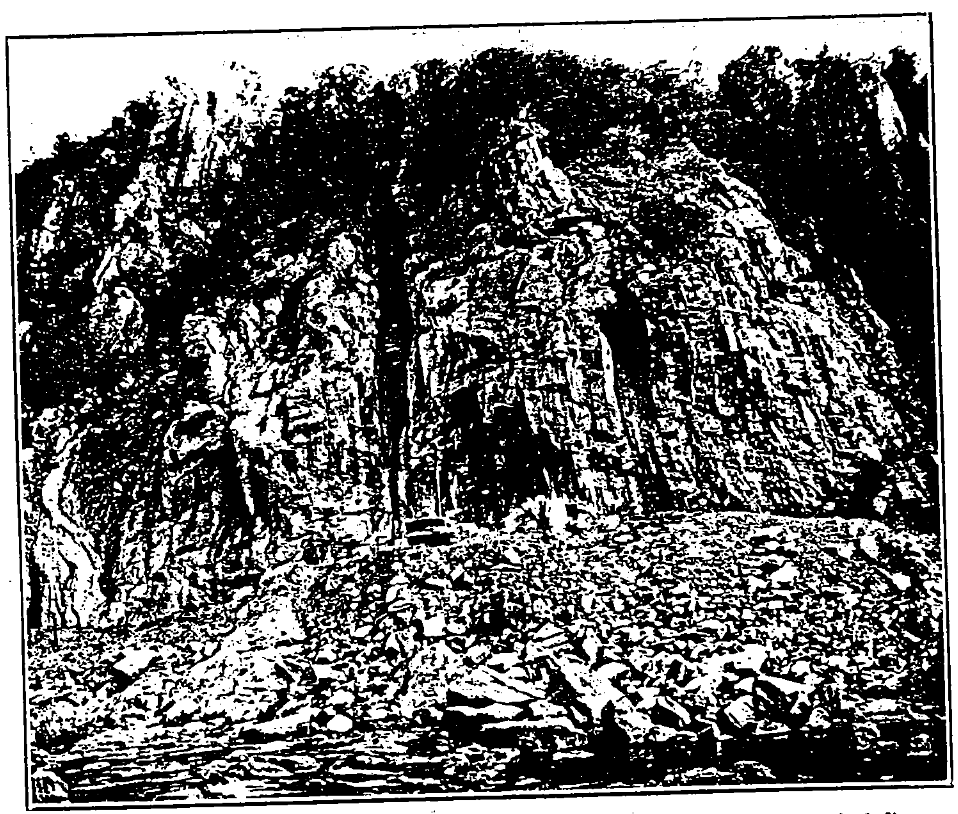
A. UNEQUAL HARDNESS. East Timbered Hills, Arbuckle Mountains

B. UNEQUAL HARDNESS. Portion of West Timbered Hills, Arbuckle Mountains, Oklahoma.



A. UNEQUAL HARDNESS. Parallel disposition of alternating hard and soft formations in the south side of the Arbuckle Mountains, two miles north of Springer, Okla.

B. UNEQUAL HARDNESS. Looking northwest across the southeast end of the Dougherty anticline, one mile northeast of Dougherty, Okla.



STREAM ADJUSTMENT TO STRUCTURE. Arbuckle limestone with vertical dip. East wall of Wasnita river gorge, one-quarter mile south of Crusher, Okla hypothenuse along the north side, from Millcreek to Boggy Depot, a distance of thirty miles. The other two sides converge towards Ravia, with the greatest width of ten miles near the western part. The area of this triangular granite mass is approximately 148 square miles.

Although this igneous area has been called the Tishomingo granite, it is not wholly a granite, since certain igneous rocks, quartz-monzonite, aplite, granite, porphyry and diabase occur as associates. The diabase appears as numerous dikes of a gray to dark blue or black basic rock of varying texture. These associated rocks are common throughout the granite, often crossing one another. The aplite is seen in less numerous dikes of a pale pink to white color, cutting the granite. The granite-porphyry occurs rarely in well-defined bands in the common granite. The quartz-monzonite is associated with the granite in small areas and apparently as phases of it. The granite itself is a coarse red variety, in general a biotite-granite, rich in tourmaline and poor in ferro-magnesian silicates. Pegmatite veins appear as coarser aggregates of the minerals found in the granite.

In speaking of the surface characteristics Taff says:

"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." (1)

For the most part, the Tishomingo granite is covered with a heavy growth of timber. A detailed petrographic description of sample rocks of this area by Mr. Ernest Howe has been published in the Tishomingo Folio, page 2.

The contact of the granite with contiguous rocks may be grouped into three catagories, which correspond to the three sides of the triangle: (1) On the west side, the granite is overlain by the Reagan formation of Middle Cambrian age; (2) On the north side, except for two small outcrops at Reagan, it occurs along lines of faulting, in contact with repeated beds of the Arbuckle, Simpson, and Viola formations of Upper Cambrian and Ordovician age; (3) On the south side, the overlap of the Trinity formation of lower Cretaceous age presents a dovetailed aspect on the map. The granite is of pre-Cambric age, since Cambrian sediments occur across it along the west side.

Colbert Porphyry: The two remaining igneous areas in the Arbuckle Mountains are known as the East and West Timbered Hills of the Garrison plateau. The chief rock constituting these timber-covered hills is a porphyry, named after Colbert Creek of the West Timbered Hills. Typical exposures may be seen along the east side of the East Timbered Hills, near Turner Falls on Honey creek. These igneous masses tend in a northwest-southeast direction and with the Tishomingo granite constitute the axial part of the Ar-

1 Taff, J. A., U. S. Geol. Surv., Prof. Paper, No. 31, p. 18, 1904.

buckle Mountain uplift. On the northeast, they come in contact with sedimentary formations, chiefly the Arbuckle limestone of upper Cambrian and Ordovician age, while on the southwest the Reagan formation occurs normally, as it was deposited upon and against the porphyry. The area of the porphyry masses in the two hills is approximately seven square miles.

There is associated with the porphyry a red, brown to pink, aporhyolite, which in places is also strongly porphyritic. Fine specimens of the pink aporhyolite were collected by the author in the canyon of Garrison creek, West Timbered Hills. These were even textured and without porphyritic character. Where weathered, it often has a deep red color. As in the Tishomingo granite, numerous diabase dikes of dark blue to gray color penetrate the igneous masses. The Colbert porphyry, like the Tishomingo granite, is of pre-Cambrian age, since the Reagan sandstone, Middle Cambrian, was deposited upon them.

Sedimentary Rocks

Reagan Formation: This is chiefly a coarse sandstone with shale and limestone in the upper part. The largest exposure occurs in the Pontotoc plateau along the west side of the Tishomingo granite. Seven other exposures appear in the mountains, two on the north side of the granite, one each on the southwest sides of the East and West Timbered Hills, and one each on the northwest and northeast corners of the West Timbered Hills. The thickness of the formation is variable, ranging from a few feet to 500 feet, with an average thickness of 300 feet. The sandstone portion in contact with the granite or porphyry has a basal arkose granitic member, which is variable in occurrence and thickness. The overlying sandstone is composed chiefly of coarse quartz grains; oftentimes green and red sands with some clay occur above the sands next the limestones. This is well exposed along the Royer road, south of the West Timbered Hills, at the head of Colbert creek, where it has been prospected for copper. Small outcrops of iron ore appear locally. Near the top, the beds are more calcareous and are commonly stratified with argillaceous layers that are more easily eroded, occurring usually as grass-covered slopes beneath the more residual massive to thin-bedded Arbuckle limestone. The calcareous beds of the Reagan contain Middle Cambrian fossils.

Arbuckle Formation: The Arbuckle is largely a white to light blue limestone with many dark thin shaly bands, and a cream-colored to white crystalline dolomite near the base. Occasionally thin beds of sandstone or siliceous limestone occur, especially near the top of the formation. This is the competent structural member of the Arbuckle Mountain uplift. It ranges in thickness from 4000 to 6000 feet and is exposed over 358 square miles. Owing to the orogenic movements of Pennsylvanian time, it has been broken and highly faulted in the Wapanucka, Millcreek and Washita synclines.

On the other hand, however, it is bent into broad folds across the axes of the Hunton, Belton, Tishomingo and Arbuckle anticlines, giving shape to the Arbuckle Mountains. All of the higher paleozoic formations, the Simpson, Viola, Sylvan, Hunton, Woodford, Sycamore and Caney, conform more or less closely to the pattern set by the Arbuckle formation. Its contact with the igneous and sedimentary rocks along lines of faulting is approximately 134 linear miles. This is greater than the unfaulted contact of 122 miles. In addition to the above estimates, the Arbuckle is in contact with itself along two lines of faulting, one a northwest extension of the faulted Wapanucka syncline from Viola to near Sulphur, and the other the southeastward prolongation of the Washita syncline, from Wyatt to Ravia. Since there are frequent local disturbances in the broader folds across the axes of the anticlines, for example, in the headwaters of Falls creek of the Garrison plateau, it is difficult to estimate the actual thickness of the formation. The Arbuckle is the principal formation of the Arbuckle Mountains and because of the vast erosion of overlying beds occupies the central part of the uplift. The exposures are broad, treeless and slightly undulating, forming rock prairies.

Complete sections occur west of the Tishomingo granite area, on the Pontotoc plateau, and south of the East and West Timbered Hills, on the Garrison plateau. The fossils, however, indicate that in the section southwest of the East Timbered Hills, the basal 2000 feet are repeated.

Taff *(1)* gives the following general section for the Arbuckle limestone, west of the Tishomingo granite area. The strata dip about 10 degrees to the west, and the distance is nearly six miles:

> "Beginning at the base there are thin-bedded silicious limestones 50 feet thick. There is a gradual change upward from these thin beds into the succeeding member, 300-400 feet thick, which consist chiefly of heavy-bedded, dull bluish and cream-colored dolomites. Many of these massive beds are indistinctly bedded and weather into very irregular brown and sometimes nearly black bowlders. Others are more crystalline marble-like and pinkish or gray colored. Succeeding these come about 250 feet of thin-bedded granular limestone and compact blue limestones which pass gradually into the main body of the formation, consisting of 3500 to 4000 feet of massive, compact magnesian limestone, the lower half of which contains chert in places. These limestones on weathering usually present smooth, white surfaces of practically the same color as the fresh rock. As the top of this thick member is approached the limestone beds become less magnesian and thinner and are succeeded by the highest member, which is composed of limestone interstratified with occasional sandy beds and strata of red, yellow and green clays."

Taff, Ulrich, and the writer have examined the beds for fossils. Those that have been found occur almost wholly in the thin-bedded shaly limestone members at the top. A few trilobites and brachiopods from the lower 700 feet have been identified by Walcott as of Upper Cambrian age.

1 Taff, J. A., U. S. Geol. Surv., Geol. Atlas, Tishomingo Folio, No. 98, 1903.

In the next 2000 feet, there is no apparent change in the lithologic character of the strata, but fossils are absent. Immediately above this level, the fossils are of Ordovician age. It is apparent that this region was one of quiet marine waters during Upper Cambrian time and continued as such on into the lower Ordovician. At and near the top of the Arbuckle formation, occasional thin beds of shale, containing Hormotoma, Leperditia, Orthidae and Graptolites, occur intercalated between alternating beds of limestone, sand and red, yellow and green clays. Lists of the Ordovician fossils identified by Ulrich appear in the Tishomingo Folio, page 3, and in Professional Paper, No. 31, page 22.

Some small outcrops of iron ore occur in the dolomite horizon at the east end of the West Timbered Hills, along the road between the two Royer ranch houses. Similar beds occur at apparently the same horizon half a mile south of the big spring, on Eightmile creek.

Other iron-ore beds occur on the Pontotoc plateau at various points, but these will be considered more at length in the chapter on iron ore.

Simpson Formation: This formation is composed of sandstone and fossiliferous limestone interbedded with greenish clay shales and marls. In order of deposition, it comes just above the massive Arbuckle limestone. Because of the intensive folding and faulting which has occurred in the mountains since its deposition, the Simpson represents nowhere its original slope of marine sedimentation, but conforms to the folds of the competent Arbuckle strata. Complete sections do not appear in every exposure, since faulting and erosion have affected the greater part of them. Such sections, however, have been noted along the south side of the Garrison plateau, from two miles northeast of Poolville to the west wall of the Washita river canyon. Three miles east of the canyon, the complete section again appears and continues with a southeast strike to a little beyond Millcreek, where it is faulted down against the Tishomingo granite.

West of Hickory Creek, the strata dip gently at approximately 20 degrees to the southwest (Plate XIII); at Henry House Creek, 35 degrees to the south, while in the Cool, Oil and Mill creek gorges they dip 75 degrees to the south. This difference in the angle of dip makes a broader surface exposure in the west than in the east. A comparison of sections made at Hickory, Henry House, Oil and Mill creeks shows that along the southwest side of the Pontotoc plateau the basal sandstone averages 145 feet thicker than the corresponding member along the south side of the Garrison plateau. Where there is a noticeable increase in the amount of sandstone, there is a noticable decrease in the amounts of limestone and shale.

In the vicinity of Nebo, the Simpson crops out over an area of approximately 12 square miles. It presents the smoothest topography of any considerable area in the mountains, since the slopes of the broad shallow valleys of Oil Creek are gentle, producing fer-

tile soils that conceal the eastern half of the area. The village of Nebo is located along the mid-western border of the area, between two prominent sandstone ridges. The contact with the overlying Viola limestone along the western border is exposed, while the eastern one with the Arbuckle limestone is almost entirely concealed.

In the Tishomingo Folio Taff gives the following general description of the Simpson:

"This formation is composed of sandstone and fossiliferous limestones interbedded with greenish clay shales and marls. There are three sandstone members; one of local occurrence at the base, one near the middle and another near the top of the formation. Many of the beds occurring in these sandstone members are composed of pure quartz sand. In places such sandstone beds are indurated, while at other localities they are compsed of massive friable sand. Occasionally there are calareous beds and even limestone layers interbedded with the sandstone. These sandstone members range in thickness from thin strata to beds aggregating 200 feet. This variability in thickness is most pronounced in the basal member which rests upon the limestone of the Arbuckle formation. In places it is not present and the limestone of the Simpson formation is in contact with the Arbuckle limestone. Between these sandstone members there are thinner sandstone strata, usually separated by several hundred feet of limestone and shaly strata. The lower and middle sandstone layers are usually thicker than the upper one. The sandstone member near the middle of the formation seems to be the most persistent in character and thickness and beneath it the limestone and shale contain a rather well-defined fauna. When once located it may be easily recognized again, and can be used as a reference horizon to separate the formation into two parts.

"The middle and upper sandstone members naturally separate the limestone and shaly beds of the formation into three members. The lowest limestone member includes probably a little more than half of the formation and is approximately 1000 feet thick. It consists of granular, semi-crystalline limestone in the lower part; this is followed by thin limestone and green shale interstratified. This member contains one and in some places two beds of sandstone, usually but a few feet thick. The middle limestone member is approximately 400 feet thick, and consists of interbedded soft shales and limestones. The highest limestone member consists of thin, semi-crystalline limestone and shale, similar to much of the deposits lower in the formation."

A considerable area, with thinner beds, variable structure and exposures, occurs in the rough slopes of Little Blue and Delaware creeks, north and south of Pontotoc. Considerable banks of sand appear a mile above the "witch hole" on Delaware Creek, four miles west of Bromide, (Plate XIV), and also in Sections 15, T. 1, S., R. 7, E. The strike of the beds is to the north and south across the axis of the broad Hunton anticline, with a gentle dip to the east. In the rough topography in the vicinity of Delaware Creek, buttes of the Simpson formation occur, capped occasionally with remnants of the once overlying Viola limestone. These rounded hills, together with the long Viola-capped ridge extending east to Bromide, and the Wapanucka limestone ridge at the Rock Academy, constitute what Marcou called the Delaware Mountains. Since these buttes are on the verge of the faulted Wapanucka syncline, *(1)* their "porous gray quartzite beds" dip at "very slight angles in many directions," comparable "to the uneven curvature of a saddle." *(2)*

In the Millcreek syncline near Millcreek, and Buckhorn, the section is not complete and sandstone members are very much indurated. To the south of Vaughan and Alhambra, southeast of Sulphur, the formation lies nearly flat and is generally covered by soil. North of the base line at Hickory and Roff, and eastward from Roff to the vicinity of Franks, some of the strata are missing. At Hickory the sandstones are very much indurated, causing sparks to fly when struck with the hammer. Resting upon the Arbuckle limestone, remnants of the once more extensive deposits of the Simpson occur as sandy outliers covered with timber or as smaller rounded hills covered with indurated sand pebbles and tufts of tall grass. Some of the weathered sandstones in these areas have become so hardened that the identity of the grains is almost lost. These rocks often present smooth vertical faces, which have been used as razor hones in Dallas, Texas.

In the vicinity of Roff, the strata dip gently to the north. Some three miles east, only the highest sandstone, the overlying shales and thin-bedded limestones are present in the section. In section 23, T. 2, N., R. 10 E., the dip of the strata becomes steep, since the Franks syncline pitches eastward from here. The Simpson beds appear only in the south limb of the syncline, and are oftentimes concealed by timber growth and soils.

Along the northeast border of the Garrison plateau, the Simpson crops out in the rough slopes of the large and small streams which drain into the Washita river. The strike of the beds is northwest-southeast, while the dip is at a very high angle to the northeast. The Simpson and the Viola, Sylvan, Hunton and Woodford formations dip at high angles—88 degrees, since they constitute the northeastern limb of the Arbuckle anticline. They are exposed on the surface as a series of parallel ribbon-like bands, the top of this anticline having at one time been truncated by erosion to the extent of peneplanation. As the anticline narrows toward the Washita River gorge, the formations give out in turn, the outermost first disappearing. In the northeast corner of the Garrison plateau, these formations are much faulted and folded and partially concealed by the Franks conglomerate. A long narrow faulted block of Simpson crops out along the north edge of the West timbered Hills, as indicated on the maps. With the exposure of the Simpson in the axial trend of the small Dougherty anticline northwest of Dougherty, the distribution of this interesting formation is concluded.

1 Taff, J. A., U. S. Geol. Surv., Prof. Paper, No. 31, p. 39, 1904.
2 Hill, R. T., Am. Jour. Sci., 3d Series, Vol. XLII, p. 118, 1891.

The textural characters of the formation are variable, due to the oscillating and shifting conditions of sedimentation during the time of marine deposition. The fossiliferous horizons are numerous and the number of species is large. The preliminary study of the fossils indicates that the beds were deposited during the Chazy, Lowville and Black River epochs of the Ordovician period.

Lists of the fossils identified by Ulrich are published in the Tishomingo Folio, No. 98, page 3, and Professional Paper, No. 31, pages 24-25, 1904.

Most of the sandstone horizons of the Simpson are suitable for glass sand. For a discussion, see the chapter on Glass Sand in this report.

Viola Limestone: This formation is chiefly a limestone, thus differing from the Simpson, which is largely a sandstone with prominent limestone and shaly bands, and the overlying Sylvan which is a shale. As the limestone is more resistant to weathering than either the preceding or succeeding formations, it is recognized, near the edge of the plateau, in rounded hills or long narrow ridges. Where it extends across the axis of broad anticlines, for example, the Tishomingo and Hunton anticlines, or dips gently, it forms prominent escarpments and more gently sloping rounded hills.

There are seven areas of considerable outcrop in the mountains. Two occur near the border of the Garrison plateau, one reaching along the south side and the other paralleling the northeast edge. The remaining four appear on the Pontotoc plateau, one in the south side of the uplift extending from near the Washita River valley to Millcreek, a second in the southwest part, reaching across the axis of the Tishomingo anticline from Buckhorn Creek to within a mile of the south edge of the plateau, where it is faulted down in the eastward extremity of the Washita syncline. A third is bowed up slightly across the axis of the Hunton anticline and extends from Bromide, on the south to Franks, on the north. It forms the prominently rounded hills and high ridges along the northeast border of the mountains, from Coal Creek to Franks. A fifth area of considerable extent reaches from northwest to southeast across the axis of the Lawrence anticline. Outcrops isolated by folding, faulting and erosion occur in the Millcreek syncline near Millcreek, south of Sulphur, in the axis of the Dougherty anticline north of Dougherty, and in some faulted blocks across the northeast corner of the Garrison plateau. The occasional rounded hills beyond the Washita River southwest of Davis, without doubt, suggested to Hill the term "Potato Hills" for the Arbuckle Mountains.

The formation is approximately 700 feet thick and has been divided into three parts lower, middle and upper, on the basis of both the fossils and the lithologic appearance of the beds. Although this division has been made, the limestone appears massive on fresh exposures, due to a continuous and but slightly variable deposit of limestone. On weathered surfaces where the rocks stand on edge, as in Tulip Creek canyon (Plate VIII A.) north of Springer, and on Oil Creek (Plate IV, A.) the bedding is well marked, a bed being rarely more than a foot in thickness.

The lower and upper parts are composed of thicker and less evenly stratified beds than the middle part. Nodular masses of chert appear most abundant in the lower and middle parts of the limestone. In texture the densest and finest limestone occurs in the middle part, the lower portion containing more shaly limestone, especially near the base, while the upper includes some beds that are uneven, earthly, coarsely crystalline, and fossiliferous.

The contact of the Viola with the Simpson shows that marine conditions were continuous, since there is a gradual transition from the Simpson beds up into the more limy ones of the Viola. The fossils indicate no break until the dividing line between the middle and upper parts is reached. Here they would seem to mark a hiatus, as the Utica, Frankfort and Lorraine representatives have not been found. A list of the fossils identified by Ulrich appears in the Tishomingo Folio, pp. 3, 4, and Professional Paper No. 31, pp. 26-27. At the top there is an abrupt change from the coarsely crystalline beds of the limestone to the dark bluish or greenish clay shales of the Sylvan.

Sylvan Shale: This formation is found usually in narrow timber-covered valleys (Plate VIII, A.), near the edge of the Garrison and Pontotoc plateaus. In some of the much faulted synclines, Millcreek, for example, it appears near the center of the plateau.

The distribution of the Sylvan is not only closely akin to that of the Viola, but even more so to that of the overlying Hunton, since it, too, is thin and does not resist erosion to the same degree as the Viola. Where the Viola and Hunton dip at high angles, as along the south and northeast borders of the Garrison plateau, the Sylvan crops out in narrow timbered valleys with wide bottoms, the stream parallel with the strike generally meandering back and forth across its soft bed, between the bounding limestone walls. Where the Viola limestone is exposed over extensive areas, as mentioned above, the Sylvan shale has been eroded back until it occupies narrow belts at the foot of the escarpments formed by the more resistant ledges of the Hunton formation. Although the exposure of the preceeding Arbuckle, Simpson, Viola and succeeding Hunton and Woodford formations are wide and irregular in outline, the Sylvan is bandlike, seeking the cover of the rocky ledges and the forest tree, it not being sufficiently strong to resist the attack of the agents of weathering and erosion. (See Map).

The shale is variable in thickness, being thinner in the eastern part of the uplift than in the western. *(1)* A mile south of Hunton, it is about 60 feet in thickness, while a half mile south of Falls Creek, near the Washita River, it is 300 feet thick. Between Franks and Hunton, and for a few miles northwest of Franks, there are numerous examples where the Sylvan is thin and wanting or correspondingly thick, the results of fautling and folding.

1 Taff, J. A., U. S. Geol. Surv., Professional Paper No. 31, p. 28, 1904.

In texture, the basal Sylvan is a dark blue clay. Throughout the middle and upper parts of the formation, it consists of a green clay on fresh exposures, but of a lighter green or yellow on prolonged exposure.

North and southeast of Dougherty and at Lawrence, gypsum crystals of a yellowish color, ranging in size from a small button to the bredth of one's hand, have been found in the middle and upper parts. The finest crystals that were seen are in the office of the Oklahoma Portland Cement Company at Ada. The crystals are usually not large and as noticed on a weathered bank of the abandoned site of the Oklahoma Oolite Stone Company's brick plant near Lawrence, they appear in thin beds from 30 to 50 feet below the top. From an analysis made by the Oklahoma Portland Cement Company, there is a greater and more uneven amount of lime beneath the basal Hunton ledge than near the middle of the formation. This is more likely the result of percolating waters than a peculiarity of sedimentation, since the greater mass of the Hunton has been eroded back from two to three miles to the east.

The present knowledge of the condition under which gypsum is formed argues that there must have been a very much restricted arm of the sea with an adjacent low-lying land, during the deposition of the Sylvan shale. The few fossils that have been collected from the basal blue shale remind one of the muddy-water fauna of the Utica and not the clearer water forms of the Richmond as found in the upper part of the Viola. Professor Schuchert of Yale University correlates the Sylvan with the Maquoketa shale, which is exposed a little south of St. Louis, Missouri, and to the north in Iowa and Minnesota. In the middle and upper parts, no fossils whatever have been found, but in their stead crystals of gypsum occur. It is probable that the murky water became so charged with muds and salts that it was impossible for life to exist in this sea, which represents the last vanishing stage of the Richmond or uppermost Ordovician. It may be that this unfossiliferous portion was deposited during the short hiatus indicated by the absence of a fossil record in America.

Hunton Formation: The textural features of this formation have been defined by Taff as a "thick and thin-bedded light blue to cream-colored limestone, shaly limestone and marl." The formation has been divided into three members—lower, middle and upper Hunton. The lower and upper members are chiefly limestone, while the middle one consists of shaly limestone and marls. After careful study the writer finds on lithologic grounds, that no hard and fast lines can be drawn between the lower and middle members, since the thin-bedded limestone on the lower side grade gradually up into the thin-shaly limestones on the upper side. Between the middle and upper members, the line of demarcation is more distinct, marls being succeeded somewhat abruptly by thin-bedded limestones bearing flint nodules.

In the field, however, the threefold division is generally conspicuous, the bounding limestone members persisting as prominent ridges or escarpments, while the middle member, being of softer material, weathers into swales or terraced slopes.

The members as defined by Taff are as follows:

"The basal member consists of whitish massive crystalline limestone which in places included a bed of oolite at or near the base. A thin bedded, compact limestone usually may be found at the top. In the Tishomingo Quadrangle this member ranges in thickness from thin beds to strata about 25 feet thick.

"The middle member is composed of white or cream colored and occasionally pinkish rather soft limestone beds interstratified with more friable marly lime and rarely calcareous clay, aggregating an average thickness of about 100 feet. This member on account of the softness of the beds, usually outcrops in swales between the harder members on each side. The variability in hardness of different beds, however, causes them to be exposed in minature terraces and slopes.

"The middle member grades upward through a few feet of marly white limestone into the top member, which consists of crystalline and in part cherty bluish to white limestone with occasional thin marly strata. In places this crystalline limestone is overlain by several feet of very cherty limestone. Most of the chert in this limestone is flinty and massive and weathers in angular bowlders; often the beds that contained it have decomposed."

The distribution of the Hunton at the time of its deposition was doubtless coextensive with that of the underlying Sylvan, Viola, Simpson and Arbuckle formations. Owing, however, to the Pennsylvanian folding and faulting and to erosion, much of it has been concealed in the synclines or worn away so that it now crops out near the borders of the anticlines.

Taff states that the Hunton varies in thickness from 0 to 300 feet, having an average of 160 feet. The variation in thickness has been ascribed chiefly to changes of volume of intervening beds. On the east side of the mountains, it has a thickness of 160 feet and increases toward the west, where it is about 300 feet thick.

The lists of fossils in Professional Paper, No. 31, together with the large supplementary collections of the writer show that there should be a different arrangement of the beds according to their faunal characteristics. As defined by Taff, the Hunton embraces rocks of Silurian and Devonian age. This formation will be treated fully in a forthcoming paper.

Woodford Chert: In various places, the writer has noted the unconformity between the Woodford and the Hunton, both by the lithologic characters of the members and especially by the fossil horizons of the Hunton that come in contact with the Woodford. From the few fossils, lingulas, conodonts and dadaxylons, that have been found embedded in the Woodford, it is believed to be Mississipian in age.

1 Taff, J. A., U. S. Geol. Surv., Geol. Atlas, Tishomingo Folio, No. 98, p. 4, 1903.

The following statement of Taff *(1)* gives the essential characteristics of the formation:

"The Woodford chert has an estimated average thickness of 550 feet. It varies somewhat in lithologic character. In places massive chert rests upon the limestone; in others 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 laminae. 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 occurs just above the Hunton in its exposures throughout the mountains. In some of the intensely faulted synclines, the north limb of the Franks syncline, for example, it appears as occasional lentils in contact with the Hunton. It is very extensively exposed in the east limb of the Dougherty basin southeast of Dougherty, where at the "Burning Mountain," the extreme S. E. corner of Section 18, T. 2 S. R. 3 E, a precipitous bluff about 100 feet high appears. It is heavily timbered wherever found. Where the strata are steeply inclined and the overlying Sycamore limestone is present, as along the south side of the Garrison plateau, (Plate XIII, B.) it occurs in narrow valleys and rough hilly land between the prominent limestone ledges of the Hunton and Sycamore formations (Plate XXIV). Where the overlying Sycamore limestone is absent, as along the northeast border of the Pontotoc plateau near Franks, the Woodford outcrops in the level of the recent peneplain surrounding the mountains.

Sycamore Limestone: This formation is apparently a lentil of limestone appearing in the western part of the mountains. It is exposed along the south side as the first ridge of the plateau from near Poolville, to Ravia; also in the vicinity of Dougherty and along Buckhorn Creek. It has been observed with certainty only upon the flanks of the Tishomingo and Arbuckle anticlines.

Taff *(2)* described it as follows:

"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 the 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."

1 Taff, J. A., U. S. Geol. Surv., Prof. Paper, No. 31, p. 32, 1904.

2 Ibid., p. 33.

Caney Shale: The Caney shale does not enter into the plateau of the Arbuckle Mountains, but it was concerned in the uplift, since it conforms to the structure of the underlying formation. Being generally soft it weathers down to the level of the bordering plain of the mountains. It has been described somewhat fully in the Tishomingo Folio, page 5. The general characteristics of the formations have been given by Taff, as follows:

"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 ironstone concretions and occasional lime Septaria. The whole formation is estimated to be about 1600 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 age of this fauna can be safely placed as post-Devonian and evidence thus far obtained is favorable to correlating it with the upper portion of the Mississippian series."

Franks Conglomerate: At the close of the Caney epoch, the formations constituting the present Arbuckle Mountains remained no longer in a more or less horizontal position beneath the sea but began to assume their present complex folds.

The Franks Conglomerate is a basal formation, which was deposited upon the eroded flanks of the mountains, particularly on the north, northwest and northeast sides of the uplift. "It varies 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." (Ibid, page 34.)

The bromide spring at Sulphur, comes to the surface through this formation. It constitutes the high bluff on the south side of Rock Creek in the vicinity of the spring.

CHAPTER III.

THE STRUCTURE OF THE ARBUCKLE MOUNTAINS.

Introduction: The study of the structure of the Arbuckle Mountains has been completed only in a preliminary way. Taff has discussed certain features of the structure in the Atoka and Tishomingo folios and in Professional Paper No. 31, of the United States Geological Survey. In the last report he dwells upon (1) the History of the Geologic Structure; (2) the Character of the Folding and Faulting; and (3) describes the Hunton, Belton, Tishomingo and Arbuckle anticlines and the Wapanucka, Millcreek and Washita synclines. Since the publication of that report the studies of the author upon the Hunton formation have revealed another anticline and syncline in the northeast part of the mountains. They have been named the Lawrence anticline and Franks syncline after towns located within each respective fold.

Complex Folds: The previous discussion as to the type of the Arbuckle Mountain uplift has proved to be inadequate for the purposes of this report. Taff *(1)* makes but the single statement: "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 steeply flexed." A geanticline is a composite fold produced by the lateral thrust having acted upon in a single direction. *(2)* It may be observed, however, that in the Arbuckle Uplift there must have been two opposing thrusts, one major and the other minor, since two sets of folds have been produced which intersect each other at almost right angles. Such a district may be described as one of complex folding. *(3)* The more important set of folds, those extending N. 76 degrees W, corresponding to the major thrust, may be called the longitudinal folds while the cross folds, corresponding to the minor thrust may be called the transverse folds.

Longitudinal Folds: The longitudinal folds consist of anticlines and synclines, the relative positions of which is shown in the outline structural map (Plate XII). Beginning at the northeast corner of the uplift, they occur in the following order: (1) the Lawrence anticline; (2) the Franks syncline; (3) the Hunton anticline; (4) the Wapanucka syncline; (5) the Belton anticline; (6) the Millcreek syncline; (7) the Tishomingo anticline; (8) the Dougherty anticline; (9) the Washita syncline; and (10) the Arbuckle anticline. The axes of these folds trend approximately N. 70 degrees W.

1 Taff, J. A., U. S. Geol. Surv., Prof. Paper No. 31, p. 38, 1904.
2 Van Hise, C. R., Jour. Geol., Vol. 4, p. 344, 1896.
3 Ibid., p. 345.

Transverse Folds: The general direction of the axes of the transverse folds is at right angles to that of the longitudinal ones. They are not so well defined since they are either larger or smaller folds than the longitudinal ones. They are as follows: (1) the Dougherty basin; (2) the Vine dome; (3) the larger truncated Roff dome, in the Pontotoc plateau, with ill defined north-south axis running from Roff to near Tishomingo, Okla.

Folds of a Higher Order: These are smaller folds which are to be found upon the flanks of the longitudinal or transverse folds, usually the transverse. There are numerous examples of these of which only the more prominent ones will be mentioned: (1) small transverse folds in the broad expanse of the Hunton of the Tishomingo anticline three to four miles southeast of Dougherty, Okla.; (2) various small longitudinal and transverse folds in the Hunton formation on the Lawrence anticline one to three miles east of Lawrence, Okla.; (3) small transverse folds in the southern limb of the Arbuckle anticline. Taff *(1)* says: "The rocks in the southern limb of the Arbuckle anticline have been crumbled to a small extent, apparently by forces active in the direction of the trend c 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 six miles east." Although the folds of the uplift may be considered seperately as longitudinal, transverse, and of higher orders, the resultant of the two opposed thrusts is manifest in each of the folds.

Effects of major and minor thrusts: In regard to the varying strength of the major and minor thrusts, Van Hise *(2)* has made the following statements: "In proportion as the major and minor thrusts approach each other in power the canoes become shorter and broader. Where they are nearly equal the folds are associated with canoes, which may be in one or two directions in the same region. Where the two sets of cross folds are about equally conspicuous the strikes and dips of the rocks vary constantly, their direction depending upon what part of the complex folds is under observation."

In applying these principles to the Arbuckle Mountains the complex folds are to be considered in three dimensions, since they are generally upright pitching anticlines and synclines or domes and basins. The following points may be noted: (1) The major and minor thrusts have approached each other in strength since the length of both the longitudinal and transverse folds is not much greater, if at all, than their width. (2) In the most completely preserved of all the anticlines, the Arbuckle, the truncated strata surrounding the East and West Timbered Hills have the quaquaversal dips, suggesting doming in the comparatively little compressed central and west portions of the fold. (3) To the north of the

1 Taff, J. A., U. S. Geol. Surv., Prof. Paper No. 31, p. 46, 1904.
2 Van Hise, C. R., Jour. Geol. Vol. 4, p. 346, 1896.

highly compressed and faulted east portion lies the Dougherty basin. It is a short-wide rectangular basin with its longest axis extending a little east of north, athwart the axes of the Dougherty and Tishomingo anticlines. (4) From two to three miles northwest of Dougherty, Okla., the truncated Vine dome shows strata with quaquaversal dips. This dome appears to be slightly elongated from north to south although the southern end is concealed beneath alluvial deposits of the Washita River. The north end abuts against and alters slightly the strike of the strata in the southern limb of the Dougherty anticline. The name Vine is suggested by Vine creek, which flows in a southwest course across the dome like uplift (5). Associated with this dome and the Dougherty anticlic are two canoe valleys which pitch northwest and southeast, respectively, from the north end of the dome. (6) In the contacts of the equally conspicuous Dougherty basin. Vine dome, Dougherty and Tishomingo anticlines the strikes and dips of the rocks vary constantly, "their direction depending upon what part of the complex folds is under consideration." (7) The Washita and Mill Creek synclines on the one hand and the Wapanucka and Franks synclines on the other, form wide V shaped re-entrant angles on opposite sides of a dome whose ill defined axis runs in a slightly west of north direction from near Tishomingo to Roff, Okla. This axis passes across the broad bases of the northwestward pitching Tishomingo anticline and the eastward pitching Hunton anticline. The depressed Viola near Sulphur, and the faulted Simpson strata at Hickory, are regarded as exposed portions of reentrant synclinal structures which have been concealed by the Carboniferous overlap along the west side of the Roff dome.

Factors modifying the form of the folds: The factors modifying the form of the folds have been five in number. They are as follows: (1) the almost equal power of the major and minor thrusts; (2) the competent structure; (3) the light load; (4) the crystalline base; (5) the faulting. These factors may be considered more at length in the order named.

1. Almost equal power of thrusts: That the major and minor thrusts had almost equal power is to be learned from the well defined Vine dome, the Dougherty basin, and from the larger Arbuckle, Tishomingo and Hunton anticlines which are almost as broad as long.. If there had been but a single thrust the folds would have been long and narrow and unlike the present ones. As the Arbuckle and Tishomingo anticlines are steeper in their north limbs than in their south ones it would seem that the major thrust came from the southwest. It is difficult to determine whether the minor thrust was supplied from the southeast or northwest

2. Competent Structure: The term competent structure *(1)* has been defined as follows: "Where a force tangential to the earth's

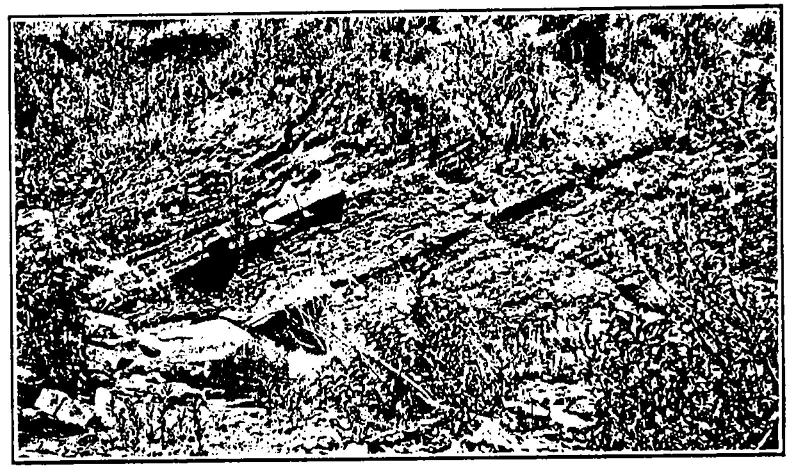
1 Willis, B. and Hayes, C. W., Am. Jour. Sci., 3d Series, Vol. XLVI, p. 263, 1893.

surface affects a stratified mass it is transmitted by the strata in the direction of their lateral extent and by each stratum according to its rigidity. . . . The stratum which thus most effectively transmits pressure may be called the competent stratum." In considering a columnar section of the strata concerned in the Arbuckle uplift, (Plate XII) it may be noticed that it is composed of weak and strong members. The rigid strata in the order of their importance are the Arbuckle, Viola, Hunton and Sycamore limestone. They constitute more than half of the thickness of the entire uplift which averages about 10,000 feet. Of these the Arbuckle limestone, 4,000 to 6,000 feet thick, is easily the most massive and strongest and thus constitues the compenent stratum.

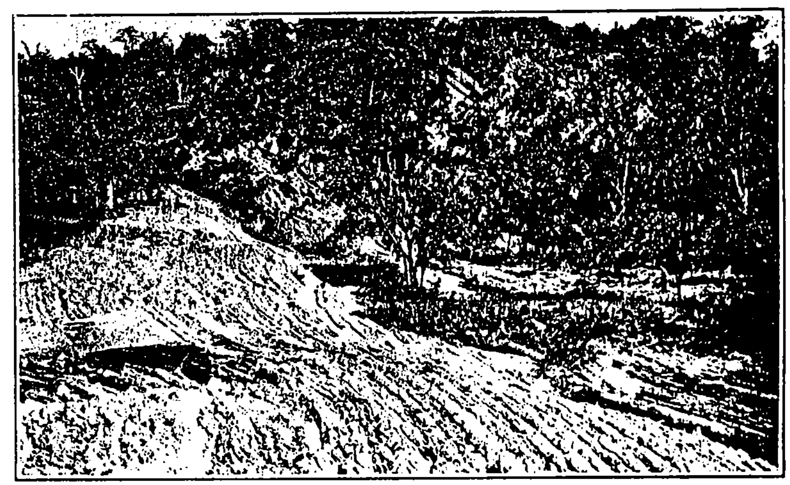
The competent stratum having been determined the development of anticlines and synclines follows the law of anticlinal development as defined by Willis: *(1)* "In strata under load an anticline arises along a line of initial dip, when a thrust, sufficiently powerful to raise the load, is transmitted by a competent stratum. The resulting anticline supports the load as an arch, and being adequate to that duty it may be called a competent structure." In the formation of domes and basins there are two or more thrusts instead of one applied to the competent stratum in directions at right angles to each other. Since there is more than one rigid stratum concerned in the folds of the Arbuckle Mountains, the Viola, Hunton and Sycamore formations, they may be considered as less competent members which alternate with relatively incompetent strata of the Simpson, Sylvan, Woodford, Caney and Gleen formations. In an anticline or dome each rigid member carries up the immediately overlying incompetent load. The total weight of the arch or dome is transmitted proportionally through the limbs of the various rigid strata, but the chief weight is transmitted by the competent stratum, the Arbuckle limestone, to the adjacent synclines. Thus in response to the major and minor thrusts the various pre-Pennsylvanic beds have been heaved up into a complex competent structure of broad anticlines, synclines, domes and basins.

3. The Light Load: The thickness of the beds above the competent stratum, the Arbuckle limestone, at the time of the uplift was possibly not greater than 4000 feet. This was not enough to produce flowage in the Arbuckle limestone, since the combined thickness of the competent stratum and the cover would not reach below the zone of fracture. *(2)* In the mechanics of mountain making 4000 feet of sediments are considered to be a very light load and under such conditions overturned folds and thrust faulting are the results rather than open or close folding. Overturned folds and thrust faults, however, do not occur in the uplift. It is believed this result was obviated by the presence of two almost equal thrusts

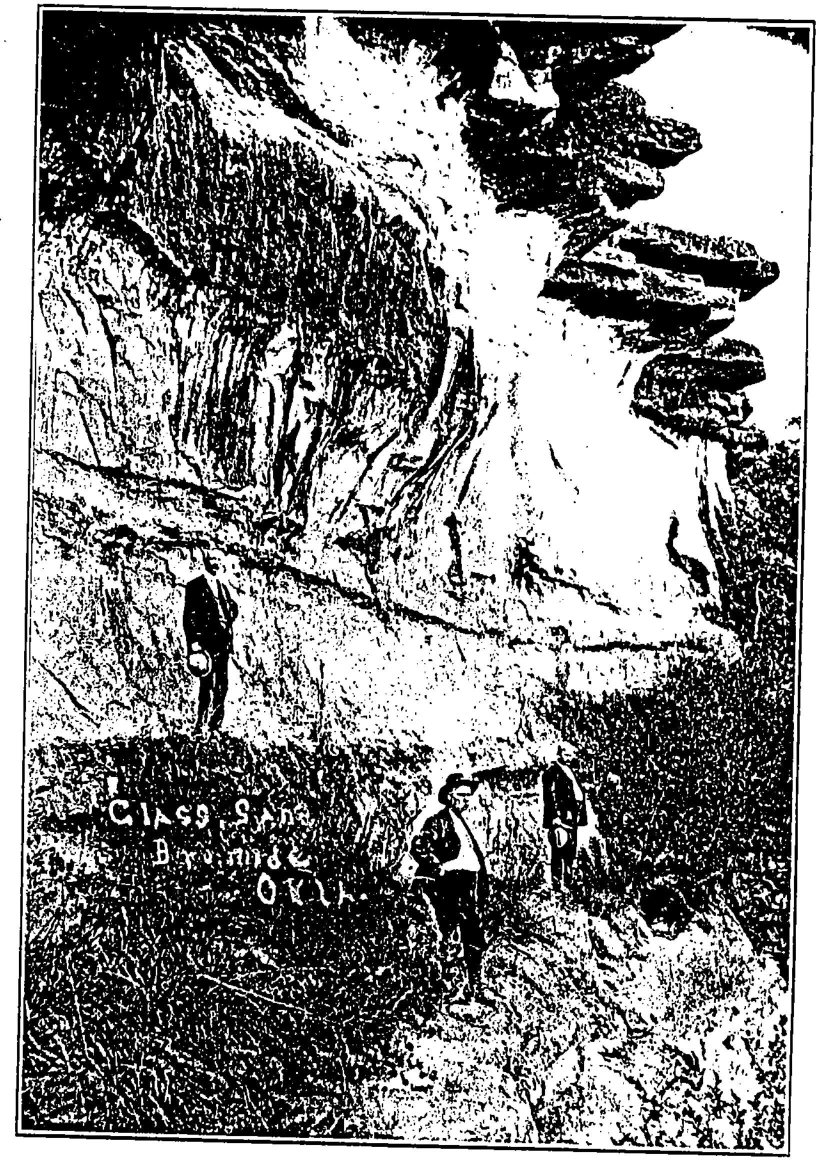
1 Willis, B., U. S. Geol. Surv. 13th Am. Rept., Pt. II, p. 250, 1893.
2 Van Hise, C. R., Jour. Geol. Vol. 4, p. 201, 1896.



A. Exposure of green Simpson shales in the west bank of Dalton creek, Arbuckle Mountains, Okla.



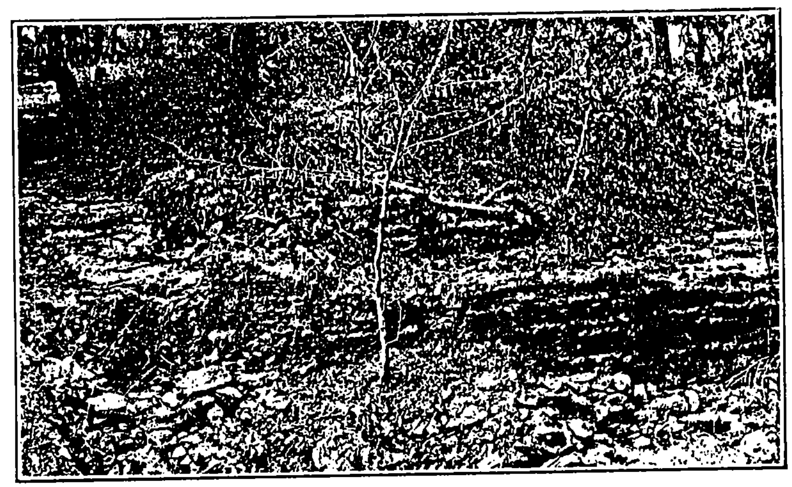
B. Woodford chert at "Little Falls" on Hickory creek, one mile north of Woodford, Okla.



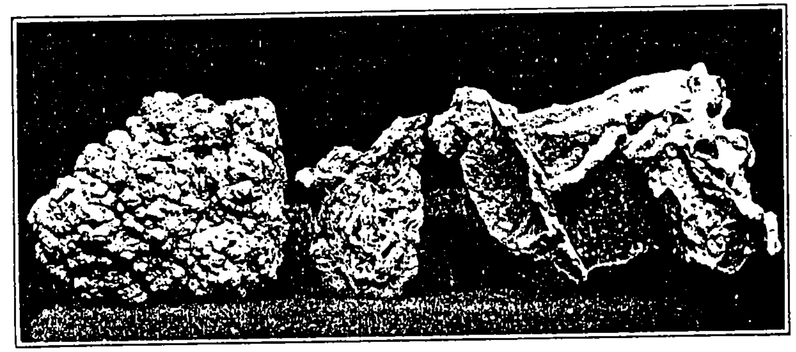
A bank of the Simpson glass sand, Delaware creek, four miles west of Bromide, Okla.

PLATE XV

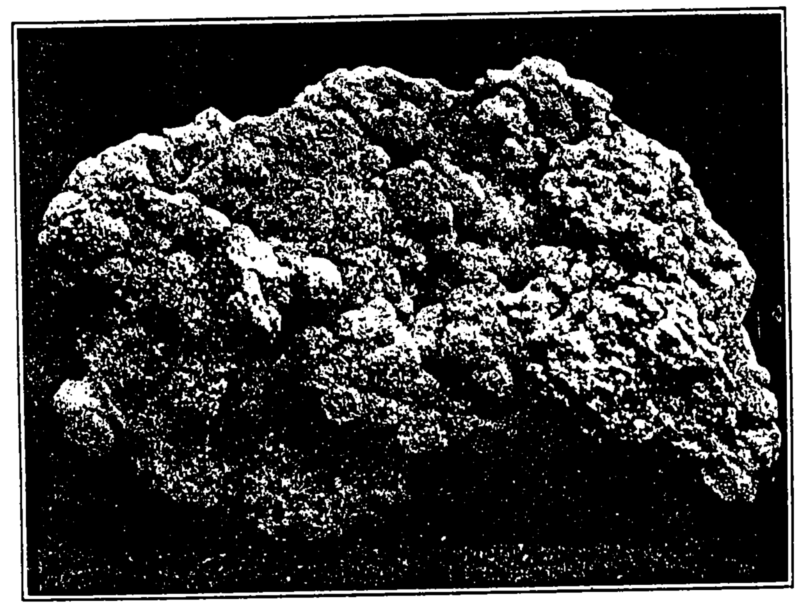
A. STRUCTURE. Local fault scarp in the Mosely limestone (basal Hunton), Lawrence anticline, center of Sec. 9, T. 2 N., R. 6 E.



B. STRUCTURE. Fault scarp of a prominent fault in the Mosely limestone (basal Hunton) in bed of small stream, Lawrence anticline, N. E. 1-4 Sec. 17, T. 2 N., R. 6 E.



A. Three specimens of manganese iron ore illustrating botryoidal, porus and box-shaped structures. Arbuckle Mountains, Okla.



B. Botryoidal forms of iron ore as exterior coatings of fine-grained sandstone. Viola formation three miles northeast of Roff, Okla.

which were opposed and thus developed the complex folds of broad anticlines, synclines, domes and basins.

4. *The Crystalline Base:* The crystalline base of granite and a. lied rocks has been one of the factors modifying the form of the folds. It is considered to have been buried possibly 10,000 feet just previous to the time of the uplift. The Reagan sandstone, Middle Cambrian, rests unconformably upon it and there are no intrusive masses of igneous rocks to be found within the sedimentaries. No doubt as a homogeneous mass it offered great resistance to the major and minor thrusts in arching the sedimentary rocks. It has been affected, however, by the normal faulting which afforded great displacements of the overlying paleozoics. *(1)* A block structure resulted in which some blocks were depressed while others remained stationary or have been carried upward by later uplifts. The more denuded surfaces of the Tishomingo and Arbuckle anticlines warrants this statement.

5. *Faulting:* One of the greatest of the adjustments modifying the form of the folds was faulting. From a study of the major faults of the district it has been observed that generally the overhanging side has descended with reference to the other. They should be classified as tension faults rather than compression faults or as usually defined normal faults rather than thrust faults. It is most probable that gravity has been the predominent force and that the overhanging side, with its smaller base, has been pushed down. But normal faults are not the only kind that are in evidence. In the Millcreek syncline heave faults *(2)* are in evidence. A fine example of where the tilted beds have evidently been moved horizontally for over a mile to the east, is indicated by the present position of a fault block along the fault plane a mile eastward from its original mooring in the north limb of the Tishomingo anticline. The direction of the strike, thickness, and orientation of the Woodford, Hunton, Sylvan and Viola formations in the block are the same as for those beds present in the north limb of the Tishomingo anticline one mile to the west of the block. This block outcrops four miles west of Mill creek,Okla. (Geologic Map, Plate XXIV). Another instance was noted by Taff *(3)* on the south side of Sec. 34, T. 2 S., R. 3 E.

The major faults which usually run parallel with the longitudinal folds are strike faults. They are not numerous but seem to affect the limbs of the synclines causing in places great vertical and horizontal displacements. The hades are steep and it is probable that this part of the earth's crust has not been greatly dilated. Prominent fault scarps (Plate XV, A and B) are to be seen frequently in the limestone beds along the major and minor faults.

Minor transverse faults have been mentioned by Taff *(4)* in the

1 Taff, J. A., U. S. Geol. Surv., Prof. Paper No. 31, pp. 40, 44, 1904.
2 Ransome, F. L., Economic Geol., Vol. I, p. 786, 1906.
3 Taff, J. A., U. S. Geol. Surv. Prof. Paper No. 31, p. 45, 1904.
4 Ibid., p. 40.

Wapanucka syncline. They are not uncommon in the mountains, the author having noticed many local ones in studying the Hunton formation.

The faults of the Arbuckle Mountains are normal or heave faults, but when it is considered that almost the entire north limb of the Tishomingo and Arbuckle anticlines, east of the Washita river canyon, have been faulted down, it may be seen how the original extent of these folds has shrunken as the result of faulting. The axial planes of these folds are inclined to the South. Remnants of a synclinal trough along the fault line between these two anticlines were considered by Taff *(1)* as probable eastward extensions of the Washita syncline. The structural history of the Arbuckle anticline east of the Washita river canyon is complex and demands further field investigation before it can be fully explained.

If it were possible to measure the length of the greatly faulted limbs of the truncated complex folds this would be a factor in determining the presence of overturned folds. In order to make such an estimate it is necessary to restore the folds to the form they possessed before being affected by erosion and faulting. It is impossible to do this at the present time since a sufficient number of accurate sections across the folds have not been made.

DESCRIPTION OF THE FOLDS

General: The more or less detailed description of seven of the folds, the Hunton, Belton, Tishomingo, and Arbuckle anticlines and the Wapanucka, Mill creek and Washita synclines has already been given by Mr. Taff *(2)* and need not be repeated here. Under Tishomingo anticline brief mention was also made of the Vine dome, the Dougherty anticline and the Dougherty basin, although they were not named. No mention whatever was made of the Lawrence anticline and only the following was said with reference to what is now called the Franks syncline: *(3)* "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." Since this was written the boundaries of this syncline have been retraced and considerably altered, as may be seen by comparing the Geologic Map (Plate XXIV) with Taff's *(4)* map of the region. In order to fix more definitely the boundaries of the various folds and to show at a glance their relations, an outline structural map has been prepared (Plate XVI).

1 Ibid., pp. 42, 43.
2 Ibid., pp. 38-46.
3 Ibid., p. 39.
4 Ibid., Plate I, opp. p. 20.

Franks Syncline

General Features: This syncline occupies not only the central part of T, 2 N., R. 6 E., but extends westward until it terminates in a fault line near the section line between sections 14 and 23, T. 2 N., R. 5 E. It is thus triangular in shape and like the Wapanucka syncline forms a reentrant angle which opens eastward, toward Franks and Stonewall, Okla. The statement made above in regard to the steeply upturned beds and faulting is true, but instead of having only Simpson beds in the south limb and chiefly Viola limestone in the north limb as mapped by Taff, it has been found that there are banded exposures of Hunton and lenticular masses of Viola limestone, Sylvan shale and Woodford chert as mapped in Plate XXIV.

Northwest Limb: A lentil of Woodford chert has been preserved in the south central part of Sec. 10, T, 2 N., R, 6 E., while two more are to be found in the north part of Sec.17 of the same township and range. They are steeply inclined, and considerable thicknesses of Woodford are to be seen, but they are only short lentils since a prominent fault line brings them in contact with the Franks conglomerate. In Section 17 a second fault line crosses the Hunton and merges with the innermost one before passing far beyond that section. Between the fault lines the middle and upper Hunton beds are steeply inclined S. E. toward the axis of the syncline. The basal Hunton limestone beds (Mosely) to the northwest are but very slightly inclined in the same direction. In the northwest corner of Sec. 18, T. 2 N., R, 6 E., the Hunton and Sylvan beds terminate along a fault line which bears northwest-southeast. Along the east side of this same section a lentil of basal Hunton limestone crops out along the east foot of the high Viola limestone hill. No Sylvan is exposed here, the Hunton being in contact with the Viola. Small dark masses of asphalt assist in locating the contact. In the southwest corner of Section 18 a small lentil of Sylvan shale and almost a complete section of the Hunton appear on edge. The Hunton exposure can be traced southwestward, chiefly by the oolite and glauconitic limestone of the lower member, across the south side of Sec. 33, T. 2 N., R. 5 E., to near the half mile stone on the section line between Secs. 14 and 23, T. 2 N., R. 5 E., where it is cut out by a strike fault from the southwest limb of the syncline.

Southwest Limb: About half way along the east side of Sec. 24, T. 2 N., R. 5 E., the Viola, Sylvan and Hunton outcrops are on edge. The Sylvan soon gives out to the southeast due to intense local folding. The Viola and Hunton beds, however, can be traced southeast towards Franks. In the east side of Sec. 29 and the west side of Sec. 28, T. 2 N., R. 6 E., just north of Big Spring creek, the Sylvan shale outcrops again for about one half mile. To the south of it a partial section only of the Viola is present, while to the north the Hunton is more or less complete, the Franks conglomerate forming an uneven contact with it. The Woodford is evidently faulted down along the entire southern limb and also along the northern limb except for the three lenticular exposures mentioned above, since asphaltic carboniferous sandstone and conglomerate are not only in contact with the Hunton but are likewise oftentimes on edge. In the southern half of Sec. 28, T. 2 N., R. 6 E., lenticular exposures of Viola and Hunton limestones, in contact with one another, outcrop between Simpson beds on the southwest and Franks conglomerate on the northeast. Only partial sections of the Viola and Hunton formations may be observed, due to their attenuated exposures between prominent strike faults. About one fourth mile due west of the southeast corner of Sec. 28, T. 2 N., R. 6 E., the oolite, glauconitic and pink crinoidal crystalline limestone, basal Hunton, and a few feet of yellowish shaly limestone beds outcrop. The dip is 32 degrees, 10 degrees west of south. The natural order of the beds, however, is somewhat reversed, the oolite, the base of the section, appearing at the east instead of the south edge of the outcrop. The Simpson and Franks contacts are not sharp. In the northeast corner of Sec. 33, T. 2 N., R. 6 E., the Viola, Sylvan and Hunton formations are completely hidden, chiefly by Franks breccia and conglomerate.

In the N. W. 1-4 Sec. 34, T. 2 N., R. 6 E., four blocks of Hunton have been so moved about that they occupy almost a transverse position to the general northwest-southeast strike of these beds in the southern limb of the Franks syncline. They are almost concealed by the thick growth of timber and the overlap of Franks conglomerate on the north. These blocks may be described more in detail:

Block No. 1: Lying in the northwest-southeast strike of the Hunton in the bluff, on the west side of the wagon road leading from Franks to the Big Spring, a block of the Clinton bears 15 degrees E. of south. Dip 59 degrees E. N. E. The oolite and a bit of Sylvan shale are exposed. Franks breccia overlaps the exposure on the north.

Blocks No. 2 and 3: Some 300 yards northwest of Block No. 1 in the northwest-southeast strike of the Hunton blocks Nos. 2 and 3 have the relation one to the other and to the adjoining beds as shown in Figure 10. In block No. 3 twelve feet of oolite are exposed at the base. This is the thickest section of the oolite observed in the mountains. The basal one and a half feet is a white oolite limestone containing crinoidal fragments, and is comparable to the same zone in the oolitic limestone exposures at Lawrence, Okla., and elsewhere. The dip is 78 degrees S. W. and the strike 30 degrees E. of south. The section continues upward with 3 feet of white crystlline glauconitic limestone, 39 feet thin bedded to massive crystalline pink crinoidal limestone, and 50 feet, approximately, of yellowish moderately thin bedded shaly limestone. The Franks conglomerate overlaps on the northeast.

Block No. 4: One hundred yards a little north of west of block

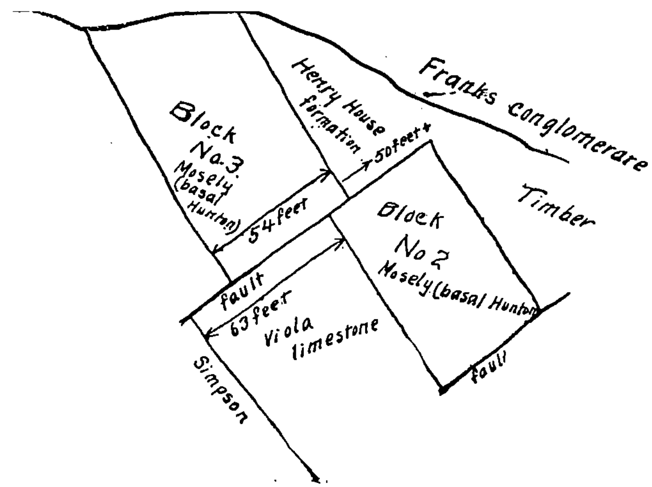


Fig 10. Structure. The approximate relation of Fault Blocks Nos. 2 and 3, in the southwest limb of the Franks syncline, N.W 1/4. Sec. 34. T 2N., R6E.

No. 3, block No. 4 appears. The combined thickness of the oolite, glauconitic white crystalline and pink crinoidal limestones is 51 feet. Dip 90 degrees, strike S. S. E. The initials C. A. R. '08 were outlined with the hammer point on the south face. About 90 feet of yellowish, moderately thin bedded shaly limestone occur above these beds and beneath the Franks conglomerte. The Simpson sandstone runs N. W.-S. E. 50 feet southwest from the nearest oolite corner.

A prominent strike fault passes near the south edge of these blocks and continues southeastward across Big Spring Creek to the southeast corner of Sec. 36, T. 2 N., R. 6 E., a mile beyond the edge of the mountains. It is believed a similar fault passes across the north edge of these blocks, for vertically disposed conglomerate beds are to be seen in a few places in contact with the Hunton. Talus slopes of conglomerate material, however, generally conceal the contact.

Hunton exposures appear in the northwest-southeast line of strike of the formation in the southeast bank of Big Spring creek. The glauconitic limestone comes in contact with the Viola, the Sylvan shale and oolitic limestone being faulted down. The Hunton is broken up into many small blocks, generally too small to map, and is pitched about very much. The basal Hunton limestone in contact with the Viola, runs well up on the north side of the rounded hill shown in Sec. 34, T. 2 N., R. 6 E., on the Stonewall topographic sheet and District Map "A." The Hunton is about 325 feet thick with a dip of 50 degrees N. E. Where Big Spring creek crosses the Hunton some 25 feet of Franks conglomerate are exposed in the east bank in contact with the upper crystalline limestone beds.

In conclusion it may be said that faulting has greatly affected the formations in the northwest and southeast limbs of the Franks syncline, and that "the rocks are depressed by faulting as well as by folding."

Lawrence Anticline

General Features: This anticline includes the most northeasternly exposed formations concerned in the Arbuckle uplift. It lies to the north and west of the Franks syncline and has been called the Lawrence syncline after Lawrence, Okla. The anticline pitches to the eastward, the axial trend being a little north of east. The beds are but gently inclined and but slightly faulted and in these respects are in marked contrast to those of the Franks syncline. The general dip of the Viola, Sylvan, Hunton and Woodford formations is 10 degrees to the east. This is disturbed, however, by a number of longitudinal and transverse folds of various orders. The longitudinal folds, which are the more prominent, bear generally northeast southwest. They may be considered in order, beginning at the south side and passing to the northwest.

Fold No. 1: The largest of the longitudinal folds is an anticlinal one whose axis runs in a west-east direction through Sections 7, 8, 9, 10, 11 and 12, T. 2 N., R. 6 E. Bois d'Arc creek in crossing the Hunton flows for nearly two miles along the axis of the anticline. In the south limb the strata are highly tilted only in close proximity to the great fault in the northwest limb of the Franks syncline. In the north limb they are more gently inclined toward South Jackfork creek.

Fold No. 2: In Sec. 4, T. 2 N., R. 6 E., the strata in the north and south banks of South Jackfork creek dip at an angle of 7 degrees toward a synclinal axis which follows the general course of this stream bed through Sections 5, 4, and 3, T. 2 N., R. 6 E. This is very noticeable at "Cedar Bluff" and to the north of the creek for one-fourth mile along the Hunton-Woodford contact.

Fold No. 3: This is a low anticlinal arch paralleling the general course of South Jackfork creek about one fourth mile to the north of that stream.

Fold No. 4: This is a shallow synclinal fold which bears a little north of east near the township line, about one half mile north of the bed of South Jackfork creek in Sections 5, 4, and 3, T. 2 N., R. 6 E. "Biscuit Mound" on the township line, and beds a little to the south of west, and a little to the north of east from this point occupy axial positions.

Fold No. 5: This is a narrow anticlinal fold whose axis runs through the southwest corner of Sec. 31, (township corner) and the northeast corner of Sec. 33, T. 3 N., R. 6 E. This explains the outcrop of the basal Hunton limestone in a tongue like form along this axis in Sections 31 and 32.

Fold No. 6: This is a synclinal fold which is observed at Lawrence, Okla., and to the east of Lawrence in the basal Hunton limestone members. Its axis extends northeastward. North Jackfork creek follows it in the south side of Sec. 28, T. 3 N., R. 6 E.

Fold No. 7: This fold may be noticed as a low anticlinal arch in the southwest corner of Sec. 30, T. 3 N., R. 6 E., and continuing northeast towards the center of Sec. 29. A local fault with down throw on the south side extends for about one half mile along the south side. A fault scarp and fault breccia were noticed along this fault in the southeast corner of Sec. 30. The north limb of this anticline has a 5 degree dip.

Fold No. 8: Around the center of Sec. 30, T. 3 N., R. 6 E., the basal Hunton limestone strata dip to a 25 foot lentil of Brownsport shaly limestone which has escaped erosion in the hollow of a shallow basin. The dip from the northwest, west and southwest is between 10 degrees and 15 degrees while to the east it is less than 5 degrees W. The axis of this syncline or basin thus gently rises to the east down the small stream. Along the east side of Sec. 30, about one fourth mile south of the half section corner, in the bed of this same creek, some 3 feet of oolite are exposed for a distance of

100 feet. The white crystalline glauconitic limestone of the basal Hunton rises as a ten foot wall above the oolite in the north bank of the stream. The pink crinoidal limestone of the basal Hunton crops out about 100 feet north of the creek and extends north to the vicinity of the half section corner and the Price school house. The log of a well bored at this school house shows 47 feet of basal Hunton and 54 feet of Sylvan shale.

Fold No. 9: This fold constitutes a low anticlinal arch which lies a short distance from No. 8 and converges with No. 7 in the west central part of Section 29, as may be seen in the basal Hunton exposure of that section. The axial trend is from northwest to southeast across the north central part of section 30 to the central part of Section 29, T. 3 N., R. 6 E.

Fold No. 10: This is a shallow synclinal fold whose south limb is exposed along the north line of Section 30 and the north half of Section 29, T. 3 N., R. 6 E. The axial portion is concealed beneath Woodford and Carboniferous sediments to the north.

The transverse folds are smaller than the longitudinal ones, nevertheless, they are present. Two examples are noticeable. (1) About the center of Sec. 4, T. 2 N., R. 6 E., with limbs dipping at 15 degrees E. and W., strikes directly across the axis of Fold No. 2 in the bed of South Jackfork creek. (2) A transverse fold crosses the northeast corner of Sec. 31 in a northwest-southeast direction from Sec. 32, T. 3 N., R. 6 E. The strata dip in opposite directions from the axial portion of this ridge at angles between 10 degrees and 15 degrees.

In conclusion it may be said that the Lawrence anticline and its smaller folds are comparable to the Hunton anticline in the vicinity of Hunton, Okla., and also to the western margin of the Tishomingo anticline three to four miles southeast of Dougherty, Okla.

CHAPTER IV

MINERAL RESOURCES

Iron and Manganese

Iron is present in all of the rocks of the Arbuckle Mountain, both igneous and sedimentary, occurring (1) as a coloring constituent in all of them; (2) as scattered ore bodies in the Reagan, Arbuckle, Viola and Hunton formations. The oxides, sulphides and silicates of iron, the chief minerals present, have played a very subordinate role and are to be considered as accessory minerals.

Since iron is the chief coloring matter in all rocks, it is not unnatural to find in this particular region that certain ones are almost pure white, while other are variously colored. In the case of the Woodford chert, there is, in addition to the iron, a considerable amount of carbonaceous material. It shadows the iron in fresh exposures, the thin-bedded shaly rock appearing black or bluish in color. Where points or bluffs, however, have been exposed to the agents of weathering the carbonaceous matter is leached out and the various orange tints indicate the presence of iron.

In the igneous rocks, iron is present both as silicates and oxides. Of the silicates present, biotite occurs almost invariably as an important constitutent, while hornblende and muscovite are less prominent. Augite is conspicuous in the basic dikes which penetrate the granite and allied rocks. As to the oxides of iron, titanite, magnetite and hematite are present. Titanite occurs as extremely perfect crvstals in the biotite granite. Magnetite is abundant in the basic dikes and granite porphyries, where, in the latter, iron stains all the feldspar constitutents. In the aplite dikes, there are small amounts of magnetite and hematite. These oxides and silicates of iron appear as small crystals disseminated through the igneous rocks, and are here important only in that they give color to building stone and are the original sources of the iron of economic value found in beds and pockets in sedimentary rocks.

In the sedimentary rocks the iron occurs as oxides and sulphides. The sulphide, iron pyrites, is found in small crystals scattered through all the formations. The oxides occur in small pockets, except high up in the Reagan formation south of the West Timbered Hills where a poor grade of ore appears in thin beds.

The pockets consisting of iron and maganese are found in the Arbuckle, Viola and Hunton limestones. They appear on or near eroded limestone surfaces, in the form of knobs, and generally occupy the higher prominent points because of their greater resistance to the action of weathering. About 400 feet from the base of the Arbuckle formation, ore masses occur frequently in a porous

dolomitic horizon. They vary in size from masses smaller than a pea to those as large as a hogshead weighing tons. The smaller nodules are in great abundance and of better quality than the large masses which may be porous, box shaped, or botryoidal in outline and texture. The figured specimens (Plate XVII, A.) illustrating these features suggest that masses of limestone or dolomite containing ferrous carbonate have been dissolved and carried away, but that the iron, oxidized to the ferric condition in the process, has become insoluble and has gradually concentrated.

In some of the exposures in the Viola, near Fitzhugh, fine-grained sand was found filling, in part, the porous or cavernous nodules. In other cases, the rock weathers into botryoidal forms, the sand occupying the inside, the iron the outside of such masses. In the figured specimen (Plate XVII, B.), it is to be noted that a lichen has grown over such a surface thus presenting a pitted surface.

In the Hunton formation near the type locality, two pockets of manganese iron ore were worked in 1891 and in 1905. As the information concerning these ore bodies is more complete than that of any other area in the mountains, these deposits may be considered at greater length. Their location is indicated upon the large map in Section 17, T. 1 S., R. 8 E. The geological horizon is in the pink crinoidal limestone at the top of the Mosely formation (Clinton) in Taff's basal member of the Hunton.

In the Mineral Resources, U. S. Geol. Surv., 1892, Mr. Hunton, a person interested in these pits, gives the following information concerning them:

"Not much work has ever been done to ascertain the full extent of these deposits. At one opening the surface soil has been removed from 2 to 6 feet in depth for a space of say 30 to 70 feet. At another opening the surface soil is not over 2 feet deep; from this opening which is say about 20 to 100 feet, was taken 97 tons of black oxide of manganese and about 300 to 400 tons of carbonates, large quantities of which are still in sight, not taken out."

In 1891 these pits produced 206 long tons of manganese ore, having a total value of $1,174.00, with a value per ton of $5.70. The ore was hauled by wagons some twenty miles, to Lehigh, Indian Territory, and from there shipped to Chicago for manufacture into spiegeleisen. The twenty mile haul was too expensive to insure a margin of profit, so that after one year's operation mining was discontinued. In 1905 the mines were again worked, following the completion of a new branch of the Rock Island railroad. The ore was hauled to Wapanucka, ten miles distant from the mines, and shipped to various points in Missouri. No statement as to the amount shipped was obtainable. Since then the pits have remained unworked.

In composition the ore consists of black oxides and red, brown and gray carbonates. The black oxides are found both above and below the carbonates. The analyses of seventeen carloads shipped to the Illinois Steel Company give the following results:

Analyses by Illinois Steel Company of Black Oxide of Manganese from Hunton, Oklahoma, 1892.

Cars	Weight, less moisture lbs.	Iron Per cent	Silicon Per cent	Phosphorous Per cent	Manganese Per cent	Moisture Per cent	Price per ton
2	44,003	6.00	1.40	0.055	39.66	4.05	$10.32
2	52,226	6.15	1.45	.066	39.67	4.75	10.31
2	49,807	5.72	1.70	.060	43.18	3.25	12.09
2	45,816	6.76	1.20	.053	38.54	4.05	10.02
5	156,738	8.00	1.50	.050	40.50	3.70	10.93
4	93.910	8.09	...	....	35.78	5.00	8.95

Analyses by Rattle and Nye of Cleveland, Ohio, of Manganese Carbonate Ores from Hunton, Oklahoma, 1892.

Per cent Mangenese	Per cent Phosphorous	Per cent Manganese	Per cent Phosphorous
27.25	0.032	25.48	0.053
4.42	.119	25.99	.061
24.71	.066	28.68	.047

In United States Mineral Resources for 1891, the analyses of eleven samples of ore from Hunton, Oklahoma, are given as follows:

Analyses of Hunton, Oklahoma, Manganese Ore.

Silica Per cent	Iron Per cent	Manganese Per cent	Phosphorous Per cent	Sulphur Per cent
.30	2.46	51.78	.053	
.75	3.07	59.55	.026	
.85	4.92	40.28	.046	
1.30	1.23	43.18	.036	
2.00	1.84	49.34	.053	
.60	5.53	52.35	.056	
1.40	5.95	42.95	.050	
.35	1.23	63.50	.023	
.83	2.46	46.05	.047	.024
.73	3.58	42.07	.033	.04
...	...	42.71	.061	

In the summer of 1908, Mr. W. H. Jackson furnished to this Survey the following analyses made in June, 1907, by the Kansas City Chemi-Technic Laboratory Company from samples collected from prospects along the proposed line of the Missouri, Oklahoma, and Gulf Railroad:

The analysis of the ore from prospect No. 1 shows that the iron is prominent but that the manganese is not.

Prospect No. 1 (Iron ore): This is a very good grade of brown hematite. The very low phosphorous and the absence of sulphur makes this a desirable iron ore.

$Mn^3\ O^4$	5.20
$Si\ O^2$	4.60
$Fe^3\ O^4$	52.05
$Al^2\ O^3$	8.75
Ca O	8.00
Mg O	trace
Loss on ignition, CO^2 etc.	9.52
Moisture	1.20
$P^2\ O^5$	0.31
Total	96.63

Metallic manganese	3.74
Metallic iron	36.44
Phosphorous	0.12
Sulphur	none

Prospect No. 2, Sec. 17, T. 1 S., R. 8 E., Hunton Locality.

Mn tetro oxide (Mn^3 O^4)	24.60
Si O^2	1.60
Fe^2 O^3	15.40
Al^2 O^3	0.40
Ca O	24.20
Mg O	trace
Loss in ignition, CO^2 etc.	32.08
Moisture	1.08
Phosphorous pent-oxide (P^2 O^5)	0.30
	99.38

Metallic Manganese	17.71
Metallic Iron	10.78
Phosphorous	.11
Sulphur	none

Prospect No. 4, (Manganese nugget), Sec. 17, T. 1, S., R. 8 E., Hunton locality.

(Note: These manganese nuggets were lying on the surface of the ground.)

Mn tetro-oxide (Mn^2 O^4)	84.20
Si O^2	1.28
Fe^2 O^3	2.86
Al^2 O^3	1.34
Ca O	2.20
Mg O	none
Loss on ignition (CO^2)	5.48
Moisture	.80
P^2 O^5	.38
Total determined	99.90

Metallic Manganese	61.05
Metallic iron	2.01
Phosphorous	.16
Sulphur	none

(Note: This is a very desirable manganese ore.)

Prospect No. 6 (Manganese Ore), S. E. 1-4 Sec. 17, T. 1 S., R. 8 E., 1 1-2 miles south of Hunton, Oklahoma.

(Note: This was taken from the abandoned pit from which the Illinois Steel Company took 17 car loads, mentioned above.)

Mn^3 O^4	78.00
Si O^2	3.60
Fe^2 O^3	2.85
Al^2 O^3	1.66
Ca O	5.00
Mg O	none
Loss by ignition (CO^2)	7.60
Moisture	1.00
P^2 O^5	.34
Total	100.05

Metallic Manganese	24.16
Metallic iron	14.00
Phosphorous	.11
Sulphur	none

From the foregoing it will be noticed that although all the samples have been collected from the vicinity of Hunton, Oklahoma, they vary in the amount of iron and manganese present. Samples were collected from other outcrops in the mountains for the Oklahoma Geological Survey laboratories, but the report of analyses has not yet been received. From the general appearance of the ore in the field, iron and manganese are oftentimes associated in the same pocket.

As regards the amount of ore the iron and manganese ore pockets are for the most part widely scattered throughout the mountains, thus tending to retard development. It has been estimated that the ore in the various localities would, if gathered together, cover a tract of twenty-one acres two feet deep or contain 1,829,520 cubic feet. This seems to be a conservative estimate, for in many cases the ore is from two to five feet thick, while in only a few others is it less than two feet in thickness.

Lead and Zinc

Lead and zinc occur in the Arbuckle Mountains, but in very small amounts.

A small amount of lead has been found by the chemist of the Oklahoma Portland Cement Company, in the company's quarry in the Viola limestone at Lawrence. Numerous small galena crystals were also noticed along a fault line in the Hunton limestone, N.

E. 1-4 Sec. 17, T. 2 N., R. 6 E. Some prospecting has been done, but the outcrops are few and of small extent, not warranting further development.

Some poor specimens of zinc ore, seen at Millcreek, were reported from the Millcreek syncline. Other specimens of a very good quality, though said to be of local origin, evidently came from Missouri, Arkansas or northeastern Oklahoma zinc and lead regions. Various localities cited as zinc bearing, proved upon inspection to be misrepresented. Zinc ore, however, was found in place as small crystals of sphalerite disseminated through the Arbuckle limestone, on the right bank of Colbert Creek, Sec. 17, T. 1 S., R. 1 E. It is known locally as the Dr. Hope and Miss Sober prospect. No test as to the richness of this ore has been made, but form the very small size and number of the crystals it is believed not to be in paying quantities.

Gold, Silver and Copper.

Gold, silver and copper ores do not occur in the Arbuckle Mountains in paying quantities. Traces of gold, such as occur in most all stream courses, may be found in the alluvial deposits along the rivers and larger creeks. The green color in the Reagan formation south of the West Timbered Hills and elsewhere is not due to the presence of copper ore, as some prospectors have imagined, but arises from the disseminated green grains of glauconite, which is of organic origin.

Phosphate.

The small round nodules in the black to gray Woodford shale and chert contain phosphate. Samples were collected from various localities and turned into the Survey laboratories for tests, but no report has been received to date. Owing to the sporadic occurrence of these nodules, it is believed, however, that the amount of phosphate present is very small.

Coal.

Coal does not occur in the Arbuckle Mountains. A few thin beds, from one to six inches thick, were pointed out to the writer in S. E. 1-4 Sec. 21, T. 2 N., R. 6 E., but these are of Pennsylvanian age and occur along the western border of the basin which contains the Colgate and Lehigh coals. These beds dip to the east, down stream, at a greater angle than the bed of the creek, and consequently disappear beneath it.

Sand—Glass Sand.

Sand occurs in the Arbuckle Mountains in the Reagan, Arbuckle, Simpson and Franks formations. In the Reagan, it is arkosic to medium grained and basal in position, resting unevenly upon the eroded surface of the granite. It contains a moderate percentage of iron, which, together with its coarseness, debars its use as a glass sand.

In the upper 1000 feet of the Arbuckle formation, thin beds of white fine-grained sandstones occur interbedded with gray limestone and yellowish shales. The thickest bed of sandstone is approximately five feet in thickness, while the others are often not more than from two to four inches in thickness. The thinness of the beds will probably not warrant their exploitation, although as a glass sand the quality seems very high.

The Simpson contains three prominent, and in same places, five sandstone members. The remaining parts of the formation consist of intercalated beds of limestone and green shale. The sandstones are, as a rule, quite thick and uniform in size of grain. The basal one resting upon the Arbuckle formation is approximately 153 feet thick along the south side of the mountains between Ravia and the Washita river gorge. West of this gorge, it is about five feet thick yet in many places it is wanting. The middle and upper sandstones are more prominent and less variable in thickness than the basal one. In cross section they are conspicuous, for each bears a belt of timber paralleling the strike of the formation. In the northeast part of the mountains, between Roff and Franks, the section is not complete. the basal and middle members being absent.

The Simpson sandstones are fine, even grained, and contain but a small percentage of iron, thus appearing white except upon long exposure, where the small iron content has oxidized, staining the sand yellow to red in color. The analysis by the Kansas City Chemic-Technic Laboratories Co., of a sample collected by W. H. Jackson, of Bromide, from a prominent bluff on Delaware Creek, (Plate XIV), gives the following results:

Analysis of Simpson Sandstone From Near Bromide, Okla.

$Si\ O^2$	99.20
$Fe^2\ O^3$	0.30
$Al^2\ O^3$	0.60
$Ca\ O$	trace
	100.10

In various places, the fine-grained, generally friable sandstone has been altered to a quartzite rock approaching in hardness the Arkansas novaculites. This appears to be due not to dynamic processes, but possibly arises from the deposition of secondary silica as a result of weathering.

Particular instances of such induration occur along the section line running east of Roff, around the triangulation station at Hickory and a little north of Millcreek. Those east of Roff appear oftentimes as slender spines or pinnacles with one or more perpendicular faces rising sometimes four feet from the ground. They possess such fine dense texture and smooth faces that they have been used as excellent razor hones by barbers in Dallas, Texts. A well driller at Millcreek informs me that these indurated sandstones are not peculiar to the surface but have been encountered in wells 120 feet deep. This hardening of the sandstone is a serious objection to its use as a glass sand.

Good exposures of friable sandstone occur along the Delaware Creek in sections 15 and 35, T. 1 S, R. 7 E. At the present time, these localities are from ten to fifteen miles from the railroad. Another exposure, in cross section, faces the Washita River, a quarter of a mile south of Crusher. Excellent outcrops are also to be found two miles northwest of Ravia, and along the south side of the mountains from Poolville, to the Washita River gorge.

Besides the occurrence of sand in the Reagan, Arbuckle and Simpson formations, the Franks Conglomerate (Pennsylvanian) and the Trinity sands (Comanche) are available sources. Unlike the sands in the upper part of the Arbuckle and Simpson formations, those of the Franks and Trinity are not constant as to size of grain, but vary from coarse to medium and also contain a variable amount of iron. They are not reliable for glass-making, but are excellent for building purposes. No estimate has been made as to the amount available, although it is known to be great, especially in the Trinity.

Building Stone

The Tishomingo granite, the Arbuckle limestone, the Viola limestone and parts of the Hunton and Sycamore limestones are suitable for building purposes. They have not as yet been extensively quarried.

The granite, however, has been used in the construction of the tribal capital building at Tishomingo, a large bank building, and two immense dams on Pennington Creek to provide water and electricity for Tishomingo (Plates XVIII, XX). A granite quarry is contemplated at Troy, on the Frisco Railroad. With the possible exception of the granite in the Wichita Mountains, the Tishomingo granite area is the largest and most easily accessible in the State.

The remaining building stones are limestones, the sandstones being few and usually friable and not good for building purposes. At Roff and Hickory, the Arbuckle limestone has been quarried and used in constructing business blocks. At Millcreek, the Viola limestone to the south of the town supplies stone for a large number of the business buildings. At Dougherty, the Sycamore limestone has been quarried and used in the construction of various buildings. The oolite limestone at the base of the Hunton forma-

PLATE XVIII

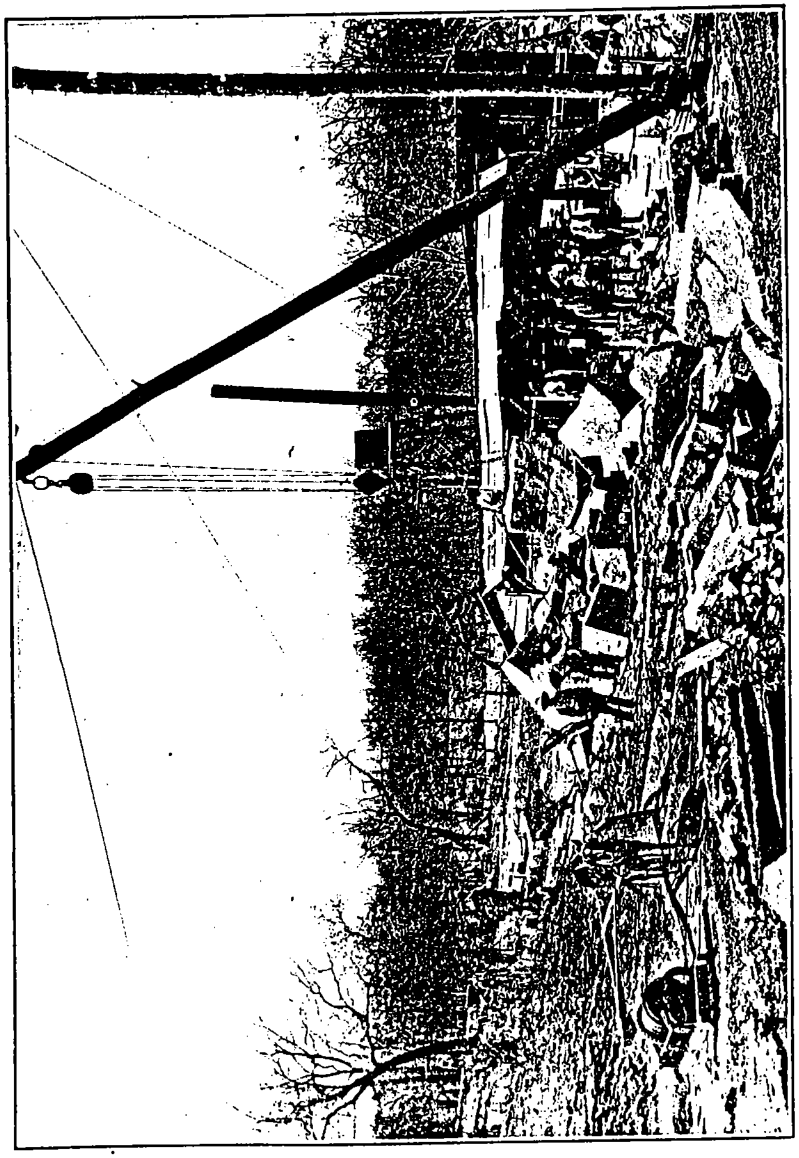
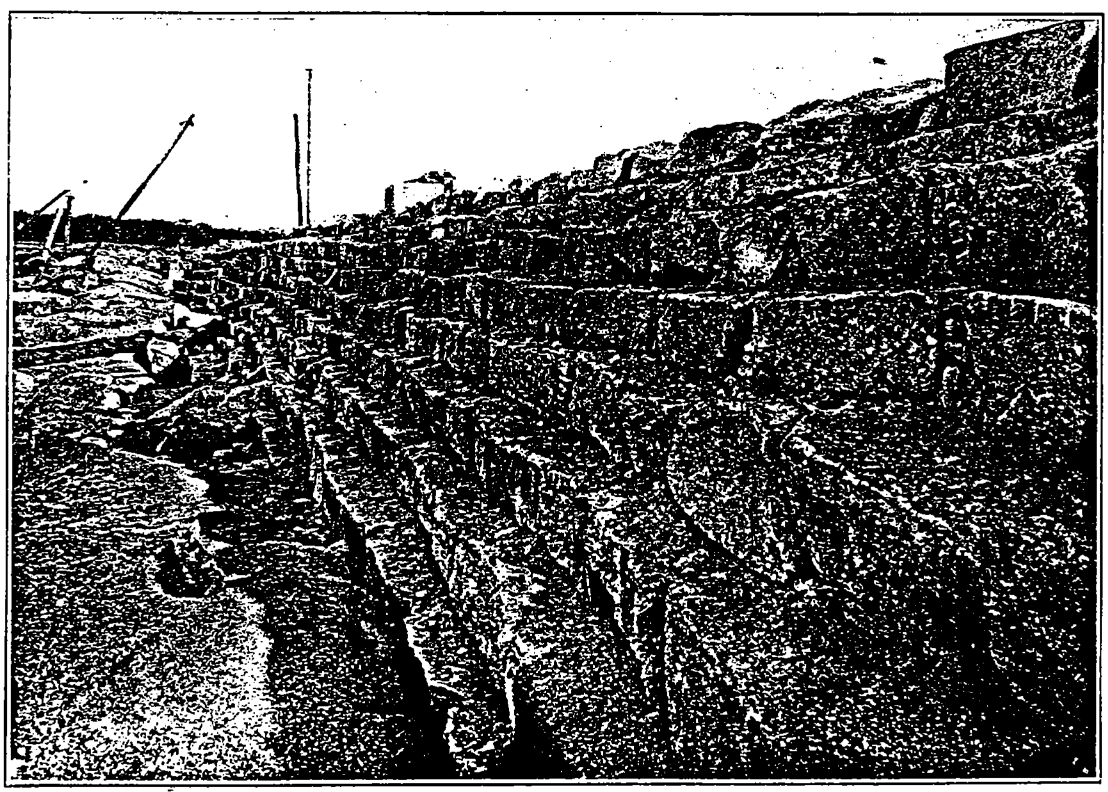
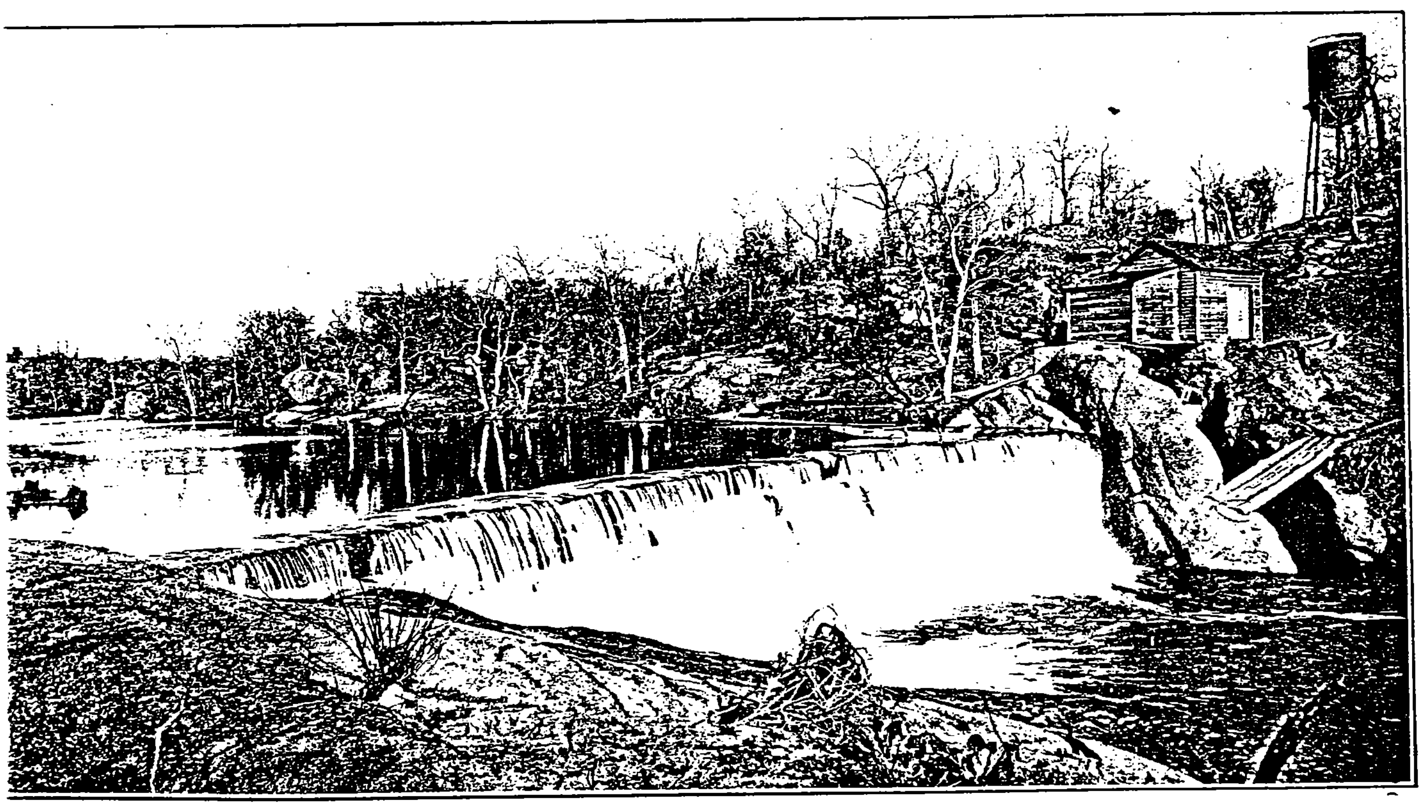


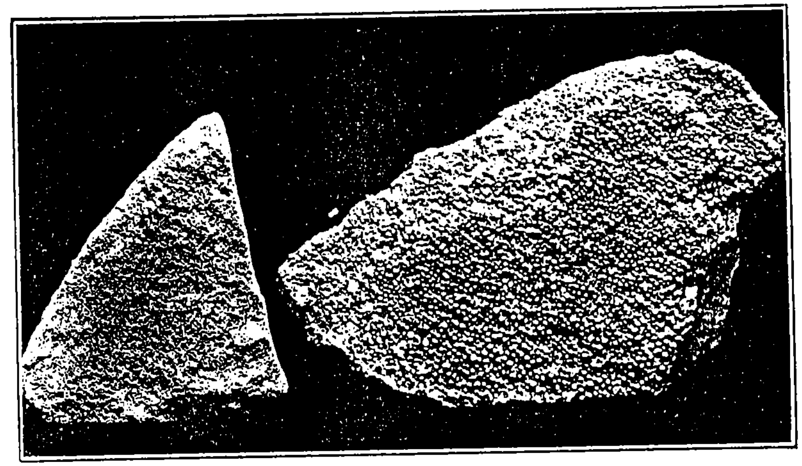
PLATE XIX



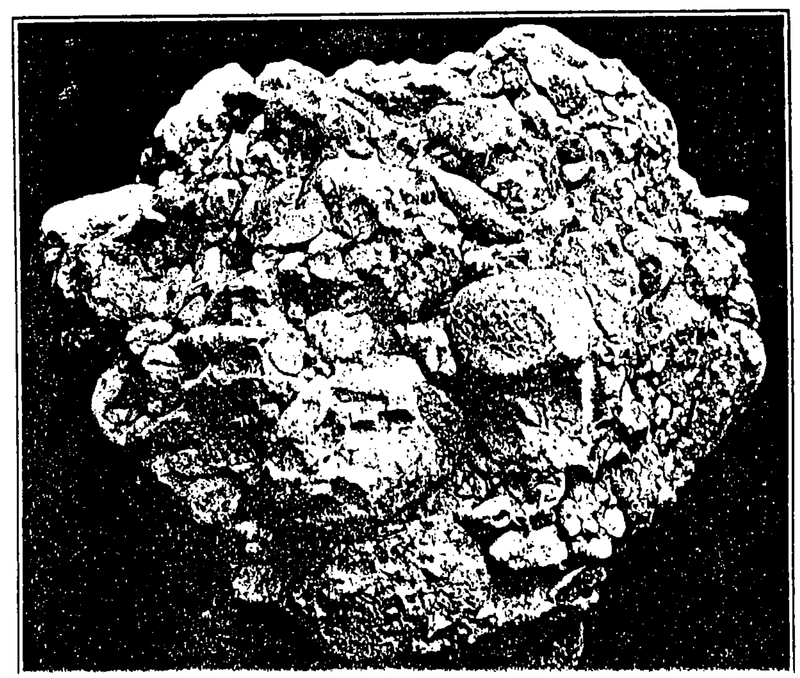
The electric light plant dam constructed of gra nite on Pennington creek, Tishomingo, Okla.



The city reservoir dam, constructed of granite, Pennington creek, Tishomingo, Okla.



A. Two specimens of oolitic limestone illustrating uneven size of grain. One mile southeast of Hunton, Okla.



tion (Plate XXI,A) has been quarried and used in the construction of various buildings throughout the State. It is not being worked at the present time. The crystalline basal members of the Hunton near "White Mound," four miles southeast of Dougherty, present good exposures for quarrying.

The green to yellowish shales in the Simpson and Sylvan formations afford material for brick making, but thus far they have been but little utilized.

Cement

At the present time (1910), there is but one Portland cement plant using raw material from the Arbuckle Mountains. This is the Oklahoma Portland Cement Company, located near the Frisco Railroad in the southwestern part of Ada. Although the plant is situated at Ada, to better meet labor and water conditions, the quarries are six and a half miles southwest, at Lawrence. The cement is known on the market as the "O. K." brand and is used extensively in Oklahoma and northern Texas.

Composition of Cement: From numerous experiments and tests made by geologists of the U. S. Geological Survey, particularly those which are being conducted at the present time in the U. S. Geological Survey Testing Laboratories at St. Louis, Missouri, it has been ascertained that the raw material must be of correct chemical composition for use as a cement material. This implies that the material, if a limestone ($Ca\ CO^3$) must contain as small a percentage as possible of magnesium carbonate ($Mg\ CO^3$). Under present conditions from five to six per cent is the maxium permissable. Free silica ($Si\ O^2$) in the form of chert or sand must be absent, or present only in small quantities—one per cent or less. Alkalies and sulphates, if present should not exceed three per cent. If the limestone is a slaty limestone, or "cement rock," the proportions between its silica and its aluminum and iron should fall within the limits:

$$\frac{\text{Silica}}{\text{Aluminum} + \text{Ferric Iron}} > 2 \; : \; \frac{\text{Silica}}{\text{Aluminum} + \text{Ferric Iron}} < 3.5$$

The Oklahoma Portland Cement Company has kindly furnished the following analyses of raw products from its testing laboratories:

Samples of Sylvan Shale

Serial No	Si O^2	$Fe^2 O^3$ and $Al^2 O^3$	Ca O	Mg O
479	42.56	17.20	12.58	6.22
506	40.84	18.84	13.80	5.22
507	43.06	18.24	10.70	6.60
508	42.50	18.50	11.36	6.14

Sample of Viola Limestone

Serial No.	Si O^2	$Fe^2 O^3$	$Al^2 O^3$	Ca O	Mg O	CO^2	Pb
20	.42	.10	.70	55.08	.28	43.11	.32

From the foregoing tables, it will be seen that there is a slight variation in the amounts of the various oxides present in the shale samples enumerated, and consequently every car-load sent in from the quarry has to be analyzed. The limestone runs so even in composition that the analysis of but one sample is given here. The average of the percentages shown in the magnesia column of both the shale and limestone samples would indicate that the maximum amount of magnesia permissible is being used.

Quarrying: The raw materials are obtained from open excavations in the Sylvan shale (Plate XXII, A) and Viola limestone at Lawrence, Sec. 36, T. 3 N., R. 5 E. The contact of the shale and limestone at the quarries follows closely the trend of a north and south branch, a tributary of South Jack Fork Creek. The limestone occurs on the west side, but dips 10 degrees to the east beneath the shale

Amount Available: The Sylvan shale and the Viola limestone, the sources of the cement material, crop out over considerable areas in the Arbuckle Mountains, as may be seen on the large map of the region (Plate XXIV).

Mr. Eckel *(1)* of the U. S. Geological Survey makes the following estimation: "A Portland cement plant running on dry raw materials, such as a mixture of limestone and shale, will use approximately 20,000 tons of raw material a year per kiln. Of this amount, 15,000 tons are limestone and 5,000 tons shale. Assuming that the limestone weighs 160 pounds per cubic foot, which is a fair average weight, each kiln in the plant will require about 190,000 cubic feet of limestone a year. As the shale or clay may be assumed to hold considerable water, a cubic foot will contain not over 125 pounds of dry material. Hence, each kiln will also require about 80,000 cubic feet of shale or clay. A cement plant is expensive, and in order to justify the erection of such a plant, **there should be in sight at least 3,800,000 cubic feet of limestone, and 1,600,000 cubic feet of clay or shale for each kiln.**" Although these figures seem large there are in the Arbuckle Mountains hundreds of times as much material resting on the surface, not to mention other shale and limestone formations which are good for cement purposes.

Location with respect to Transportation Routes: Since Portland cement is a bulky product, its value is much influenced by transportation routes. The Oklahoma Portland Cement Company's plant at Ada is well located, since there are three lines of railway leading out from that city; namely, the Frisco, the M. K. & T., and the Oklahoma Central. As these are competitive roads, disaster is thus obviated, adverse conditions having arisen where there was but a single railroad.

Location with respect to fuel supplies: To quote Mr. Eckel again: "Every barrel (380 pounds) of Portland cement marketed implies that at least 200 to 300 pounds of coal have been used in the power plant and the kilns. . In other words, each kiln in the plant will, with its corresponding crushing machinery, use up from 6,000 to 9,000 tons of coal,a year. The item of fuel cost is therefore highly important, for in the average plant 30 to 40 per cent of the total cost of the cement will be charged to coal supplies."

Location with regard to market: The two cement plants in Oklahoma, one at Ada and the other at Dewey, have been built since 1904 For a new plant to become established in the trade, it should have a local market area, within which it may sell upon a non-competitive basis and have easy access to a larger though competitive market area. Prior to 1904, there were two Portland and one natural cement plants in southwestern Kansas, and a Portland cement plant in Dallas, Texas. These older plants compete with the two in Oklahoma, although at the present time the latter mills have large local markets.

Methods of manufacture: At the present time, no natural cement rock is being worked in Oklahoma. The Hunton limestone, however, of the Arbuckle Mountains, in its middle shaly horizons,

1 Eckel, E. C., Bull. 243, U. S. Geol. Surv. p. 40, 1905 .

gives some indications that it might be so used, but it has not been tested.

The product placed upon the market by the two Oklahoma cement plants is an artificial one known as Portland cement. It is obtained by burning to semifusion thoroughly mixed pulverized materials containing lime, silica and alumina in certain proportions, and by milling to a fine powder the clinker resulting from this burning.

Soils

The soils of the Arbuckle Mountains are varied both in kind and depth. For the most part, they are to be considered as of poor quality. For the Tishomingo area, a soil survey has been made by the U. S. Department of Agriculture, the report of which was issued October 4, 1907. The northern third of the area surveyed deals with the soil arising from the various rock formations found in the Arbuckle Mountains. On the soil map of that area it is to be noticed that the kinds and boundaries of each soil do not correspond with the limits of the geological formations, but extend across them, following more closely the drainage systems rather than the strike of the formations. Where the drainage features are not very much in evidence, however, each formation produces its characteristic soil; for example, the granite—the Tishomingo gravelly loam; the Arbuckle limestone—the Rough Stony land. What has been found true of the northern third of the Tishomingo area applies equally well to the soils of the rest of the Arbuckle Mountain plateau.

Road Metal

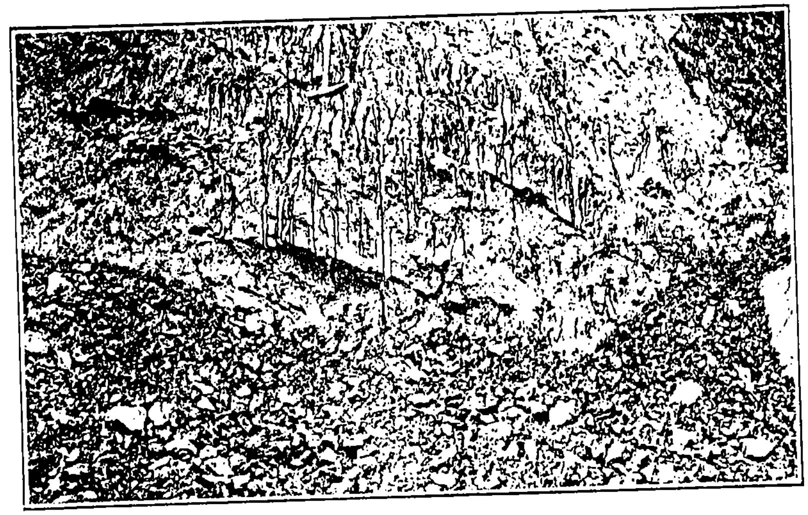
There is abundant material in the Arbuckle Mountains which may be used for road ballast. The Tishomingo granite may be cut into blocks for street paving purposes. The black basalt, in dikes cutting the granite is more durable for country roads than the limestones but it lacks the cementing qualities. The arkosic gravel of the Reagan and Trinity formations in and about Tishomingo and Ravia is used in large quantities in Dallas, Texas, and other cities in laying asphalt and cement pavements. It is also used in large quantities as a railroad ballast on the Frisco and Rock Island lines. Limestone, although very abundant, has not as yet been used for country roads. Large amounts of crushed limestone have been used extensively for ballast, concrete and riprap on the Santa Fe railroad. All of this material has been supplied from a large quarry and crusher in the Arbuckle limestone at Crusher, (Plate V). At the present time four grades of screening are produced. They are known as No's. 1, 2, 3 and 4 and the grains of each have respectively the diameter 1-8, 1-4, 1-2 and 1 inch. When visited in September, 1908, a force of 100 men was employed, producing on the average, 15 cars, of 60,000 pounds capacity, per day. The quarry is very

PLATE XXII

A. Oklahoma Portland Cement Company's quarry in the Sylvan shale, Lawrence, Okla.

B. Asphalt mill two miles southeast of Woodford, Okla., on Pennsylvanian sandstone which has a vertical inclination.

PLATE XXIII



A. Asphaltic limestone in quarry wall three miles north of Dougherty, Okla.

B. Asphaltic sandstone and shale in open cut quarry, Brunswick, Okla.

large and it was estimated that 1,684,800 tons were taken from it annually and with a possible age of ten years it has supplied 16,-848,000 tons. With better civil conditions prevailing now than in the recent past it is to be hoped that the country roads surrounding the mountains will be improved. As the rocks south and east of the mountains are chiefly Pennsylvanian black shales, and make almost impassable roads during the rainy season, it is high time that they be ballasted.

Asphalt

The asphalt deposits in and about the Arbuckle Mountains are of great extent. The locations of the outcrops have been indicated on the geological maps accompanying the report (Plate XXIV). These outcrops have been worked intermittently owing (1) to the oscillating nature of the demand and supply of this product and (2) to the control of the market by the Asphalt Trust. At the present writing only a few of the quarries are being operated.

The asphalt is known locally as either "sand asphalt" or "lime asphalt." The sand asphalt occurs chiefly in the fine grained Simpson sandstone (Ordovician) and the various Pennsylvanian sandstones surrounding the mountains (Plate XXII B and XXIII B). The asphaltic limestone is of less extent being formed chiefly in the Viola limestone which immediately overlies the Simpson formation. (Plate XXIII, A). The richest examples of these deposits occur in the vicinity of Gilsonite, Oklahoma, and are controlled by the Barbour Asphalt Company of Philadelphia.

It would seem from the character of the material and the nature of the outcrops that these deposits have resulted from the slow evaporation of gas and oil by natural processes. The truncation of the large anticlines and domes by the agents of erosion has permitted the entomed gas and oil to rise to the surface along the variously inclined strata.

Various general and detailed reports of these asphalt deposits have already been published. The more noteworthy of them are as follows:

1. Elridge, G. H. The Asphalt and bituminous rock deposits, Indian Territory, 22nd Ann. Rept. U. S. Geol. Survey, Pt. 1, pp. 262-320, 1901
2. Taff, J. A. Description of the unleased seggregated asphalt lands in the Chickasaw Nation, Indian Territory, U. S. Dept. Interior, Circular No. 6, 14 pp., 1904.
3. Taff, J. A., Asphalt and bituminous rock, Mineral Resources U. S. for 1906, pp. 1131-1137, 1907.

CHAPTER V

SUMMARY

A brief and general summary will serve in this place to emphasize the more important results of the present study.

1. Conclusions regarding the Physiography of the Arbuckle Mountains.

(1). The erosion stage of the Arbuckle Mountain plateau is early maturity. The streams are youthful and have steep gradients except the long ones of the Pontotoc Plateau which still flow nearly in the level of the moderately dissected Cretaceous peneplain. The rivers and streams on the bordering plain have reached maturity since they meander and are aggrading their flood plains. The effect of unequal hardness is shown not only in the pre-Pennsylvanian limestones of the plateau which rise 200-400 feet above the soft rocks in the bordering plain, but also in the upturned weak shales and sandstone members of the plateau, which outcrop in narrow timbered valleys between grass covered limestone ridges. The mountains have not always remained dormant since the prominent uplift of Pennsylvanian time was followed by times of elevation during the Jura-Trias, Eocene and Pliocene periods. This is attested by records of the Cretaceous base level and the interrupted Miocene and Pleistocene erosion cycles. On account of this periodic uplift and the unequal hardness of the rocks, stream piracy and adjustment have developed, especially in Buckhorn and Delaware creeks.

II. Conclusions Regarding the Stratigraphy of the Arbuckle Mountains.

(1). As the detailed study of only one of the formations of the Arbuckle Mountains has been completed, the Hunton, much remains to be done in this interesting field. The discussion of the various formations which appear in this report is the result of preliminary studies made by Messrs. Taff, Ulrich and the writer. writer.

(2). A brief review of the literature on the Arbuckle Mountains shows that the reports are meager and that the more valued articles have appeared since 1901.

III. Conclusions Regarding the Structure of the Arbuckle Mountains

(1). As regards the structure of the Arbuckle Mountains they constitute a district of complex folds and not one of composite folds as described by Taff. Two sets of folds have been developed which intersect each other at almost right angles. A longitudinal set, extending N. 70 degrees W. is more prominent, since they

were formed by a major thrust acting at right angles to their present extension. That the minor thrust was almost equal to the major one is evident (1) from the longitudinal anticlines and synclines, which are almost as broad as long, (2) by the formation of domes and basins, (3) by the presence of transverse folds. That the region is still more complexly folded is shown by the presence of folds of a higher order upon the flanks of the longitudinal and transverse folds. All of these folds are to be considered in three dimensions since they are upright pitching anticlines, synclines, domes and basins. The factors which have modified them have been (1) the almost equal power of the major and minor thrusts, (2) the competent structure, (3) the light load, (4) the crystalline base and (5) the faulting.

(2). As regards the individual folds the Lawrence anticline and Franks syncline deserve special mention since they are here described and mapped for the first time.

IV. Conclusions Regarding the Mineral Resources of the Arbuckle Mountains.

(1). No precious or metallic minerals occur in the Arbuckles in paying quantities except iron and manganese.

(2). The large deposits of non-metallic minerals, such as asphalt, glass sand, cement materials, building stone, sand, gravel, etc., have been but little utilized.

(3). With better civil conditions prevailing now than when a territory and with a growing demand for increased production it is to be hoped that capital and labor will develop these immense resources.