OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

Circular No. 15

PHYSICAL CHARACTERISTICS OF THE ARBUCKLE LIMESTONE

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NORMAN
January, 1928

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By

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INTRODUCTION

The Arbuckle limestone has long been of interest not only to geologists but to all who are attracted by significant features of natural phenomena. So resistant is this formation to erosion that it outcrops over scores of square miles in the Arbuckle and Wichita Mountains and the Criner Hills, having a total mapped outcrop of about 380 square miles.

Where the edges of the tilted strata outcrop one above another in regular succession, they have been likened to great furrows of rock turned up by some enormous force. Largely because of the want of detailed section, the Arbuckle limestone has been cited as a marked illustration of a great body of limestone deposited under remarkably uniform conditions to the great thickness early estimated to be 4,000 to 6,000 feet.

In grading the new highway (U. S. No. 77) across the mountains between Davis and Ardmore, cuts of five to ten feet were made into the rock particularly in the upper 3,500 feet and at several other levels in this formation, exposing to view largely unweathered parts which had never been seen before, and giving a new and unprecedented opportunity for study. Even to the casual observer this new cut reveals points of interest, particularly in that it shows that the reason for the wonderful rows of outcropping rocks is due largely to resistant beds alternating with non-resistant ones, so that differential erosion causes the resistant ones to jut out in elongate, narrow ledges.

A more specific interest in the Arbuckle limestone of great economic importance to the driller has developed because this formation has been considered non-petroliferous. Accordingly, it has been taken as the proper place to stop the drill when it has "struck the top of the Arbuckle lime." It also holds the interest of the oil producers, because of its supposed relation to the siliceous lime and Turkey Mountain sand struck far down in the deep

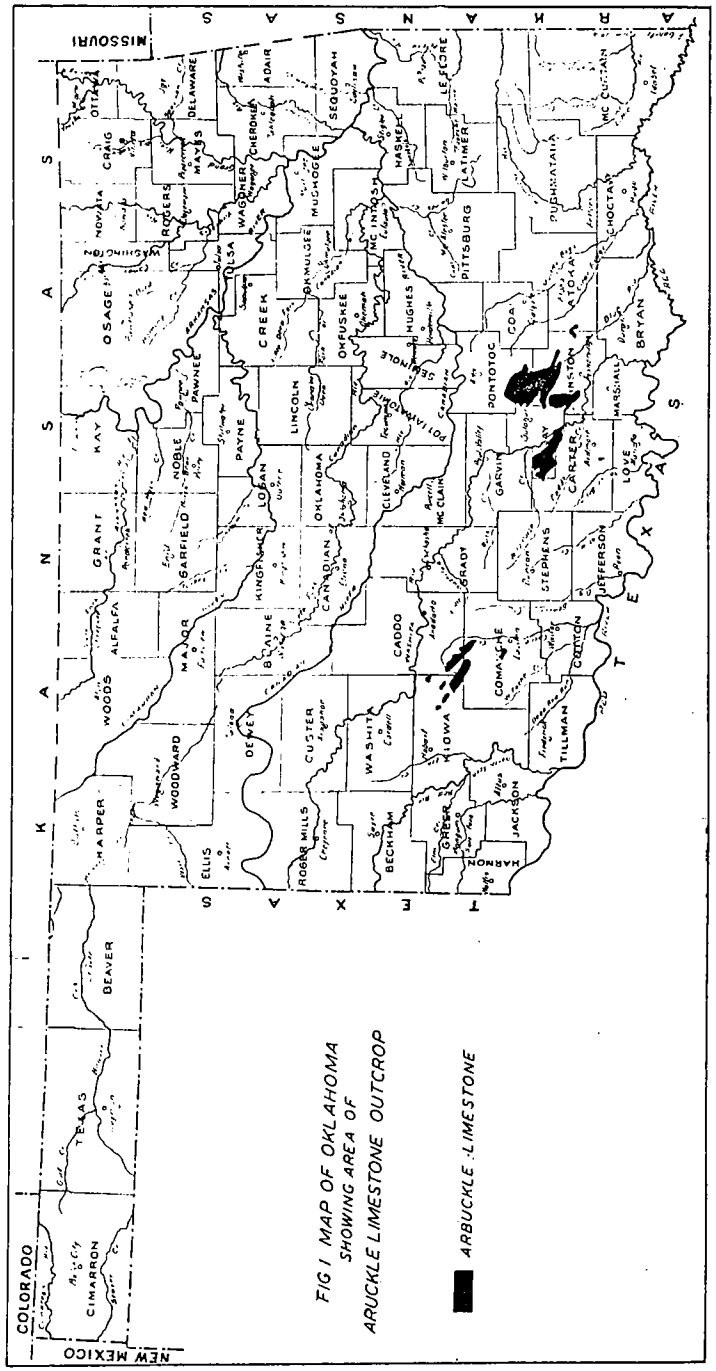


FIG 1 MAP OF OKLAHOMA SHOWING AREA OF ARUCKLE LIMESTONE OUTCROP

wells of the State. Because of the widespread interest in this formation, it is proposed to give briefly a fairly detailed section with information in regard to composition and general physical characteristics, with some suggestion of the numerous changes which took place during its formation. Only such detail will be used as seems necessary to supply the most significant data. This paper is to be followed shortly by one on the faunas and sub-divisions of this formation, by Dr. E. O. Ulrich.

The authors take pleasure in acknowledging the competent and enthusiastic field assistance of Rex McGehee and J. A. Stone.

TOPOGRAPHY AND DRAINAGE

In the Arbuckle Mountains the Arbuckle limestone is exposed for the most part over broad low plateaus on which outcrop the truncated edges of the tilted beds, giving evidence of a slightly elevated old peneplain.

The area is only slightly dissected and the amount of relief is, in general, small. The larger streams are clearly antecedent. Only two streams run for considerable distance across the formation; namely, Blue River and Pennington Creek. However, many small streams rise in it and radiate from it in all directions. In many instances these are started by springs and are fed by others along the course. In the Wichita Mountains the Arbuckle limestone on the north is separated from the granite peaks by a broad valley, and due to the northward dip it forms a steep southward facing escarpment along its southern edge. While a number of ravines have eroded into the formation in this region, most of them have not been cut sufficiently deep to maintain permanent streams.

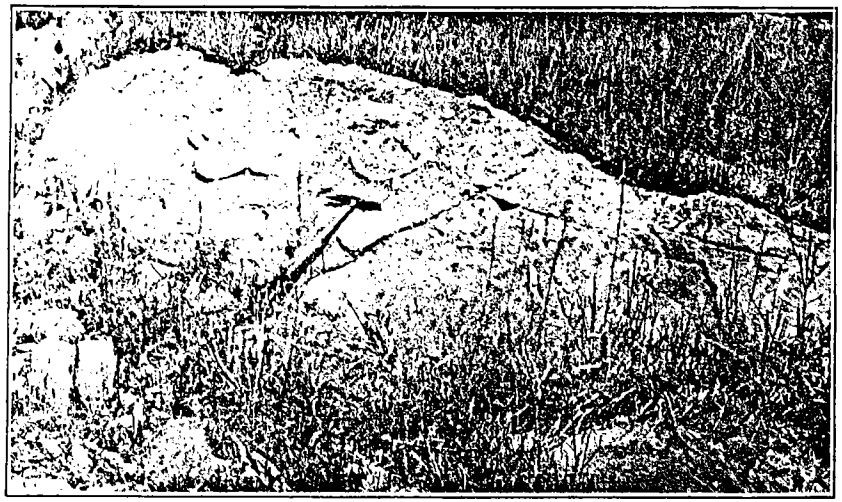
COMPOSITION

To determine the composition in any minute detail of a formation of the thickness of the Arbuckle limestone would be wholly impossible in the restricted time allotted to this study. Were all the changes in composition and characteristics noted, there would be several thousand instead of the few hundred given in this brief paper, particularly if the rest of the formation were exposed for study as the upper 3,400 feet have been by the cut along the newly graded road. In general it may be said that the upper and middle parts consist of limestones, siliceous and shaly in part, and two major and three minor masses of nearly pure dolomite near the base, the dolomites being separated from each other by limestones and the lower one separated from the Reagan sandstone by limestones in a similar manner.

Besides these major differences in composition of the limestones, dolomites, and dolomitic marble, there are numerous dif-

PLATE I

A. Conglomerate one foot thick marking base of Simpson and beds beneath at the top of Arbuckle limestone. A very persistent bed which at the Ardmore-Davis road is 42 feet and six inches above algal bed shown in Pl. I B. (sec. 21, T. 2 S., R. 1 E.)



B. Algal bed 42 feet and six inches below top of Arbuckle limestone. Top of bowl-shaped algae exposed on surface marking a very persistent horizon. Picture taken in sec. 20, T. 2 S., R. 1 E.

ferences in the amount of quartz and silt present. The quartz occurs in two different ways, as rounded detrital grains either large or small, or as secondary replacements in angular grains, in chert nodules or in replacement in oölite or of fossils. Rounded grains of detrital quartz occur at many horizons, and they are present in sufficient amounts in Beds No. 1, 6, 10, 23, 24, 27, 56, 76, and 89 to make either very siliceous limestones or calcareous sandstones. In the oölites tiny quartz grains seem to have formed the nucleus for the oölitic grains, and some of the angular pieces of quartz seem to give evidence of having replaced either calcite or dolomite. Some of the quartz shows that it originally came from igneous rocks by intergrowths of quartz and feldspar and by inclusions of zircon and apatite. There is also a great variation in the amount of silt present. In some horizons it occurs in sufficient amounts to give the rocks the characteristics of shale rather than limestone.

Microscopic examination shows that the calcite occurs as coarse and fine grains and as pebbles in conglomerates, as secondary growths around calcite and quartz grains in mosaics of fibers with radiating fibers, in fossils, in oölitic grains, and in veinlets.

There is comparatively little dolomite in the upper part of the formation, though a sample from the lower part of No. 1 of the section shows as high as 15 per cent. Most samples in the upper part show little or no dolomite, but in 9 samples scattered from No. 43 to No. 106 the dolomite varies from 16 to 32 per cent. The two large dolomitic masses in the lower part of the formation are almost pure dolomites, as 27 samples average 95 to 96 per cent dolomite with a number of samples running 99 per cent. The limestones between the dolomites show 12 to 18 per cent dolomite and the limestone below the lowest dolomite shows 9 per cent dolomite, 82 per cent calcite, and 9 per cent silt. The dolomites vary in color from pikn to white, gray, buff, and brown.

The relatively pure dolomites are of two types, one fine grained, in which they have a very sandy appearance and can readily be mistaken for sandstone, and the other coarse grained, in which they have a marked marble-like appearance. Strangely enough these two types alternate in rather short range, 16 of these alternations occurring from No. 186 to 202. Dolomite is present as a cement around detrital quartz and around calcite pebbles in the lowest conglomerates. In the larger dolomitic masses there is a strong suggestion that the dolomite is primary, because of the abrupt changes between dolomite and limestone where they alternate several times, and because these two types of rock extend as great broad bands far along the strike of the formation.

STRUCTURE

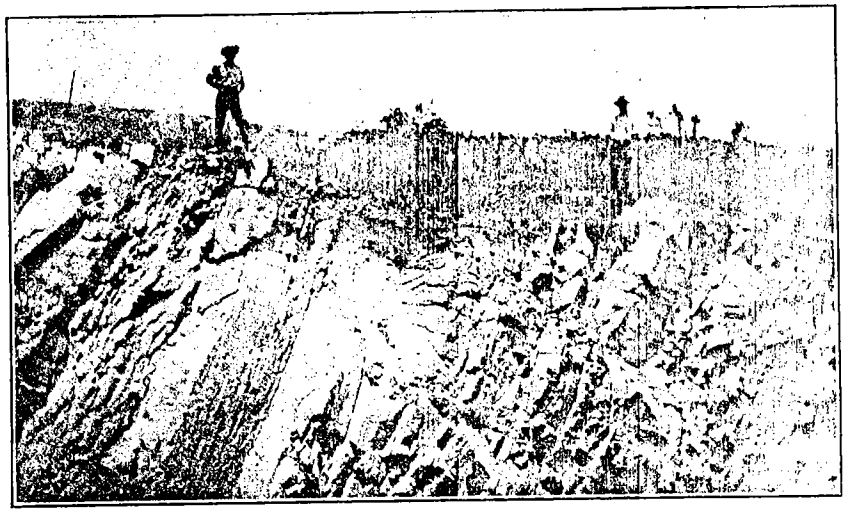
Structures of the Arbuckle limestone may be considered as primary or secondary, or as a combination of the two. The primary structures to be considered are bedding, laminations, algal structures, and disconformities, those which may be in part primary and in part secondary are texture, concretions, oölites and chert nodules, and the secondary structures, joints, solution cavities, folds, and faults.

As a formation the Arbuckle limestone is extremely well bedded, and many of the beds hold a constant thickness for many miles, giving evidence of constant conditions of sedimentation for these even beds. However, the beds vary greatly in thickness; from a fraction of an inch to five or more feet, and the thinner beds are far less constant than the thick ones. In general more thin beds are found in the upper part, but some occur in the upper dolomite, between the dolomites, and near the base of the formation. More thick beds are found in the middle of the formation, but even in the upper part thick beds alternate with groups of thinner ones. These alternations together with the variation in the amount of silt and detrital quartz give evidence of hundreds of changes in sedimentation, only a part of them being shown in the section below. Some of the thin beds consist of shaly limestone, and some calcareous sandstones with very slight representation of argillaceous shales. Some of the siliceous limestones and sandy shales are finely laminated with distinct lamellae indicating very numerous minor changes in sedimentation. Bedding planes have been largely obliterated in parts of the lower dolomite, and in the folded part of the upper dolomite southwest of the Chapman ranch house.

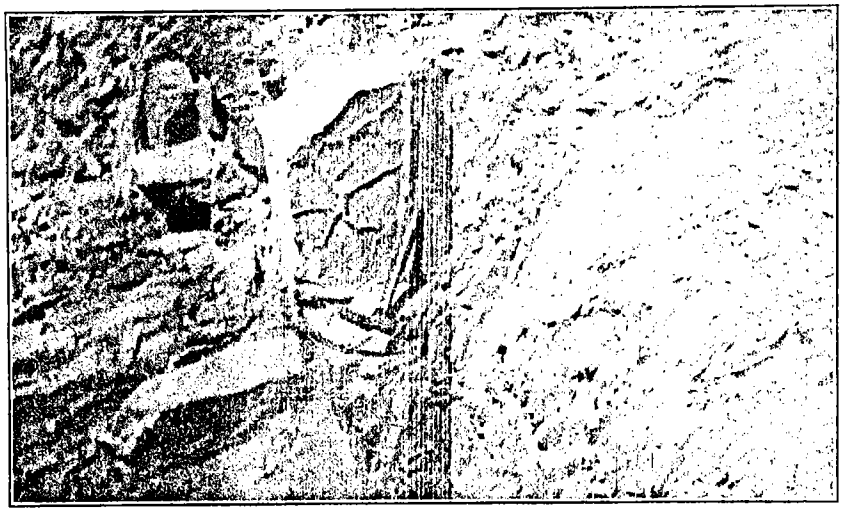
Algal structures occur at a number of horizons in the upper half of the formation and particularly in one near the top. (See Plate I, B). The algal beds are usually rather closely associated with conglomerates or breccias and probably represent shallow water deposits. Another evidence of shallow water deposits is shown by the mud cracks in Plate II, B, and by wormtrails and burrows found frequently in the upper part of the formation.

Disconformities occur at a number of horizons with conglomerates and breccias as shown in Plate I, A. One occurs only a short distance below the main algal bed, and six others at intervals in the upper part of the formation. A peculiar conglomerate occurs along the road east of the East Timbered Hills in which gray limestone pebbles are imbedded in a matrix of pink dolomitic marble, thus suggesting that the marble is younger than the adjacent limestone, or that the fragments in the conglomerate were secured from a limestone which has disappeared.

PLATE II



A. The outcropping edges of two resistant, siliceous, limestone beds with 12 feet of sandy shaly limestones between illustrating how the thin beds weather and become covered with vegetation. About 500 feet below the top of the Arbuckle along Ardmore-Davis road.



B. Reverse of mud cracks in a sandstone underlain by many feet of thin, sandy, shaly beds. Along Ardmore-Davis road 470 feet below top of Arbuckle formation.

The texture varies from fine stony to coarse crystalline. Most of the limestones are fine grained and compact, but the upper dolomite is extremely variable with many alternating fine and coarse beds. Coarse textures are more common in the lower dolomite, but in parts it has very fine texture.

Concretionary action has not been very marked in this formation except in developing chert nodules and oölites. A few large calcareous concretions occur in the sandy shales, two disc shaped forms having been seen about one foot thick and three feet in diameter. However, chert nodules are abundant in the upper and middle parts of the formation and many of the fossils are silicified. Numerous oölitic horizons occur in the zone of twelve hundred feet starting about 3,400 feet below the top. Most of these oölites have become silicified.

Jointing is developed to a far less degree in the Arbuckle limestone than it is in a number of the formations in the sedimentary series above it, particularly the Woodford chert and the Sycamore, Chimneyhill, and Viola limestones. The relatively slight development of joints in this part of the Arbuckle limestone may be due in part to the nature of the formation, but probably more largely to the fact that it was buried deeply beneath several thousand feet of superjacent rocks when the folding took place. An intimation of the weight which must have been on this formation when it was folded is given in the fact that a five foot bed of limestone was deformed abruptly in the sharp quaquaversal fold near the head of Falls Creek without fracturing. See Plate IV. A. Doubtless before the thousands of feet of erosion took place, the top of the folds of Arbuckle limestone which arched high above the porphyry and granite in the Arbuckle and Wichita mountains, the upper part of those great folds probably did show jointing developed to a much higher degree. However, some jointing is seen in the eroded "roots" of these mountains. Two major sets of joints are developed, one approximately parallel with the apex of the folds and another about normal to that direction. Then particularly in some of the thinner beds more closely spaced joints are developed to a considerable degree.

Through some of the joints underground drainage has been developed, resulting in the formation of numerous small depressions in the surface, some large sink holes, and some caves of large size. This underground drainage supplies many large springs for streams which head in this formation and radiate from it.

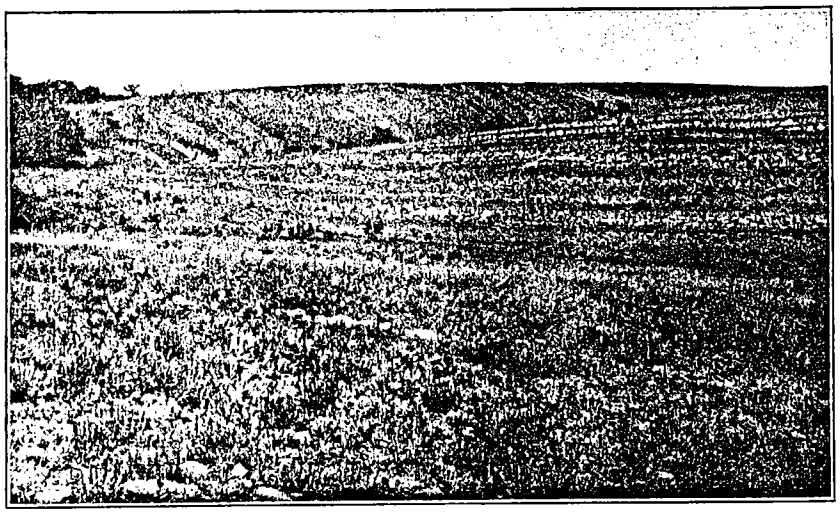
Folds of three orders have been well developed in the Arbuckle limestone. In the Wichita Mountains a great arch of this formation doubtless extended far above the tops of the granite masses forming the core of those mountains. This formation is largely

covered on the south side of those mountains, but on the north side a large exposure with infacing escarpments, several miles north of the granite, dips to the north and extends beneath the edge of the overlapping red beds. The Arbuckle anticline and other folds of like magnitude doubtless extended high above the porphyry in the Timbered Hills and the granite to the east. The section below was measured in the southwest limb of the Arbuckle anticline. In the southwestern part of the mountains this formation outcrops for a width of nearly five miles with direction of dip remaining constantly in one direction over most of that distance. This wide outcrop of the formation on the south side of the porphyry in the Arbuckles is the reverse of the condition in the Wichitas where only a narrow outcrop occurs north of the porphyry. Dips in the upper part of the formation in the southwestern edge of the Arbuckle anticline are as low as 20 degrees, at the Ardmore road 55 degrees, on the east side of the Washita River south of Big Canyon (Crusher) 75 degrees at the top and about 90 degrees near the axis. Northwest of Ravia the dip in the upper part of the formation is also about 90 degrees. The axis of the Arbuckle anticline cuts diagonally across the formation so that only about 1,000 feet of the upper part is exposed on the south side of the axis along the east side of Washita River. Dips in the upper part of the Arbuckle limestone in the eastern and northeastern part of the Arbuckle Mountains are generally low, varying from 8 to 15 degrees.

A number of folds of the second order have been developed with axes nearly normal to those of the larger folds. One of these transverse folds starts about three miles northeast of Woodford where it shifts the outcrop of the Arbuckle limestone southward for one-half mile. It is a very sharply folded anticline about three-fourths of a mile wide and it extends northward toward the West Timbered Hills, and can be traced in that direction for about three and one-half miles, until the rocks become soil covered in that part of the plateau. Other better known folds of this order with axes parallel to those of the larger folds, are the Dougherty anticline and Scotts Dome. Numerous small folds of the third order occur in various parts of the formations, one being illustrated in Plate IV. A.

A number of major faults cut the Arbuckle limestone, and in general their trace is nearly parallel with the axes of the major folds. One of these larger faults at the south end of the Dougherty Basin has a throw of over 3,000 feet. Many of the contacts of the Arbuckle limestone with other formations are fault contacts for long distances, particularly in the eastern part of the Arbuckle Mountains, and it is faulted against the Colbert porphyry for several miles in the East and West Timbered Hills. A number

PLATE III



A. General view of upper part of Arbuckle limestone showing outcropping edges of siliceous limestone beds with intervening zones of sandy shales and shaly limestones covered with low vegetation. Taken across base of Simpson looking toward the northwest in sec. 19, T. 2 S., R. 1 E., west of Henryhouse Creek.

B. Rough weathering of upper dolomite in which rough masses of heavy beds stand three to four feet above the surface. Thin beds between weather more rapidly and more evenly. One-half mile southeast of Chapman ranch house. Storage tank shows to right of middle background, and East Timbered Hills are in extreme right background.

of small faults lie wholly within the formation, the oblique and dip faults showing in the offset of the beds for a few feet. A fault which occurs in this formation along the Santa Fe railroad near the north edge of the quarry at Big Canyon is shown in Plate IV. B.

AGE AND CORRELATION

In his work with Mr. Taff in working up the geology of the Arbuckle Mountains, Mr. Ulrich placed the Arbuckle limestone in the middle and upper Cambrian and lower Ordovician[1].

In his revision of the Paleozoic systems in 1911, Mr. Ulrich places the very basal part of the Arbuckle limestone questionably in the upper Cambrian and creates two new periods between the Cambrian and Ordovician for the rest of it. Most of the lower Arbuckle he places in his new division of the "Ozarkian" and the middle and upper Arbuckle in his second new division the "Canadian"[2]. From unpublished correspondence it is gathered that little change would be made in this classification of 1911, except that more specific information in regard to the faunas makes it desirable to consider the Arbuckle as a group of at least three formations for which new names are being considered at the present time. According to the table of formations in the last reference, various parts of the Arbuckle are to be correlated with thirteen or fourteen formations of eastern and central United States, beginning with the Nolichucky at the base and ending with the Bellefonte and Beekmantown at the top. The Ellenberger limestone of Texas is correlated with part of this formation, and the siliceous lime of the deeper horizons in the northern part of the State is supposed to represent some part of it.

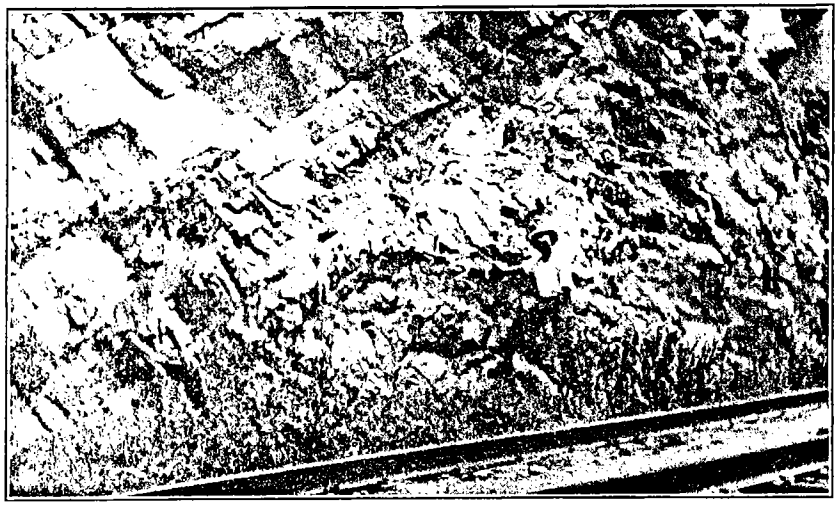
THICKNESS

As the Reagan sandstone is not exposed on the east side of the East Timbered Hills, the base of the Arbuckle limestone can not be located there; accordingly measurements were stopped at the base of Bed No. 214 of the section. However, the formation was measured from the northwest corner of sec. 23, T. 2 S., R. 1 E., to a point near the southwest edge of the East Timbered Hills. As the contact of the Arbuckle and Reagan is covered at the northeast end of this line of measurement, 98 feet of limestone is included which lies between the base of the dolomitic marble and the top of the Reagan, one-half mile to the north. For most of the measured distance the dip varies between 45 and 50 degrees. Figuring an average dip of 47 degrees gives a thickness of 7,872 feet. A paced measurement from the Reagan south of West Timbered Hills in a southwesterly direction, allowing repetition for one

1. Taff, J. A., U. S. Geol. Survey, Prof. Paper 31, p. 22, 1904.
2. Ulrich, E. O., Bull. Geol. Soc. America, vol. 22, Pl. 27, pp. 608, 1911.

PLATE IV

A. End of a quaquaversal fold in which limestone beds four feet and more in thickness were flexed into a very close fold with little or no jointing. Near head of Falls Creek about a mile east of Ardmore-Davis road.



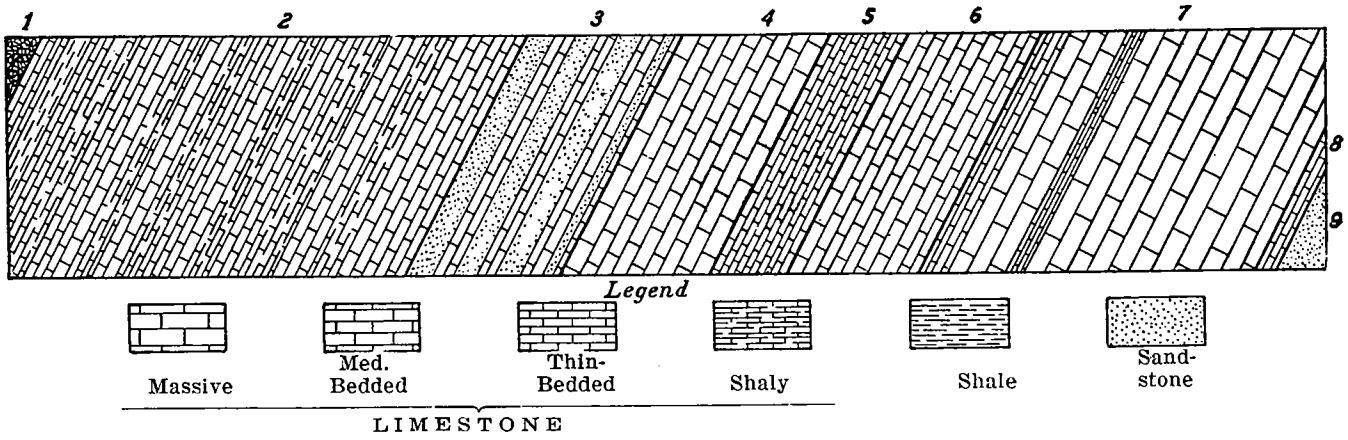
B. Fault with beds which are overthrust toward right with drag of beds shown beneath fault plane in that direction. Near northwest edge of quarry at (Crusher) Big Canyon.

fold, checked closely with this thickness. The possibility of repetition by faulting was considered, but it is thought that such repetition does not occur where the sections were measured.

DETAILED SECTION

A detailed section of the Arbuckle liemstone was measured, beginning at the top on road 12 miles north of Ardmore, starting at base of main breccia and 9 feet 1 inch above main gastropod bed in sec. 24, T. 2 S., R. 1 E. Measurement of the upper 3,400 feet was made along the road largely in short intervals as nearly as possible normal to the dip and strike. From the top of the hill and the base of the first oölite, (No. 176 of section) dips were recorded and horizontal measurements were made in a northeasterly direction on the east side of the road to a point about 80 rods east of the Chapman ranch. Thus folds were avoided which occur in the upper dolomite southwest of this ranch. At 7,137 feet a marked horizon was reached beyond which the rocks are covered for 270 feet, and beyond the covered area, the direction of strike changes on the southwest side of a plunging synclinal fold. Accordingly, measurement was shifted to a point in the marked horizon near the road northwest of the Chapman ranch, and continued to the base of the measured section. For the numbers starred there is a description of a thin section following the record of this measured section.

Graphic Section of the Arbuckle Limestone



Detailed Section of the Arbuckle Limestone[1]

(Beginning at top of formation)

*Indicates that bed has been studied in thin section.

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
					*1A.	3	77	20	Mostly iron stained silt. Few quartz grains 0.5-0.25 mm. diam.
*1	10	9	10	9	Poorly exposed, shows several limestone beds two of which measure 14" and 15". *1B.		55	45	Quartz grains 0.16-0.5 mm. diam., well rounded, detrital.
					*1C.	15	57	28	Quartz grains mostly 0.12 mm. diam.
					*1D.	12	76	12	Quartz grains 0.25-0.1 mm. diam., mostly 0.2-0.25, detrital.
*2		7	11	4	Dark gray limestone, medium grain, numerous gastropods and a few other forms.	3	88	.9	Quartz grains 0.25-0.1 mm. diam.
*3	7	9	19	1	Shales and shaly limestone poorly exposed.	12	57	31	Silt.
*4	1	5	20	6	Grayish brown limestone in three thin beds, middle one being filled with gastropods. This bed extends far eastward and westward with same fossils.	4	89	7	Mostly silt. Few quartz grains 0.1 mm. diam.
*5	5	6	26		Thin sandy limestones ½ to ¾ inches thick.	10	69	21	Considerable amount of both silt and quartz—quartz grains 0.33-0.08 mm. diam.
*6	1		27		Dark gray sandy limestone, some ostracods.	5	68	27	Quartz grains 0.1-1 mm. diam. Mostly 0.5-0.33 mm. diam., detrital.
*7	6		33		Thin limestone, shaly, slightly sandy.	10	68	22	Fine quartz 0.05-0.14 mm. diam., and silt.
8	1		34		Dark gray limestone.	2	82	16	Fine quartz 0.06 mm. diam. Some smaller and silt.
9	8	6	42	6	Shales and shaly limestone.	3	85	12	Fine quartz 0.06 mm. diam., and silt.

1. In this section descriptions and measurements are by C. E. Decker and assistants, and chemical data by C. A. Merritt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
*10	2	2	44	8	Gray resistant sandy limestone. Algal bed at top. Cryptozoan bed, which extends for many miles along the Arbuckle front.	2	50	48	Fine quartz 0.17-0.5 mm. diam. Well rounded, detrital.
*11	1	6	46	2	Fine-grained indurated sandstone. 11A.	2	63	35	Considerable amount of both silt and quartz. Quartz grains 0.1 mm. diam.
	3	10	50		Sandy shale. 11B.		76	24	Considerable amount of both silt and quartz. Quartz grains 0.05-0.1 mm. diam.
	2	8	52	8	Shaly limestone. *11C.	4	77	19	Mostly quartz 0.08-0.2 mm. diam.
12	1	9	54	5	Dark gray limestone.		91	9	Silt and quartz 0.1 mm. diam.
13	2	5	56	10	Thin-bedded limestone.		95	5	Mostly silt. Some quartz 0.05 mm. diam.
14	1	3	58	1	Limestone breccia at top followed by banded gray and black limestone below.	4	90	6	Silt and quartz. Quartz grains 0.17-0.08 mm. diam.
15	2	4	60	5	Gray banded limestone.		97	3	Mostly silt.
16	3	8	64	1	Thin-bedded, fine, sandy limestone, slightly shaly.	2	66	32	Mostly silt. Some quartz 0.17-0.1 mm. diam.
*17	1	1	65	2	Coarse blackish gray limestone with some ostracods.	6	86	8	Silt and quartz 0.1-0.08 mm. diam.
*18		5	65	7	Shale, sandy at top, argillaceous at bottom.	2	91	7	Mostly silt. A little quartz 0.05 mm. diam.
19	3		68	7	Dark limestone breccia at top, clayey limestone at base. 19A.	4	99	1	Quartz 0.05 mm. diam.
					19B.		85	11	Few quartz grains 0.05 mm. diam., but mostly yellow silt.
20	3	2	71	9	Thin shaly limestone most sandy in center, streaks of gray and yellow alternate.	2	97	1	Quartz 0.05-0.25 mm. diam., detrital.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
21	2	11	74	8	Dark limestone beds 3" to 10" thick, one bed banded with gray.		99	1	Quartz 0.02-0.25 mm. diam., detrital.
22	5		79	8	Gray shaly sandstone with yellow streaks.	2	74	24	Silt and quartz. Quartz grains 0.08-0.12 mm. diam.
*23	1	5	81	1	Breccia in cross-bedded resistant calcareous sandstone.	3	28	69	Quartz 0.33-0.17 mm. diam. Mostly 0.25 mm. diam., detrital.
24	3	6	84	7	Gray shaly limestone.		65	35	Mostly silt and fine quartz 0.04 mm. diam.
25	1	9	86	4	Limestone with 2" conglomerate in center.	4	89	7	Quartz 0.05-0.25. Mostly 0.05.
26	2		88	4	Fine light gray indurated calcareous sandstone. 26A.	4	72	24	Quartz 0.05-0.25 mm. diam. Mostly larger ones clear, well rounded, detrital.
					26B.	4	87	9	Mostly yellowish silt.
*27	3		91	4	Sandy, shaly limestone, gray streaked with yellow.	28	50	22	Quartz 0.08-0.25 mm. diam. Mostly 0.08 mm. diam.
28	1	2	92	6	Limestone breccia.		92	8	Quartz 0.06-0.25 mm. diam. Mostly 0.06 mm. diam.
29	38	9	131	3	Upper 13'-9" covered, but weathers like rest of interval of 9' which consists of thin fossiliferous limestone with a few 2'-6" beds toward base. 29A.	7	87	6	Quartz 0.1 mm. diam.
					29B.	2	90	8	Quartz 0.05 mm. diam.
30		10	132	1	Fine-grained limestone in 4" beds.		94	6	Quartz 0.05 mm. diam.
31	18	6	150	7	Sandy limestone and sandy shales, mostly thin and fissle, but with some 2" to 10" beds. 31A.	4	87	9	Quartz 0.05 mm. diam.
					31B.	3	76	21	Quartz 0.05-0.25 larger grains well rounded, clear, detrital.
32	7	6	158	1	Chocolate and gray shaly limestone.		93	7	Quartz 0.12 mm. diam.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	In.	TOTAL Ft.	In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	DESCRIPTION
33	2	3	160	4	Thin fissile gray sandy limestone.	3	89	8	Quartz 0.12 mm. diam.
*34	2	2	162	6	Dark mottled resistant sandy limestone.	6	84	10	Silt and quartz. Quartz grains 0.1 mm. diam.
35	46		208	6	Thin sandstone with 18" of thin red sandy shale and two beds of sandy limestone 2" and 8" thick. 35A. 35B.	3	91 16	6 84	Quartz 0.1 mm. diam Quartz grains up to 0.17 mm. diam., well-rounded, detrital.
36	30		238	6	Dark resistant and limestone beds 4" to 18" thick. Very resistant 18" bed at base of zone containing a few fossils, ostracods chiefly.	4	91	5	Mostly silt.
37	7	8	246	2	Dark gray sandy limestone 4', rest covered.	3	73	24	Quartz 0.12-0.06 mm. diam.
38	9	7	255	9	Fossiliferous 2' limestone bed at top followed below by 8" beds with 18" resistant limestone bed at base with numerous fossils on top of the ledge it makes.	2	89	9	Quartz 0.08 mm. diam.
39	7	8	263	5	Thin-bedded gray siliceous limestone.	6	84	10	Quartz 0.08 mm. diam.
*40	20	8	284	1	Dark coarse impure limestone, 12" bed at top followed below by earthy gray limestone. One 3' resistant limestone bed in center, about 3½' at base covered.	12	68	20	Silt and quartz 0.09-0.1. mm. diam.
41	5	6	289	7	Coarse gray fossiliferous limestone beds, thinner at bottom.	7	84	9	Quartz 0.12 mm. diam. Few smaller.
*42	15		304	7	Mostly resistant dark gray sandy limestone with a few thin cherty bands, irregular lens-shaped.	9	64	27	Quartz mostly 0.17-0.25 mm. diam., detrital.
*43	13	4	317	11	Thin sandy beds, upper 5' gray, 8' below red.	23	53	24	Reddish silt and quartz 0.06.
44	8	4	326	3	Sandy gray limestones at top 5" thick, followed by thin gray sandy beds containing two 3" beds of sandy limestone.	13	74	13	Mostly silt.
45	15	3	341	6	Shaly limestone mostly thin beds, but containing four more resistant beds 12" to 20" thick.	16	68	16	Mostly reddish silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	In.	TOTAL Ft.	In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	DESCRIPTION
*46	14		355	6	Thin gray shaly limestones, thinnest and papery for 3' at base.	26	59	15	Reddish silt and quartz 0.06-0.1 mm. diam.
*47	13	6	369		Dark gray impure limestones, thick beds at top and thinner ones at base.	16	66	18	Mostly silt. Some quartz 0.08 mm. diam.
*48	20		389		Red sandy limestones becoming thinner and more calcareous at base.	10	69	21	Reddish silt and fine quartz.
49	8	8	397	8	Thin gray sandy limestone turning pink toward base.	7	84	9	Quartz 0.05 mm. diam.
*50	23		420	8	Alternating argillaceous limestone and thin shale.	6	77	17	Quartz 0.05 mm. diam.
51	2	5	423	1	Gray shale more sandy in center.	3	87	10	Silt and quartz 0.05 mm. diam.
52	1	10	424	11	Sandy shale with 4" calcareous sandstone bed at top.	4	85	11	Silt and quartz 0.05 mm. diam.
*53	5	2	430	1	Fine-grained limestone banded chocolate and gray.	22	69	9	Quartz 0.06 mm. diam.
54	2	8	432	9	Thin sandy limestone with 8" sandy limestone at base.		92	8	Quartz 0.06-0.12 mm. diam.
*55	7	7	440	4	Fine-grained banded sandy limestone two beds being 2' thick. Beds become more sandy toward base.	4	70	26	Quartz 0.33 mm. diam., well rounded, detrital.
56	3		443	4	Yellowish gray sandy limestone poorly indurated. (Weathers to loose sand.) 56A. 56B.	10 4	83 25	7 71	Quartz grains 0.12-0.5 mm. diam. Quartz grains 0.12-0.33 mm. diam., well-rounded, detrital.
57	3		446	4	Fine-grained chocolate limestone with discontinuous gray bands.	12	77	11	Quartz 0.1 mm. diam.
*58	3	9	450	1	Thin-bedded yellowish gray sandy limestone with beds ranging from ¼" to 2", but most of them thin.	22	68	10	Quartz 0.05 mm. diam.
59	7	2	457	3	Fine-grained limestone, chocolate banded with grayish streaks.	13	75	12	Quartz 0.05 mm. diam.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cen	RESIDUE DESCRIPTION
*60	3	5	460	8	Sandy limestone 12" thick at top weathers to fine loose sand. Rest of interval gray, thin bedded shaly sandstone becoming calcareous at base.	27	41	32	Quartz 0.03 mm. diam., and silt.
*61	6	2	466	10	Argillaceous limestone at top, coarse grained purplish-brown limestone in lower 3'.	16	45	39	Very fine quartz, and silt.
62	4		470	10	Well indurated cross-bedded gray sandstone in beds 10" thick. Reverse of Mud Cracks show on underside of one bed. Picture Plate II, A. 62A.		24	76	Quartz 0.06-0.5 mm. diam., well-rounded, detrital.
					62B.	2	74	24	Quartz 0.06 mm. diam., a few up to 0.33 mm. diam., detrital.
*63	8	3	479	1	Mostly thin-bedded shaly sandy limestone containing a 10" conglomerate bed in center of zone, also contains ostracod bed in center of zone.	15	54	31	Very fine quartz, and silt.
64	1	10	480	11	Thin bedded shaly limestone.	13	78	9	Quartz 0.06 mm. diam.
65	5	10	486	9	Thin gray fine sandy and shaly limestones and sandy shales. Intraformational fold in beds at base.	6	67	27	Quartz, 0.05 mm. diam., and silt.
*66	4	2	490	11	Thin bedded argillaceous limestone.	7	73	20	Very fine quartz, and silt.
67	28	6	519	5	Mostly thin bedded fine grained chocolate limestone with about 4" of thin bedded coarse limestone included, about 6" of fine grained thin bedded limestone at base.	4	84	12	Fine quartz, and silt.
68	7	3	526	8	Sandstone and sandy shales at top, some algal structures, sandy limestone at base containing chert concretions, 4" breccia above algal zone. 68A.	6	85	9	Fine quartz, and silt.
					68B.	4	57	39	Fine quartz, and silt.
69	4	6	531	2	Thin shaly sandstone containing 3 banded sandstone beds 4" thick.	8	81	11	Fine quartz, and silt.
70	5	2	536	4	Fine grained dark chocolate limestone containing some gray lines at top, gray limestones at base.	13	80	7	Fine quartz, and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
71	20	4	556	8	Chiefly sandy limestones thin bedded at top and shaly at several horizons. Two beds reach a thickness of 4" and 6" and contain chert nodules.	4	84	12	Fine quartz, and silt.
72	35		591	8	Heavy beds of silty limestone, one 5' thick, several 2' thick.	2	83	15	Fine quartz, and silt.
73	18		609	8	Covered with talus.	6	47	47	Fine quartz, and silt.
74	5	2	614	10	Thin sandy limestone with 18" of sandy shale at base.	12	74	14	Fine quartz, and silt.
75	5	10	620	8	Sandy limestone at top grading into thin sandstone at base.	7	82	11	Fine quartz, and silt.
76	8	10	629	6	Three thick and three thin beds of gray banded even bedded limestone.	10	79	11	Fine quartz, and silt.
*77	4		633	6	Mostly shaly thin bedded sandy limestone. Beds ½-1" in thickness except one 16" bed.	32	42	26	Quartz 0.08-0.16 mm. diam., mostly 0.08 mm. angular.
78	12		645	6	Upper two-thirds of zone dark, finely banded, even bedded limestone, has most of the beds 6", but one 15" lower, one-third heavier beds of mottled chocolate color.	13	75	12	Fine quartz, and silt.
79	9	3	654	9	Sandy limestone with 3" conglomerate at base yellowish gray in color fine grained and mostly in thin beds, but contains one 18" bed and one larger of sandy shale 3" thick.	8	57	35	Fine quartz, and silt.
80	4		658	9	About 2' of sandy limestone 3" of sandy shale and 1'-9" of light chocolate fine grained limestone.	4	72	24	Fine quartz and silt.
81	13	3	672		Thin bedded yellowish gray sandy limestone with 3½' banded calcareous sandstone at base.	6	85	9	Fine quartz and silt.
82	17		689		Fine grained chocolate colored limestone except for 3' at the base where it mottled grayish brown.	4	89	7	Fine quartz and silt.
*83	4	6	693	6	Fine grained yellowish gray limestone.		99	1	Fine quartz and silt, 0.16-0.06 mm. diam.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
84		7	694	1	Yellowish gray sandy limestone part of which is somewhat shaly.	3	83	14	Fine quartz and silt.
85	2		696	1	Fine grained chocolate colored limestone with a few lenticular cherts. Top bed is very irregular in thickness and fossil bed is very sandy.	1	90	9	Fine quartz and silt.
86	7	4	703	5	Thin bedded yellowish gray sandy limestone.	4	84	12	Fine quartz and silt.
87	2	7	706		Fine grained dark impure limestone part of which is banded. Beds vary from 10" to 3' in thickness.	2	83	15	Quartz, 0.1 mm. diam., but mostly silt.
88	13	6	719	6	Thin bedded yellowish gray sandy limestone.		81	19	Fine quartz and silt.
89A	1	6	721		Top consists of two limestone beds separated by 2½" shaly layers, while the fossil part consists of an irregular chocolate colored limestone bed 20" thick.	3	93	4	Fine quartz and silt.
89B	3		724		Limestones and thin sandy shales.	2	43	55	Clear rounded quartz, 0.05-0.25 mm. diam., detrital.
90	12		736		Thick bedded sandy limestone, fresh surface gray, weathers to buff.		70	30	Fine quartz and silt.
91	10	2	746	2	Fine grained chocolate colored limestone in very thick beds. A large concretion in the fossil bed.		99	1	Fine quartz and silt.
92	7	6	753	8	Yellowish gray limestone, more shaly toward the base.	3	92	5	Fine quartz and silt.
93	16	4	770		Fine grained chocolate colored limestone. A few beds 5" to 8" in thickness, but most of them range from 2½' to 5'.	1	95	4	Fine quartz and silt.
94	5	6	775	6	Chiefly a sandy shaly zone with 7" sandy limestone beds in the center. 94A. 94B.	2	86 77	12 23	Fine quartz and silt. Fine quartz and silt.
95	7	3	782	9	Buff to chocolate colored sandy limestone in thick beds.	4	89	7	Quartz, 0.1 mm. diam., but mostly silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
96	11		793	9	Thin bedded sandy shaly limestone toward base. Color yellow at top grading into gray at base.	6	85	9	Quartz, 0.1 mm. diam., but mostly silt.
97	36		829	9	Buff to chocolate colored shaly limestones with a few sandy and shaly partings.	7	73	20	Fine quartz and silt.
98	2	4	832	1	Sandy limestone.		91	9	Fine quartz and silt.
*99	108		940	1	Mostly heavy sandy limestones 7" to 20" thick, but some thinner beds at top. Mostly chocolate in color with some mottled yellow. 99A. 99B.	75	89 25	11	Fine quartz and silt. Band 1 mm. wide in thin section.
100	1	9	941	10	Thin marly beds of limestone.	2	91	7	Fine quartz and silt.
101	5	4	947	2	Chocolate colored limestones in massive beds, contain some small ostracods.	6	86	8	Fine quartz and silt.
102	5	4	952	6	Thin bedded, very shaly limestones containing two 4" limestone beds.	11	48	41	Fine quartz and silt.
103	56		1008	6	Dark colored thick bedded limestone. Beds 18" to 3' in thickness. Breccia at the base varying from 8" to 20" in thickness.	7	84	9	Fine quartz and silt.
104	11	3	1019	9	Thin bedded shaly limestones at top and a dark gray crystalline 2' limestone bed at base. Thin fossiliferous layer near middle with Maclureas and Hormotomas.	8	79	13	Fine quartz and silt.
*105	10	9	1030	6	Partly yellow very sandy limestone and part gray limestone.	21	50	29	Quartz grains up to 0.16 mm. diam.
106	36		1066	6	(Measured west of road). Dark gray crystalline limestone beds 6" to 3' in thickness.	17	74	9	Quartz, 0.05-0.1 mm. diam., but mostly silt.
107	40	6	1107		(Measured west of road). Four ledges of resistant limestone 1' to 3' thick, probably separated by thinner limestone or shale.	7	91	2	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
*108	23	8	1130	8	Two ledges resistant dark gray limestone with thinner gray and yellow shaly limestones between.	8	88	4	Reddish silt. Quartz—minute grains, 0.05 mm. diam., angular.
109	28		1158	8	Mostly dark gray crystalline limestones with a 2′ bed of red sandy limestone at the base.	6	88	6	Fine quartz and silt.
110	4	10	1163	6	Shaly sandstone weathered to loose yellow sand at top.	3	91	6	Fine quartz and silt.
*111	7	8	1171	2	Slightly sandy limestone with sandy shale in center. Color varies from gray to pink and chocolate.	93	2	5	Fine quartz and silt.
112	45	6	1216	8	Mostly heavy beds of dark chocolate limestone with a banded sandy phase at the top.	6	85	9	Fine quartz and silt; quartz grains, 0.08-0.06 mm. diam.
113	3	3	1219	11	Thin bedded gray argillaceous limestone.	7	62	31	Fine quartz and silt.
*114	7	9	1227	8	Banded and sandy limestones with several cherty bands.		96	4	Fine quartz and silt.
115	43	10	1271	6	Dark partly mottled limestone beds 3′ to 5′ in thickness.		98	2	Fine quartz and silt.
116	8		1279	6	A variable zone of sandy limestones, thin sandstones and limestones.	2	90	8	Fine quartz and silt.
117	3	2	1282	8	Gray fine grained limestone.	2	93	5	Fine quartz and silt.
118	3	8	1286	4	Thin bedded gray shaly limestones.	4	60	36	Fine quartz and silt.
119	38		1324	4	Mostly heavy beds of dark gray limestone with some thinner beds at base.	4	90	6	Fine quartz and silt.
120	28	6	1352	10	Dark limestones, except one pink bed 2″ thick.	7	84	9	Fine quartz and silt.
121	1	9	1354	7	Banded sandy limestone.	3	90	7	Fine quartz and silt.
*122	21	8	1376	3	A zone with pink dolomitic limestone at top, fine grained dark limestone in the middle and sandy limestone at the base. 122A 122B	90 7	2 87	8 6	Fine quartz and silt. Fine quartz and silt.
123	5	2	1381	5	Heavy beds of banded chocolate and yellow limestone.	6	87	7	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
124	5	8	1387	1	Thin bedded shaly limestone sandy toward base, mottled yellow and pink.	80	5	15	Reddish silt and fine quartz.
125	9		1396	1	Fine grained heavy bedded dark limestone.	6	88	6	Fine quartz and silt.
126	2	8	1398	9	Gray banded sandy limestone.	6	77	17	Fine quartz and silt.
127	13	8	1412	5	Dark mottled chocolate limestone.	11	82	7	Fine quartz and silt.
128	7	10	1420	3	Sandy limestones with 2′ of shaly limestone at base.	8	68	24′	Fine quartz and silt.
*129	51	10	1472	1	Heavy bedded banded chocolate limestones, lower beds 3′ to 5′ thick.	1	96	3	Fine quartz and silt.
130	90		1562	1	Measured across a draw on west side of road in field. Mostly heavy bedded gray limestone.	4	86	10	Fine quartz and silt.
131	28		1590	1	Mostly dark mottled limestones, some curly. One 2′ yellow bed, one 2½′ green bed and a dark 5′ bed at base.	2	92	6	Fine quartz and silt.
132	2	7	1592	8	Yellowish gray sandstone. 132A rounded, detrital. 132B	6 5	90 88	4 7	Fine quartz and silt. Quartz, 0.05-0.25 mm. diam. Well-rounded, detrital.
133	12	8	1605	4	Mostly yellowish gray limestone. A dark bed of limestone at the base 4′ thick.	8	85	7	Fine quartz and silt.
*134	6	5	1611	9	Sandy dolomitic bed at top 18″ thick. 2½′ of loose weathered sand in middle and weathered yellowish gray sandstone at base. *134A. 134B.	42	50 59	8 41	Quartz, 0.08-0.2 mm. diam. Quartz, 0.1-0.33 mm. diam.
135	36	2	1647	11	Dark chocolate heavy bedded limestones.	33	58	9	Fine quartz and silt.
136	2		1649	11	Banded gray sandy limestone.	41	48	11	Fine quartz and silt.
137	13	8	1663	7	Heavy dark limestone with a few 4″ light bands.	31	62	7	Fine quartz and silt.
*138	14	6	1678	1	Sandy dolomite, with gray and pink banding thin, intraformational folds in one bed.	74	7	19	Quartz, 0.06-0.33 mm. diam. The larger grains are detrital.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	THICKNESS TOTAL Ft.	THICKNESS TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
139	43	7	1721	8	Mostly heavy bedded limestone one algal bed and one massive fossiliferous bed from which it is difficult to get the fossils out.	11	85	4	Fine quartz and silt.
140	95		1816	8	Dark gray limestone exposed at west side of road and measured west of fence.	6	88	6	Fine quartz and silt.
141	6	9	1823	5	Thin bedded gray shaly limestone with beds ½ to ½" in thickness.	6	85	9	Fine quartz and silt.
*142	27	6	1850	11	Thin bedded gray limestone poorly exposed. (Measured west of road.)	2	92	6	Fine quartz and silt. Quartz grains 0.1 mm. diam.
143	123	6	1974	5	Mostly heavy beds of gray limestone measured west of road. Several beds 3' to 5' thick form prominent ledges with zones of less resistant beds between.	3	89	8	Fine quartz and silt.
144	10	4	1984	9	Two zones of thin shaly limestone at top and bottom with about 2' of 4" to 5" beds in center.	4	85	11	Fine quartz and silt.
*145	11	6	1996	3	Dark heavy beds of fine grained limestone.	12	79	9	Fine quartz and silt. Quartz grains 0.12 mm. diam.
146	7		1996	10	Thin shaly limestone bed.	3	89	8	Fine quartz and silt.
*147	100	6	2097	4	(Measured inside of fence on west side of road.) Several resistant ledges of limestone alternating with zones of less resistant beds which are weathered and largely covered.	3	90	7	Fine quartz and silt.
148	119		2216	4	Limestone rather poorly exposed along road. 12" breccia at base of zone.	4	87	9	Fine quartz and silt. Quartz grains 0.12 mm. diam.
149	167		2383	4	Limestone rather poorly exposed along west side of road, several resistant beds alternate with zones of less resistant ones. In one zone the limestones are mottled with blood red to brown spots.	5	89	6	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	THICKNESS TOTAL Ft.	THICKNESS TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
150	287		2670	4	Alternating heavy and thinner beds of gray limestone with breccia near base. (Measured west of road.)	3	90	7	Fine quartz and silt.
151	15	3	2685	7	Dark gray limestone with 4' bed at top and the rest thinner and fossiliferous, contain gastropods, cephalopods and trilobites.	7	83	10	Fine quartz and silt.
152	98		2783	7	(Measured east of road.) Alternating heavy limestone 4' ledges with 8' to 15' of thinner beds between.	9	81	10	Fine quartz and silt.
153	44		2827	7	Mostly thin gray limestone. One buff limestone bed 14" thick 3' above base of zone, worm borings and trains and bryozoa abundant. Fossils numerous in 44' zone beginning 35 paces south of cattle underpass. (Measured west of road.)	6	83	11	Fine quartz and silt.
154	165		2992	7	Resistant sandy 4' limestone beds spaced 8' to 15' apart with thinner beds; mostly limestones between. Many fossils in the 65' extending from the base of zone. Also several algal beds in this part of the zone.	11	70	19	Fine quartz and silt.
155	1	8	2994	3	Gray shaly limestone.	4	79	17	Fine quartz and silt.
156	15	8	3009	11	Varied dark and light gray limestones with one 3" bed of shale. Several algal beds, one at base 4' thick.	6	87	7	Fine quartz and silt.
157	2	2	3012	1	Thin bedded light gray sandy, shaly limestone.	8	63	29	Fine quartz and silt.
158	39		3051	1	Mostly heavy bedded impure limestone. Dark and asphaltic near top of zone, lighter gray toward base of zone.	13	69	18	Fine quartz and silt.
159	35		3086	1	Thin bedded impure limestones, light brown, a few beds 8" to 15" thick.	7	80	13	Fine quartz and silt.
160	13		3099	1	Thin gray shaly sandy limestone. 160A. 160B.	7	85 77	8 23	Fine quartz and silt. Fine quartz and silt.
161	9	8	3108	9	Grayish black crystalline limestones.	9	82	9	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	In.	TOTAL Ft.	In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	DESCRIPTION
162	2		3110	9	Variegated sandy shaly limestone.	7	82	11	Quartz, 0.33-0.1 mm. diam., mostly 0.33 mm. diam.
163	10		3120	9	Dark grayish black impure limestone in beds 18" to 30" thick.	11	76	13	Fine quartz and silt.
164	3	9	3124	6	Thin bedded fine grained gray sandy limestone.	8	83	9	Fine quartz and silt.
*165	7		3131	6	Dark gray crystalline limestone in beds 30" thick.	5	90	5	Fine quartz and silt.
166	15	3	3146	9	A zone with 5' of unindurated sandstone at top, sandy shale in the center and more argillaceous shale toward the bottom.	7	32	61	Quartz, 0.14-0.25 mm. diam.
167	18		3164	9	Dark gray silty limestone.	12	66	22	Fine quartz and silt.
168	10		3174	9	Thin bedded coarse sandy limestone, 3' at base 168A. covered. 168B.	7 6	82 78	11 16	Fine quartz and silt. Fine quartz and silt.
169	145		3319	9	(Measured west of road.) Numerous massive beds 3' to 4' thick separated by less resistant beds probably of shale and sandstone. Silicified fossils occur on the surface of some of the beds and the zone contains several algal layers.		96	4	Fine quartz and silt, a few quartz grains well rounded, 0.25 mm. diam.
170	5	6	3325	3	Poorly exposed, some red sandstone and red sandy soil.		1	99	Aggregate of minute quartz grains. Red stained calcareous material has been leached out. (Probably chert, a local phase.)
171	19	6	3344	9	Thin bedded varying light and dark limestone beds.	11	82	7	Fine quartz and silt.
172	3	8	3348	5	Fine grained gray sandy limestone in beds 3" to 4" thick.	9	82	9	Fine quartz and silt.
*173	13	4	3361	9	Dark gray fossiliferous limestone.	10	89	1	Fine quartz and silt.
174	1		3362	9	Thin bedded gray sandy limestone.	4	84	12	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	In.	TOTAL Ft.	In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	DESCRIPTION
175	0		3372	9	Dark gray impure limestone.	6	77	17	Fine quartz and silt.
176	12	8	3375	5	Fine grained thin bedded gray shaly, sandy limestone.	11	80	9	Fine quartz and silt.
*177	34		3409	5	Thin bedded gray and chocolate limestone containing one 3" band of chert, and 8" bed of sandy limestone, and a fine dark gray bed of oolite 12" thick at the base. Measurements from here taken horizontally. Dip. 57° S. W., Strike N. 50° W.	7	85	8	Fine quartz and silt. Siliceous oolites, 0.12 mm. diam., with calcareous cement.
178	412		3821	5	Scattered edges of limestone beds exposed at intervals on the east side of road, were exposed in draw and on slope, the beds are mostly thick. 178A. Large chert nodules at 3' to 5' below top of this zone. Siliceous oolites occur at following distances below the top of the zone: 318; 337; 404; 413; 442; 458 feet. 178B.	9 6	86 3	5 91	Fine quartz and silt. Siliceous oolites.
*179	237		4058	5	Heavy bedded gray limestones partly exposed in pasture on east side of road. Some limestones contain much chert, massive chert nodules lie scattered over the surface 100' below top of zone. Siliceous oolites occur below top of zone at following distances; 25; 190; 210 feet.	8	88	4	Siliceous oolites with calcite cement, also iron stained siliceous oolites, 0.13-0.5 mm. diam.
*180	311		4369	5	Limestone exposed only at intervals on pasture east of road in south edge of sec. 18, T. 2 S., R. 2 E. Some indurated coarse sandy dolomite beds at base of zone. 180A. 180B.	97	94	6 3	Fine quartz and silt. Fine quartz and silt.
181	109		4478	5	Mostly gray limestone with 15' of this sandy limestone at base of zone. 181A. 181B.	6 46	92 44	2 10	Fine quartz and silt. Fine quartz and silt.
*182	519		4997	5	Mostly heavy beds of limestone ledges exposed at intervals across pasture. Siliceous oolite about 44' below top of this zone. At 530', numerous fossils occur including brachiopods, trilobites, gastropods on both sides of draw.	2	94	4	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
*183	495		5492	5	Numerous thin limestones intermingled with heavy limestones. Where measured across draw 150′ is covered, but on slope to east along the strike the same types of limestones outcrop. Dip 57o, Strike N. 60o W.	4	93	3	Fine quartz and silt.
184	144		5636	5	Numerous heavy beds of dark gray limestone weathering so as to leave rough masses standing above surface. Two zones of thin dolomites, sandy in appearance, fossiliferous, 40′ above base. 184A.	11	82	7	Mostly quartz, 0.33-0.1 mm. diam.
					184B.	92	2	6	Very fine quartz and silt.
*185	9	10	5646	3	Thin bedded yellowish gray dolomite, sandy in appearance. 185A.	95		5	Quartz, 0.13 mm. diam., and smaller.
					185B.	75		25	Fine quartz and silt.
*186	25	6	5671	9	Dark gray dolomite masses, coarsely crystalline.	93		7	Fine quartz and silt with few quartz grains, 0.33 mm. diam.
*187	3	4	5675	1	Fine grained gray dolomite in beds 4″ to 6″ thick.	96		4	Quartz 0.05 mm. diam.
*188	2	1	5677	2	Dark gray dolomite, sandy in appearance.	95		5	Quartz, 0.05-0.12 mm. diam.
189	3	4	5680	6	Banded gray sandy dolomite, mostly in fine grains but with a few large grains of quartz.	81		19	Quartz mostly 0.25 mm. diam., some smaller.
190	2	6	5683		Light gray coarse dolomite, marble-like in appearance.	97		3	Fine quartz.
191	4	10	5687	10	Thin bedded gray dolomite, sandy in appearance.	96		4	Fine quartz.
*192	1	7	5689	5	Massive gray coarse dolomite, marble-like in appearance.	96		4	Quartz grains, 0.05-0.13 mm. diam., mostly fine.
*193	1	7	5691		Thin bedded gray dolomite, sandy in appearance.	96		4	Quartz grains, 0.05-0.13 mm. diam., mostly fine.
194	1	7	5692	7	Gray, white and pink dolomite of coarse texture.	98		2	Fine quartz and silt.
195	1	7	5694	2	Thin papery light gray dolomite, sandy in appearance.	97		3	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	THICKNESS OF BED In.	TOTAL Ft.	TOTAL In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	RESIDUE DESCRIPTION
196	1	7	5695	9	Coarsely crystalline light gray dolomite, marble-like in appearance.	98		2	Fine quartz and silt.
197	2	6	5698	3	Thin bedded fine dolomite gray at top, yellow at base, sandy in appearance.	95		5	Fine quartz and silt.
*198	1	7	5699	10	Coarse light gray dolomite, marble-like in appearance.	96		4	Fine quartz and silt. Quartz grains, 0.12 mm. diam.
199	1	7	5701	5	Fine gray dolomite sandy in appearance.	99		1	Fine quartz and silt.
200	7	5	5708	10	Three beds of coarse yellowish gray dolomite, marble-like in appearance.	99		1	Fine quartz and silt.
201	2	6	5711	4	Fine gray dolomite, sandy in appearance. Rubs off readily on surface.	99		1	Fine quartz and silt.
*202	3	4	5714	8	Coarse pinkish gray dolomite marble-like in appearance.	99		1	Fine quartz and silt.
203	4	1	5718	9	Thin bedded fine gray dolomite, sandy in appearance.	99		1	Fine quartz and silt.
204	108		5826	9	Coarse gray and yellow dolomite, marble-like in appearance.	99		1	Fine quartz and silt.
205	9	10	5836	7	Thin bedded fine grained dolomite at top grading into massive resistant beds at base.	98		2	Fine quartz and silt.
206	86		5922	7	Mostly massive coarse gray and yellow dolomites with a few thin finer grained beds included. Base of this zone forms base of upper dolomite, no breccia or conglomerate at contact.	99		1	Fine quartz and silt.
*207	376		6298	7	About 150′ of thick dark crystalline limestones, 80′ of thinner limestone with area covered along road way. Probably shaly limestones, about 60′ more of heavy limestones and rest of interval mostly thin bedded limestone with a few 18″ to 2′ beds at intervals. Dip remains constant to S. W.	18	66	16	Fine quartz and silt., 0.05-0.13 mm. diam.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	In.	TOTAL Ft.	In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	DESCRIPTION
208	102	3	6400	10	Mostly thin bedded dark gray crystalline limestone with a few more dolomitic limestones included.	12	83	5	Fine quartz and silt.
209	1	7	6402	5	Thin bedded fine grained gray dolomite with a thin sandy bed.	96		4	Fine quartz and silt.
210	4	10	6407	3	Dark gray crystalline dolomite.	96		4	Fine quartz and silt.
211	3	4	6410	7	Fine grained gray dolomitic sandstone part of which shows fine bands with a pure dolomite band included. 211A.	37		63	Mostly quartz, 0.1-0.13 mm. diam.
					211B.	94		6	Fine quartz and silt.
212	29	8	6440	3	Dark crystalline dolomite, mostly of heavy beds toward base.	99		1	Fine quartz and silt.
*213	412	5	6852	8	Mostly light gray some yellow, some pink, some dark gray compact dolomitic marble.	96		4	Fine quartz and silt.
214	256		7108	8	Fine grained mostly gray dolomitic marble with some pink in color.	97		3	Fine quartz and silt.
215	28	9	7137	5	Fine grained dark limestones. Because of lack of outcrop and change in strike, the section was shifted on the base of this horizon northwest a point on the same horizon near the road.	9	82	9	Fine quartz and silt.
216	57	8	7195	1	Shale with one thin limestone included 15' above base. Shale more argillaceous at top, and more sandy toward bottom. Color light green at top and more yellow and iron stained at base.	12	76	12	Fine quartz and silt. Iron stained chert nodule. (A local phase only.)
217	18	2	7213	3	Limestone at top, light gray fine grained grading into dolomite at base.	8	80	12	Fine quartz and silt.
*218	54	6	7267	9	Pinkish white medium grained dolomite—looks like marble.	99		1	Fine quartz and silt.

Detailed Section of the Arbuckle Limestone (Cont.)

BED NO.	THICKNESS OF BED Ft.	In.	TOTAL Ft.	In.	DESCRIPTION	DOLOMITE Percent	CALCITE Percent	RESIDUE Per Cent	DESCRIPTION
219	32	6	7300	3	Mostly dark gray crystalline limestone part of which is sandy.	11	88	1	Fine quartz and silt.
*220	80	6	7380	9	Dolomite varying in color from white to pink with former predominating.	75	24	1	Fine quartz and silt.
221	33		7410	9	Dolomitic limestone with some thin beds of dolomite, sandy in appearance. 221A.	12	82	6	Fine quartz and silt.
					221B.	99		1	Fine quartz and silt.
222	85		7495	9	Pink and white dolomite, medium to coarse.	99		1	Fine quartz and silt.
*223	399		7894	9	Mostly dense crystalline dolomite. (Strike changes here.)	99		1	Fine quartz and silt.
224	98		7992		(98 feet measured between bottom of lower dolomitic marble and top of Reagan). Mostly thin bedded gray to light chocolate limestone. West side of East Timbered Hills.	12	55	33	Fine quartz or silt.

DESCRIPTIONS OF THIN SECTIONS

In the following descriptions the numbers of thin sections correspond to those used in the detailed section.

The identification of the minerals in the thin section presents few difficulties. Quartz and calcite are recognized readily. Dolomite in the form of rhombs is seen best by using convergent light and lowering the polarizer. In some cases it is impossible to distinguish coarse dolomite from calcite microscopically but such discrimination is made easily by staining methods.

1. A. *Calcite,* in four forms, (a) minute grains, difficult to distinguish, (b) a few iron stained rounded grains, (c) irregular pieces showing cleavage and twinning lamellae, part of which is in veinlets 1 mm. wide, (d) sections of unidentifiable fossils. In some of these fossils fine crystals are elongate perpendicular to the side of the shell; perhaps such crystals were originally aragonite.

Quartz grains, mostly 0.16 mm. diam., but varying from 0.05 to 0.25 mm. diam., a few well rounded, containing inclusions and undoubtedly detrital, but mostly angular. One well defined crystal, 0.25 mm. along c axis, also a perfect rhombohedron shaped quartz grain. The latter indicates replacement of dolomite by quartz.

Dolomite, a few iron stained rhombs varying from 0.04 to 0.12 mm. in length.

Limonite, stain around the edges of some of the fossils and calcite grains.

1. B. *Calcite,* in four forms, (a) irregular grains showing good cleavage and twinning, (b) rounded grains, limonite stained at the edges, and often showing secondary growths, the latter being shown by the continuity of the cleavage and twinning lines through the periphery of the original grains. These rounded grains are suggestive of clastic limestone grains, (c) a mosaic of fine calcite, (d) sections of microscopic fossils.

Quartz, well-rounded grains, 0.16 to 0.5 mm. diam., distinctly detrital. Two grains show a graphic intergrowth of quartz and feldspar indicating that they were derived originally from an igneous rock. A few minute black opaque grains, probably magnetite.

1. C. *Calcite,* in three forms, (a) iron stained minute grains, difficult to distinguish, (b) a few larger grains showing cleavage and twinning, (c) sections of microscopic fossils as in Nos. 1 A and 1 B, but smaller.

Quartz grains, mostly 0.12 mm. diam., generally angular, though a few are rounded and contain inclusions. Several rhomb-shaped quartz grains; one has both dolomite and quartz. The quartz thus is both detrital and secondary.

Dolomite, numerous iron stained rhombs, 0.2 mm. long, difficult to distinguish.

1. D. *Calcite,* in four forms, (a) minute iron stained grains, difficult to distinguish, (b) a few grains showing cleavage and twinning, (c) several rounded grains, 0.3 to 0.5 mm. diam., probably detrital showing secondary enlargement, (d) sections of microscopic fossils.

Quartz grains, 0.25 to 0.1 mm. diam., mostly 0.2 to 0.25, well rounded containing inclusions and clearly detrital.

Magnetite, a few grains.

2. *Calcite,* in five forms, (a) minute indistinguishable grains, (b) mosaic of very small grains, (c) grains, 0.3 mm. and larger, which show cleavage and twinning, (d) radiating fibres around some of the fossils and quartz grains, indicating secondary calcite, (e) numerous sections of fossils.

Quartz grains, 0.25 to 0.1 mm. diam., angular to rounded, the latter having inclusions.

Magnetite, a few grains.

3. A few grains of quartz, 0.1 mm. diam., are noticeable but the remainder of the slide cannot be identified as the grains are so minute.

4. Calcite, in three forms, (a) minute grains difficult to distinguish, (b) grains, 0.25 to 0.5 mm. diam., showing good cleavage and twinning, (c) iron stained rounded grains, 0.5 to 0.75 mm. diam., probably detrital. A small veinlet of coarse calcite showing cleavage and twinning traverses a few of these rounded grains which indicates the relative ages of these two types of calcite.

Dolomite, a few small rhombs.

5. *Calcite,* in four forms, (a) mosaic of fine grains, (b) iron stained rounded grains, 0.2 mm. diam., showing no cleavage or twinning, (c) irregularly shaped grains, 0.5 mm. diam., and smaller with good cleavage, (d) sections of fossils.

Quartz, 0.08 to 0.33 mm. diam., angular to rounded, the latter with inclusions and probably detrital. A few rhomb-shaped quartz grains indicate replacement of dolomite.

6. *Calcite,* in four forms, (a) minute grains difficult to distinguish, (b) iron stained rounded grains, 0.3 to 0.5 mm. diam.,

43. *Calcite,* in two forms, (a) iron stained minute grains difficult to determine, (b) a few well-rounded grains, 0.16 to 0.12 mm. diam., composed of a mixture of minute calcite and quartz grains. These are clearly detrital in origin.

Quartz, angular grains, 0.06 mm. diam.
Dolomite, iron stained rhombs, 0.08 mm. long.

46. *Calcite,* minute iron stained grains.
Quartz, angular grains, 0.06 to 0.1 mm. diam.
Dolomite, numerous minute rhombs.

47. *Calcite,* in three forms, (a) rounded grains, 0.1 to 0.12 mm. diam., composed of very fine crystals. These grains are iron stained in part at the edges. Some secondary growths are present as indicated by the continuity of the cleavage lines through the periphery of the original grain, (b) irregular grains, maximum size 0.75 mm. long, showing cleavage and sometimes twinning, (c) sections of fossils.

Quartz, grains, 0.08 mm. long, angular, some rhomb-shaped, the latter secondary after dolomite.

Pyrite, one crystal showing cubic faces, also several glistening faces, not cubic.

Magnetite, a few black grains.
Dolomite, iron stained rhombs, 0.08 mm. diam.

48. Red, hematite stained calcite alternates with white calcite giving the rock a finely laminated appearance. The calcite, in the form of a mosaic of fine grains, 0.03 mm.

Quartz, a few very fine grains.
Dolomite, iron stained minute rhombs, difficult to distinguish.

50. It is impossible to distinguish the individual grains even under high power.

53. *Calcite,* in two forms, (a) mosaic of very fine grains, (b) two small calcite stringers, 0.16 mm. wide.

Quartz, angular grains, 0.06 to 0.03 mm. diam.
Dolomite, many minute rhombs.
Magnetite, a few grains.

55. *Calcite,* in three forms, (a) cement between the quartz grains. This cement is partly coarsely crystallized calcite and partly a mosaic of fine grains, (b) rounded grains, 0.3 mm. diam., probably detrital, (c) a few sections of fossils.

Quartz, well-rounded grains, 0.3 mm. diam., many having inclusions which often are arranged in parallel lines.
Dolomite, a few rhombs, 0.1 mm. long.

This rock appears to consist of limestone and quartzitic detrital grains with a calcite cement.

58. *Calcite,* a mosaic of very fine grains.
Quartz, numerous fine angular grains, 0.05 mm. diam.
Dolomite, many rhombs, 0.06 to 0.1 mm. long.
Limonite, stain on several of the calcite grains.

60. *Calcite,* grains, so minute that it is impossible to distinguish them.

Quartz, many fine grains, 0.03 mm. diam.
Dolomite, minute rhombs, 0.05 mm. long, difficult to distinguish.

61. Similar to No. 60.

63. Similar to Nos. 60 and 61.

66. Similar to Nos. 60, 61, and 63.

77. *Calcite,* minute grains, slightly iron stained.

Quartz, angular grains, 0.08 to 0.16 mm. diam., mostly 0.08. Some rhomb-shaped grains indicate replacement of dolomite.

83. *Calcite,* in two forms, (a) mosaic of grains, 0.06 to 0.16 mm. diam., slightly iron stained, (b) sections of fossils.

Quartz, a few grains, 0.16 to 0.06 mm. diam.

99. *Calcite,* a mosaic of minute grains.

A veinlet, 1.0 mm. wide, consisting of 75 per cent dolomite and 25 per cent calcite, traverses the calcite mosaic, thus proving the secondary nature of some of the dolomite and calcite.

Dolomite, in this veinlet is in the form of rhombs, 0.16 mm. long.

105. *Calcite,* iron stained minute grains.

Quartz, grains, maximum size 0.16 mm. diam. One quartz grain encloses two small rhombs of dolomite.

Dolomite, many iron stained rhombs 0.1 mm. long.

108. *Calcite,* a mosaic of fine grains.
Quartz, angular grains, 0.05 mm. diam.
Dolomite, minute rhombs.

111. *Calcite,* a few small grains.

Dolomite, mosaic of small rhombs, 0.08 to 0.06 mm. long, slightly iron stained.

114. *Calcite,* mosaic of small grains, 0.05 mm. diam.

122. *Calcite,* a few minute grains.

Quartz, a few angular grains, 0.06 mm. diam.

Dolomite, mosaic of rhombs, 0.06 mm. long, slightly iron stained.

129. *Calcite,* in thinly laminated bands, 0.16 to 1.0 mm. wide. The narrower bands have the coarser material.

134A. *Calcite,* very fine grains, with the exception of one coarser piece, 1.0 mm. long.

Quartz, grains, 0.8 to 0.2 mm. diam., partially rounded and containing many inclusions. Some pieces rhomb-shaped and secondary after dolomite.

138. *Calcite,* minute grains.

Quartz, grains, 0.06 to 0.33 mm. diam., mostly small, angular to rounded, many with inclusions. The larger grains are detrital, while the smaller ones may or may not be.

142. The calcite is present in particles too minute to distinguish individual grains.

Quartz, a few grains, 0.1 mm. diam.

Dolomite, a few rhombs, difficult to distinguish.

145. *Calcite,* in four forms, (a) iron stained fine grained rounded grains, 0.12 to 1.0 mm. diam., (b) a mosaic of fine grains between the rounded grains, (c) a few grains of calcite showing twinning and cleavage, (d) sections of fossils.

Quartz, grains, 0.12 mm. diam., mostly angular.

Dolomite, iron stained rhombs, 0.12 mm. long.

147. *Calcite,* in two forms, (a) rounded grains, max. size 2 mm., enclosing many quartz crystals and dolomite rhombs, (b) coarser calcite showing cleavage between the rounded grains.

Quartz crystals, 0.12 mm. long, in the rounded calcite grains.

Dolomite, a few rhombs, one rhomb has both dolomite and quartz.

165. *Calcite,* in three forms, (a) rounded or angular grains, max. size 2 mm. diam. and containing many fine pieces of quartz, (b) calcite, showing cleavage or twinning and coarsely crystallized, forms the cement between the rounded grains, (c) a few sections of fossils.

Dolomite, a few rhombs, pleochroic, light brown to colorless.

169. The rock is finely laminated, composed of calcite grains and a few minute quartz fragments.

173. *Calcite,* light brown, fine grained forms the ground mass of the slide.

Quartz, a few small grains.

Dolomite, minute rhombs, 0.05 to 0.16 mm. in length, iron stained in the center, scattered throughout the calcite giving the appearance of dolomite phenocrysts in a fine grained ground mass of calcite. Much of the dolomite is pleochroic, brown when parallel to the long diagonal axis of the rhomb, and colorless when parallel to the short diagonal axis.

177. This slide shows calcareous oölites, cemented together by calcite. The oölites are circular or elliptical in cross-section and vary in size from 0.5 to 0.75 mm. diam. In general the nucleus is a quartz grain usually rounded, though in one case good crystal faces are noticeable. In a few instances a mosaic of fine calcite acts as the nucleus. Fine calcite fibres radiate around the nucleus and concentric rings are also present. The cement between the oölites varies from fine to coarse grained calcite.

These oölites have been formed evidently by crystallization of calcite fibres around a nucleus of quartz or calcite. The nuclei in most cases appear to be of detrital origin. The concentric rings indicate a slight change in the composition of the solution that gave rise to the calcite fibres.

179. This slide shows siliceous oölites cemented together by fine needle-like quartz crystals.

The oölites are circular or elliptical in section, max. size 1.0 mm. diam. Their nuclei are rounded quartz grains and surrounding these is brown fine grained quartz. The fibrous and concentric structure shown in No. 177 is not very distinct in this slide. A few fibres, however, can be seen and these are no longer calcite but quartz, which indicates that the siliceous oölites have been formed by replacement of the calcareous oölites.

180. *Calcite,* in three forms, (a) grains so fine that it is impossible to distinguish the individual pieces, (b) a few iron stained, rounded grains, 0.12 mm. diam., (c) one piece of coarse calcite showing cleavage.

Quartz, a few minute grains.

182. *Calcite,* in two forms, (a) mosaic of minute grains, (b) medium coarse grains showing cleavage.

Dolomite, a few rhombs, pleochroic, light brown to colorless.

183. *Calcite,* in three forms, (a) minute grains, difficult to distinguish, (b) coarser calcite showing cleavage. Part of this is in a veinlet, (c) a few sections of fossils.

Quartz, a few minute grains.

Dolomite, a few iron stained minute rhombs.

185. *Dolomite*, pleochroic, light brown to colorless, mosaic of rhombs, 0.1 mm. long.

Quartz, 0.16 mm., angular to rounded, the latter with inclusions. Some of the quartz grains show shadowy extinction.

186. *Dolomite*, pleochroic, light brown to colorless, coarse grains, maximum size 1.0 mm. long. These grains show no evidence of recrystallization.

Quartz, rounded grains, maximum size 0.35 mm. diam., with inclusions. A few grains rhomb-shaped and one good crystal, 0.5 mm. long, indicate secondary quartz.

187. Similar to No. 185.

188. *Dolomite*, pleochroic, light brown to colorless, coarse grains, maximum size 2 mm. in length. Many of these grains show cleavage and often the cleavage lines are curved.

Quartz, a few grains, 0.12 mm. diam.

192. Similar to No. 188.

193. Similar to Nos. 185 and 187.

198. Similar to Nos. 188 and 192.

202. Similar to Nos. 188, 192, and 198.

207. *Calcite* in three forms, (a) mosaic of fine grains, (b) rounded or irregular grains composed of minute dark calcite, (c) sections of fossils. One of these appears to be a bryozoan.

Quartz, a few grains 0.05 to 0.13 mm. diam., irregular in shape, also a few crystal faces.

Dolomite, fine rhombs.

213. Similar to Nos. 185, 187, and 193.

218. *Dolomite*, in two forms, (a) pleochroic coarse irregular grains, maximum size 1 mm., showing good cleavage, the latter often curved, (b) mosaic of fine rhombs between the coarser grains. This slide seems to be a composite of the two types of dolomite, the coarse and the fine.

220. *Calcite*, mosaic of fine grains.

Dolomite, coarse irregular pleochroic grains showing cleavage.

Quartz, a few fine grains.

223. This slide is similar to Nos. 185, 187, 193, and 213, only the outlines of the rhombs are not so distinct.

CHEMICAL AND MICROSCOPIC CHARACTER

By

Clifford A. Merritt

METHODS OF CHEMICAL ANALYSIS

The numerous beds of the Arbuckle and the limited time at the writer's disposal made it impossible to analyze the samples in the ordinary chemical manner, which is a time consuming procedure. Furthermore, a high degree of accuracy is not essential, for local variations will cause changes in the composition and an individual sample of rock has little value except as a type. For these reasons a quicker, though less accurate, method than the conventional one was used.

The method used, has two distinct parts, the first being the determination of the residue after treating the sample with HCl and the second being the determination of dolomite and calcite by staining. The first part follows the ordinary chemical procedure; namely, treating the weighed sample, previously crushed, with HCl, heating until effervescence ceases, filtering, drying the residue and weighing, using a "tared" filter paper as a counterpoise. The estimation of the dolomite and calcite consisted of the following operations:

1. Crush and screen a small piece of the sample, using 60 and 80 mesh screens.

2. Transfer a few grains, which passed through the 60 and were caught by the 80 mesh, to a watch glass.

3. Cover the grains with Lemberg solution[1] and allow to stand for 3 minutes. This stains the calcite a violet while dolomite remains unchanged.

1. Lemberg solution is prepared by boiling for twenty minutes a mixture of 4 grams of $AlCl_3$, 6 grams extract of logwood, and 60 grams of water, with constant stirring and with the addition of the amount of water lost by evaporation.

4. Remove the excess dye by decantation.

5. Determine the relative amount of calcite and dolomite by a microscopic count of the stained and unstained grains. A magnification of 30 is sufficient and a cross-ruled ocular is helpful but not essential. Care must be taken to estimate fractions of grains in the case of those that are stained in part only. Quartz does not stain and must not be confused with dolomite. In general the vitreous luster will identify the former. In cases of doubt a drop of HCl may be added to the material (after the grain count has been made) and if it be quartz it will remain as a residue and a correction of the grain count can be made.

The reader who desires further knowledge of staining methods for the determination of dolomite may find an excellent summary in "Manual of Petrographic Methods, Chapter XL, Johannsen".

ACCURACY OF THE METHOD

The determination of the dolomite and calcite by grain count has not a high degree of accuracy. The chief factor causing inaccuracy is that some of the grains are stained in parts only and the personal equation enters into the estimation of the fractions stained and unstained. In many cases the rocks would not stain indicating that no calcite was present and here the results naturally are accurate. In general the percentage of dolomite and calcite tabulated in the section is accurate to within 1 or 2 per cent, though occasionally the inaccuracy may be a little greater.

The determination of the residue after treating with HCl may be made as accurate as desired but in this work, in view of the fact that the dolomite and calcite determinations are not exact, no attempt was made to determine the residue beyond whole number percentages.

ANALYSIS OF THE DETAILED SECTION

The chief value of a standard section which eventually will be made when this and other sections are compared will be that of correlating drill cuttings. In general, correlations cannot be made at present from data in the above section alone, as differences in the amount of the constituent minerals will undoubtedly occur, due to local variations and to the large amount of secondary quartz (as will be discussed later). However, certain beds such as those of pure dolomite, or those containing siliceous oölites or a sequence of several beds may be used, where other means fail, as a tentative correlation.

Many readers are more interested in the broader relationships of the formation than in the details and for their benefit an attempt has been made to analyze and bring out the salient features. Such an analysis is attended by many difficulties, generalizations meet with exceptions, boundaries must be placed in order that discriminations may be made, and often the figures do not lend themselves readily to grouping.

QUARTZ

A microscopic study of the quartz shows it to vary in size from minute grains difficult to distinguish to grains 1 mm. in diameter. The finest of the quartz, less than 0.02 mm. in diameter is classified with the minute particles of kaolin and other minerals under the general term of silt, as it is impracticable to differentiate

the constituent minerals. Quartz greater than 0.02 mm. in diameter is described and the percentages given. In several specimens coarse, well-rounded grains were noted and these appear to be detrital. From a close study it appears that quartz 0.25 mm. in diameter and greater is usually detrital, and consequently for generalization purposes this size has been used as the boundary between coarse detrital quartz and finer quartz, the latter probably detrital in part, but as shown in thin section, largely secondary.

The following table brings together the beds in which coarse detritial quartz (0.25 mm.-1.0 mm. diameter) is present.

Per Cent of Coarse Detrital Quartz Present in Beds.

Bed No.	Thickness	Per Cent Quartz	Bed No.	Thickness	Per Cent Quartz
1A		20	55	432′-9″ to 440′-4″	26
1B	0′-0″ to 10′-9″	45	56A	440′-4″ to 443′-4″	7
1D		12	56B		71
2	10′-9″ to 11′-4″	9	62A	466′-10″ to 470′-10″	76
5	20′-6″ to 26′	21	62B		21
6	26′ to 27′	27	89B	721′ to 721′	55
10	42′-6″ to 44′-8″	48	132B	1590′-1″ to 1592′-8″	7
20	68′-7″ to 71′-9″	1	134B	1605′-4″ to 1711′-9″	41
21	71′-9″ to 74′-8″	1	138	1663′-7″ to 1678′-1″	19
23	79′-8″ to 81′-1″	69	162	3108′-9″ to 3110′-9″	11
26A	86′-4″ to 91′-4″	24	166	3131′-6″ to 3146′-9″	61
27	88′-4″ to 91′-4″	22	169	3174′-9″ to 3319′-9″	4
28	91′-4″ to 92′-6″	8	184A	5492′-5″ to 5636′-5″	7
31A	132′-1″ to 150′-7″	21	186	5646′-3″ to 5671′-9″	7
35B	162′-6″ to 208′-6″	84	189	5677′-2″ to 5680′-6″	19
42	289′-7″ to 304′-7″	27			

A consideration of the above table brings out the following salient features:

1. The amount of quartz varies from 1 to 84 per cent. These percentages represent the total quartz in the sample and consequently the amount above 0.25 mm. diameter would be smaller as finer material is associated. In many cases the later is more abundant than the former.

2. In the above 31 beds the quartz content is 1 to 10 per cent in 9 cases, 10-20 per cent in 4, 20-30 per cent in 9, 30-50 per cent in 3, and over 50 per cent in 6, the average being 27 per cent.

3. The total thickness is approximately 376 feet and the average thickness is therefore 12 feet. This thickness combined with the average percentage (27 per cent) of the quartz present indicates that the total amount of coarse detrital quartz is small when

compared with the formation as a whole, in fact it is 1.3 per cent, as calculated from the above figures. It is probably the case that several quartzose beds were missed in the sampling and this would raise the percentage slightly, but it is doubtful if it would reach as high as 2 per cent.

4. It will be noticed in the above table that most of the zones are in the upper part of the formation, in fact all but 9 are in the uppermost 443 feet. In this latter zone the average percentage of the coarse quartz is 30 per cent and the amount of quartz compared with this 443 feet of the formation is approximately 9 per cent. The upper part of the Arbuckle therefore contains considerably more quartz than the lower.

5. The lowermost bed containing coarse quartz is 5,636 feet from the top of the formation, such quartz being absent apparently in the lowest 2,200 feet. However, more detailed sampling may show a few beds in this latter zone.

SECONDARY QUARTZ

A study of the thin sections and the chemical analyses presents evidence of considerable secondary silicification. This evidence may be enumerated as follows:

1. The presence of quartz in the form of rhombs, indicating the replacement of dolomite. In some cases the rhombs are composed of both quartz and dolomite indicating partial replacement only. These rhombs are minute and can be seen only in the thin sections.

2. Quartz crystals with well defined faces, showing no evidence of rounding, surrounded by calcite or dolomite.

3. The presence of silicified fossils.

4. Veinlets of quarts in the calcite and dolomite.

5. The angular nature of much of the fine quartz is suggestive of secondary origin, as is also the large amount of chert.

6. The siliceous oölites appear to have replaced the calcareous oölites.

The silicification has taken place to some extent throughout the sections as almost all slides show some evidence of it. Curiously, however, there is a zone (3,174 — 4,997 feet from the top) in which considerably more silicification than in other parts of the section has taken place. This zone has silicified fossils, siliceous oölites, chert and quartz stringers. This more intense silicification seems to mark the dividing line between the two major lithologic units of the formation, for below the rocks are highly dolomitic to pure

dolomites while above the dolomite content is in general small and the rocks are essentially calcareous. The significance of this occurrence is not clear at present.

Rounded grains are seen occasionally but in general they are angular and furthermore most slides present some evidence of quartz replacing dolomite and consequently the writes believes most of the finer quartz to be secondary. If this be the case it means an immense amount of silicification and the source of the quartz becomes a problem. Perhaps it was derived in part from previously topographically higher portions of the Arbuckle formation itself.

The chert is present in irregular shaped masses in most parts of the formation but especially in the previously mentioned silicified zone. The dolomites, however, are comparatively free of it. The amount of chert when compared with the formation as a whole is almost negligible.

DOLOMITE

Dolomite is present throughout the section in variable amounts, being 3 per cent in the top bed and 99 per cent in the lowest. In general, however, the percentage is rather small in the upper part which is distinctly in contrast with the lower part where much of the formation is pure dolomite.

The upper 3,174 feet of the Arbuckle (that part above the silicified zone) contains only 5 beds with a dolomite content of over 50 per cent, and these beds are rather thin, the maximum thickness being 35 feet. However, almost all the rocks in this uppermost zone contain some dolomite and in many cases a considerable amount, over 10 per cent.

The silicified zone (1,174 — 4,997) has only two beds with a dolomitic content of 46 and 97 per cent, and these beds are rather thin. The percentage of dolomite in the remaining part of the zone does not exceed 11 per cent and therefore the zone as a whole may be considered as essentially calcareous, with, as previously mentioned, considerable silicification.

From 4,997 — 5,636 the rocks are calcareous with but two thin beds of dolomite and perhaps should be classified with the zone above though the silicification is not so marked.

From 5,636 to the base (7,894) the rocks may be classified in the following table.

Classification of Lower Part of Arbuckle Limestone.

Horizon (Feet)	Thickness (Feet)	Kind of Material
5,636 to 5,922	286	calcite, free dolomites
5,922 to 6,400	478	dolomitic limestones
6,400 to 7,108	708	calcite, free dolomites
7,108 to 7,213	105	dolomitic limestones
7,213 to 7,267	54	calcite, free dolomite
7,267 to 7,410	143	dolomitic limestones
7,410 to 7,894	484	calcite, free dolomites

The total thickness of the dolomitic zones containing no calcite is 1,532 feet which is 67 per cent of that portion of the formation outlined in the above table. Furthermore, the average dolomite content in the dolomitic limestones is 20 per cent and in addition some dolomite beds probably escaped sampling, so that it is reasonable to assume that at least 75 per cent of the lowest 2,258 feet of the Arbuckle is dolomite.

The uppermost calcite-free dolomite zone (5,636 to 5,922) consists of alternating beds of fine and coarse dolomites. There are at least 20 of these alternations, the average thickness of the beds being 14 feet. The fine dolomites have a rough sandy feel and appearance which undoubtedly often cause them to be classed as sandstones in field identification. In thin sections they are seen to consist of a mosaic of minute rhombs. The coarse dolomites are commonly marble-like in appearance but the thin sections show no evidence of recrystallization or metamorphism. These rocks consist of very coarse crystals impossible to determine microscopically from coarsely crystallized calcite. In this work they were identified by the previously described staining methods. In the dolomite zones below 5,922 feet, both the fine and coarse varieties are found but the alternations are not so well defined. The cause of this alternation of fine, then coarse, then fine, etc., dolomite is a problem to the solution of which the writer can offer no suggestions.

The origin of the dolomite is beyond the scope of this article. However, several significant facts relevant to this problem have been gleaned from the study and these will be stated.

In slide No. 99 a veinlet, 1.0 mm. wide is seen traversing the calcite. This veinlet has the composition; dolomite 75 per cent, calcite 25 per cent. Therefore, the dolomite in part at least, is later than part of the calcite. However, as shown in this same veinlet and by much other evidence some of the calcite is secondary and this secondary calcite is contemporaneous with the secondary dolomite. Many slides show quartz replacing dolomite rhombs and the secondary quartz is thus later than the dolomite, while some of

the dolomite is epigenetic much of it may be syngenetic for the localization of the large dolomite zones near the base of the formation, the alternation of fine and coarse dolomites in thin beds, and the clear cut contacts between these fine and coarse varieties all suggest a syngenetic origin. Furthermore the source of the immense amount of magnesium called for is difficult to find under a secondary origin hypothesis. It seems then that the major part of the dolomite is syngenetic and a minor amount epigenetic. However, the above is more in the nature of a statement of the problem than a solution of it.

CALCITE

The percentage of calcite in the various parts of the formation has been dealt with in an indirect manner, in the discussion on quartz and dolomite and need not be repeated here. However, other points of interest will be mentioned.

The texture of the limestone is not uniform throughout the formation, in fact several types of textures often occur in the same slide, nor is there any relationship between the texture and the position in the formation. The texture varies from coarsely crystallized to finely crystallized types. The crystal habit includes mosaic of minute grains, fibres, and coarse irregular grains. Some fragments show twinning and cleavage and some do not.

Considerable evidence of secondary calcite is noticeable. Veinlets of calcite or calcite and dolomite traverse the limestone. The secondary calcite is thus contemporaneous with the secondary dolomite. The percentage of calcite which is secondary must be insignificant when compared to the percentage in the formation as a whole.

OTHER MINERALS

Clastic grains of feldspars are noticeable in some of the slides but are not common. In a few cases the feldspar and quartz are in the form of a graphic intergrowth and thus indicate that they were derived originally from an igneous rock.

Magnetite is present in small amounts in a few specimens. It is probably detrital in origin.

Pyrite is present, but not common except in a few specimens.

SUMMARY

1. While the above section is called a detailed one, it is only relatively detailed. If all the minor changes in sedimentation were shown, the number of zones would have been increased many fold. Even in the upper part of the formation, in several wide zones across ravines or swails, only the natural surface exposures could be studied. If the rocks of these zones and of the middle and low-

er parts of the formations were exposed by cuts which would reveal the character of the beds, the changes in sedimentation in this formation would doubtless reach into the thousands.

2. The generalized section shows seven fairly distinct physical zones.

3. The upper part with its thin beds, some sandy and some shaly, seven thin conglomerates and breccias, algal beds, mud cracks, and worm trails, gives evidence of shallow water conditions, and the next zone with oölitic beds scattered at intervals through it also suggests shallow water deposition. Most of the zones of beds with detrital quartz are in the upper part, but a few of them are in the midst of the heavy middle beds.

4. The two major and three minor zones of relatively pure dolomites are separated by relatively pure limestones. Numerous alternating zones of thick and thin beds occur in the upper dolomite, and only a few thin beds occur in the lower one.

5. In the constant zones the dolomites are thought to be primary.

6. Beneath the lower dolomite there is about 100 feet of relatively thin bedded limestone resting conformably on top of the calcareous upper part of the Reagan formation.

7. Considerable secondary quartz has been deposited, especially in the middle of the formation.

8. Chemical analysis has shown that many of the thin beds, particularly in the major two dolomitic zones which look like gray sandstone and some of which appear friable, are in reality nearly pure dolomites.

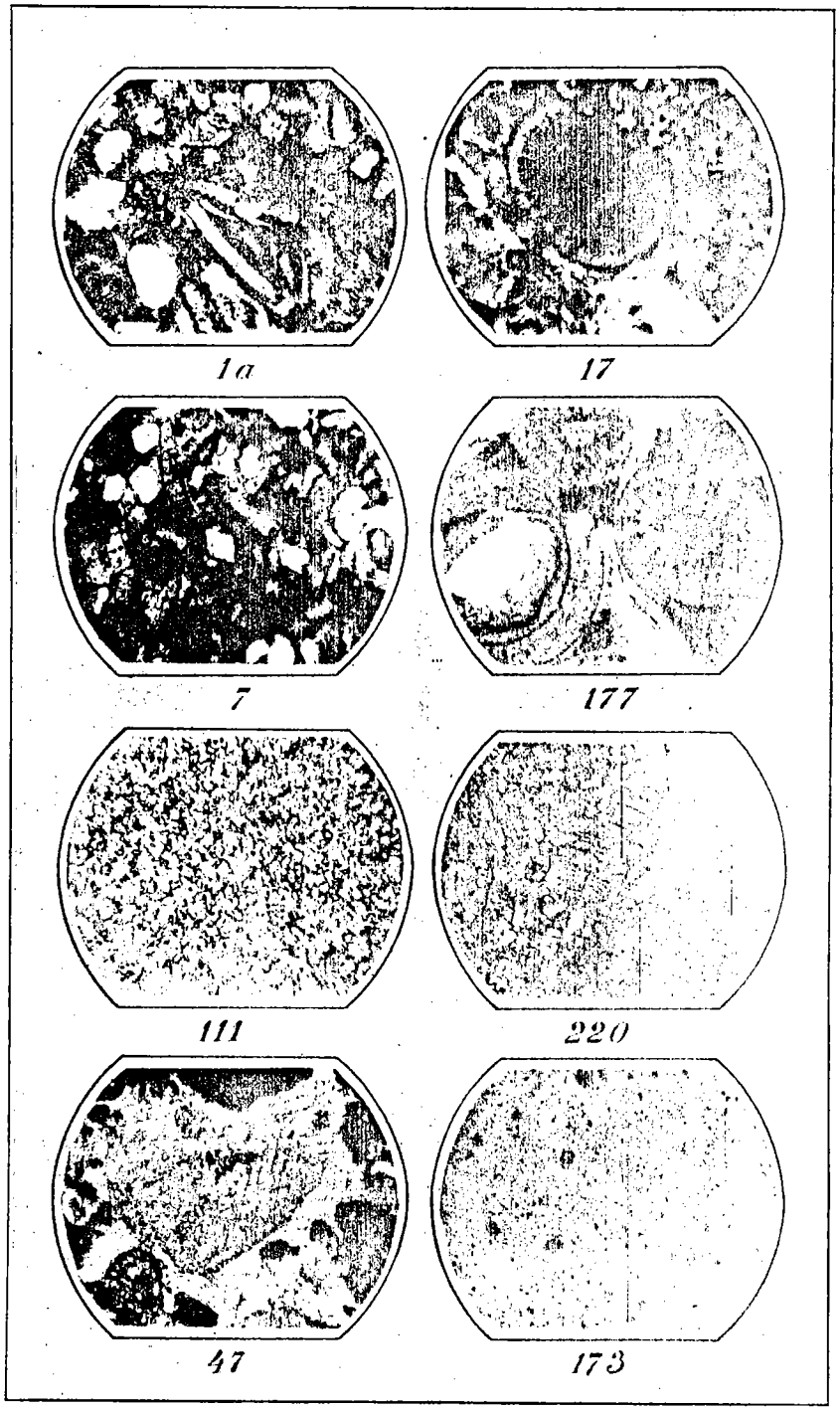
9. The thickness of the formation totals nearly 8,000 feet instead of 4,000 to 6,000 feet as at first estimated.

Photomicrographs of Microscopic Slides (*Page* 55)

The numbers correspond to those used in the detailed section. Magnification is 40 diameters in all cases.

1 A. Fossils and detrital quartz in fine grained limestone.
17. Section of a fossil.
7. Note dolomite rhomb (center of field) partially replaced by quartz.
177. Calcareous oolites. In one oolite the nucleus is quartz.
111. Mosaic of minute dolomite rhombs.
220. Coarsely crystallized dolomite.
47. Secondary growths around calcite. Note carefully the continuity of the cleavage lines.
173. Dolomite rhombs in fine grained limestone.

PLATE V



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