OKLAHOMA GEOLOGICAL SURVEY

ROBERT H. DOTT, DIRECTOR

Circular No. 26

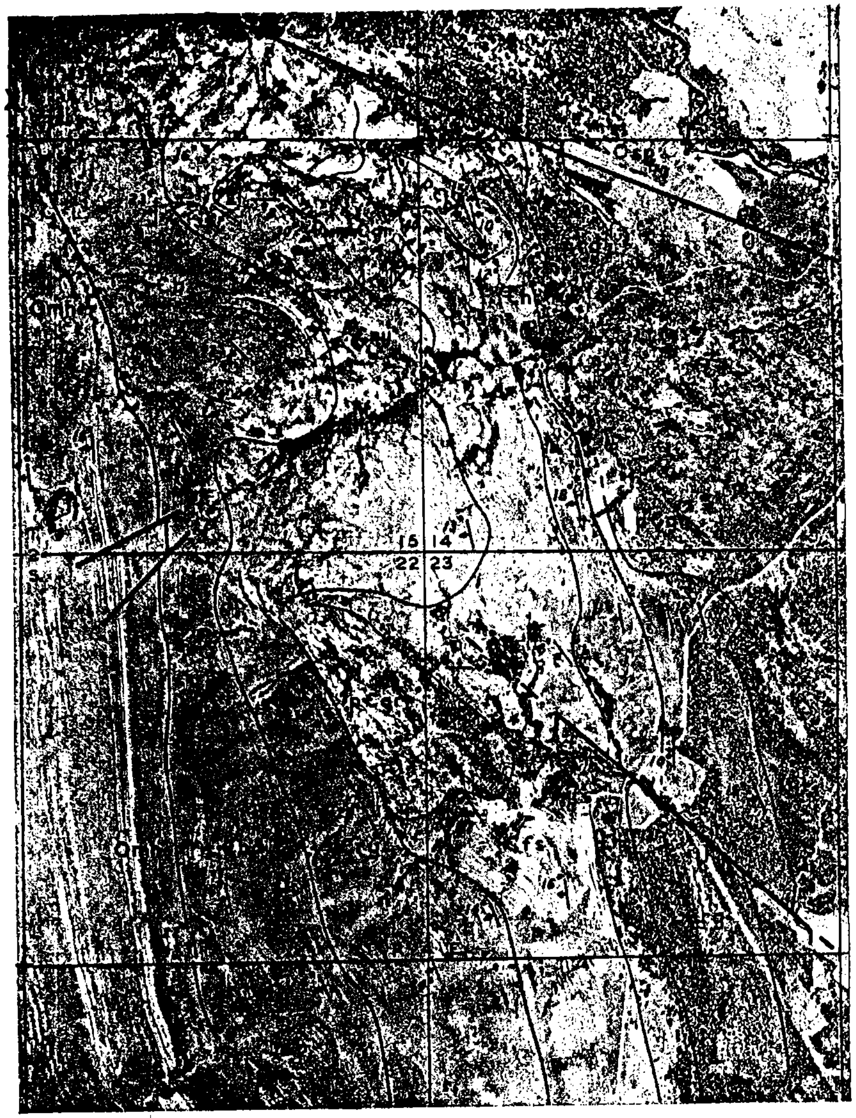
GEOLOGY AND DOLOMITE RESOURCES, MILL CREEK-RAVIA AREA, JOHNSTON COUNTY, OKLAHOMA

BY

WILLIAM E. HAM

Norman

1949



Aerial photograph showing outcrops of Cambrian strata around granite inliers in the northern part of the Mill Creek-Ravia area. For explanation of symbols see Plate I (in pocket).

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GEOLOGY AND DOLOMITE RESOURCES, MILL CREEK-RAVIA AREA, JOHNSTON COUNTY, OKLAHOMA

By William E. Ham

ABSTRACT

The Mill Creek-Ravia area covers about 15 square miles in the east-central part of the Arbuckle Mountains and contains the best known and perhaps the largest reserve of high purity dolomite in Oklahoma.

Exposed within the area is a succession, 1,875 feet thick, of Upper Cambrian sedimentary rocks, which in most places dip 10° to 20° westward and are the oldest beds in a thick sequence of Paleozoic strata that forms the west limb of the Tishomingo anticline. This anticline is 7 miles wide in the mapped area and is sharply delimited to the north and south by northwest-trending faults whose stratigraphic displacement locally exceeds 7,500 feet. The principal modification of the westward homoclinal dip is by minor faulting in the central and southern parts of the anticline. In the northern part of the area four inliers of pre-Cambrian Tishomingo granite formerly stood as islands in the Upper Cambrian sea, around which dolomites and sandstones were deposited with initial peripheral dips. About 950 feet of strata was laid down before the highest island was submerged.

The sequence of Cambrian formations consists, in ascending order above the pre-Cambrian granite, of the Reagan arkosic sandstone, Honey Creek sandy dolomite, Fort Sill limestone and dolomite, Royer dolomite, and Butterly dolomite. These formations were deposited in a marine environment, they are sparingly fossiliferous, they contain practically no chert, and all are unmetamorphosed except for local recrystallization and cementation in intensely disturbed areas.

The arkosic Reagan sandstone was derived largely from the pre-Cambrian granite and was deposited upon an irregular, eroded surface, so that its thickness varies directly with pre-Reagan topographic relief. In the central and southern parts of the mapped area the granite floor was essentially smooth and the Reagan is uniformly about 350 feet thick. In the northern part, a conspicuous granite hill that rose high above the basement floor was progressively submerged by successively higher sandstone beds, until finally it was covered by the uppermost 31 feet of the Reagan. Lithologically the

Reagan is medium-grained sandstone containing 30 percent feldspar, with a basal layer and many intraformational lentils of sandy quartz conglomerate. Glauconite and dolomite cement occur sporadically, chiefly in the upper part of the formation.

The Honey Creek formation consists of (a) a lower division of glauconitic dolomite containing about 50 percent arkosic very fine sand and silt, near the middle of which is a brachiopod zone characterized by *Billingsella* cf. *coloradoensis*, and (b) an upper division of non-sandy, non-glauconitic dolomite. These dolomite strata are equivalent to limestone at the type locality of the Honey Creek near U. S. Highway 77 in the Arbuckle anticline. The formation in the Mill Creek-Ravia area is 63 to 234 feet thick, being thinnest in the northern part of the area where buried granite highlands resulted in local shallower seas. The lower sandy division is suitable for the manufacture of rock wool.

The Fort Sill formation marks the base of the Arbuckle group and is separated from the underlying Honey Creek by an erosional unconformity. In the area of granite inliers the formation is 193 feet thick and is composed of dolomite, whereas southward from the inliers it is about 400 feet thick and consists of a lower division of thick-bedded limestone, a middle division of dolomite and dolomitic limestone, and an upper division of dolomite. The lateral gradation of limestone into dolomite was thus favored in localities where the strata are abnormally thin. Algae have contributed significantly to the building of these carbonate rocks.

The Royer formation is consistently about 550 feet thick and is composed of high purity, light-colored, coarse- to medium-crystalline dolomite. Chert is lacking and arkosic sand is rare except around granite inliers. Insoluble residue study reveals that silt aggregates and authigenic, euhedral adularia are common impurities. The upper part of this dolomite unit is equivalent to nearly all the Signal Mountain limestone in the U. S. Highway 77 section.

The youngest Cambrian formation is the Butterly dolomite. Its thickness ranges between 333 and 435 feet, the difference being the result chiefly of erratic gradation into limestone of the overlying McKenzie Hill formation of Lower Ordovician age. Arkosic sand and quartz druse in small masses occur throughout the Butterly and render it unfit for chemical use. Cream-colored, finely crystalline, laminated thin beds of dolomite constitute the distinctive lithology by which the formation can be identified.

The reserves of high purity dolomite within the Mill Creek-Ravia area are contained largely in the Royer. It crops out over about 1,400 acres and contains at least 150,000,000 tons of dolomite that is readily accessible by open pit or open face quarry methods. From

nine analyses of outcrop samples, taken to represent the stratigraphic and geographic range of the formation, it is known that the average composition is 96.86 percent theoretical dolomite, $Ca,Mg(CO_3)_2$, and 2.24 percent excess calcite, $CaCO_3$, or a total carbonate content of 99.10 percent. The calcite, present mostly in the form of radial-fibrous aggregates encrusting cavities, is a weathering product and does not occur a few feet below the surface.

Commercial production of dolomite, began in June, 1948, with the opening of a quarry in the Royer formation in the central part of the area and shipment of the stone for flux in iron ore smelting and for the manufacture of glass. The quarried stone contains 98.98 percent theoretical dolomite.

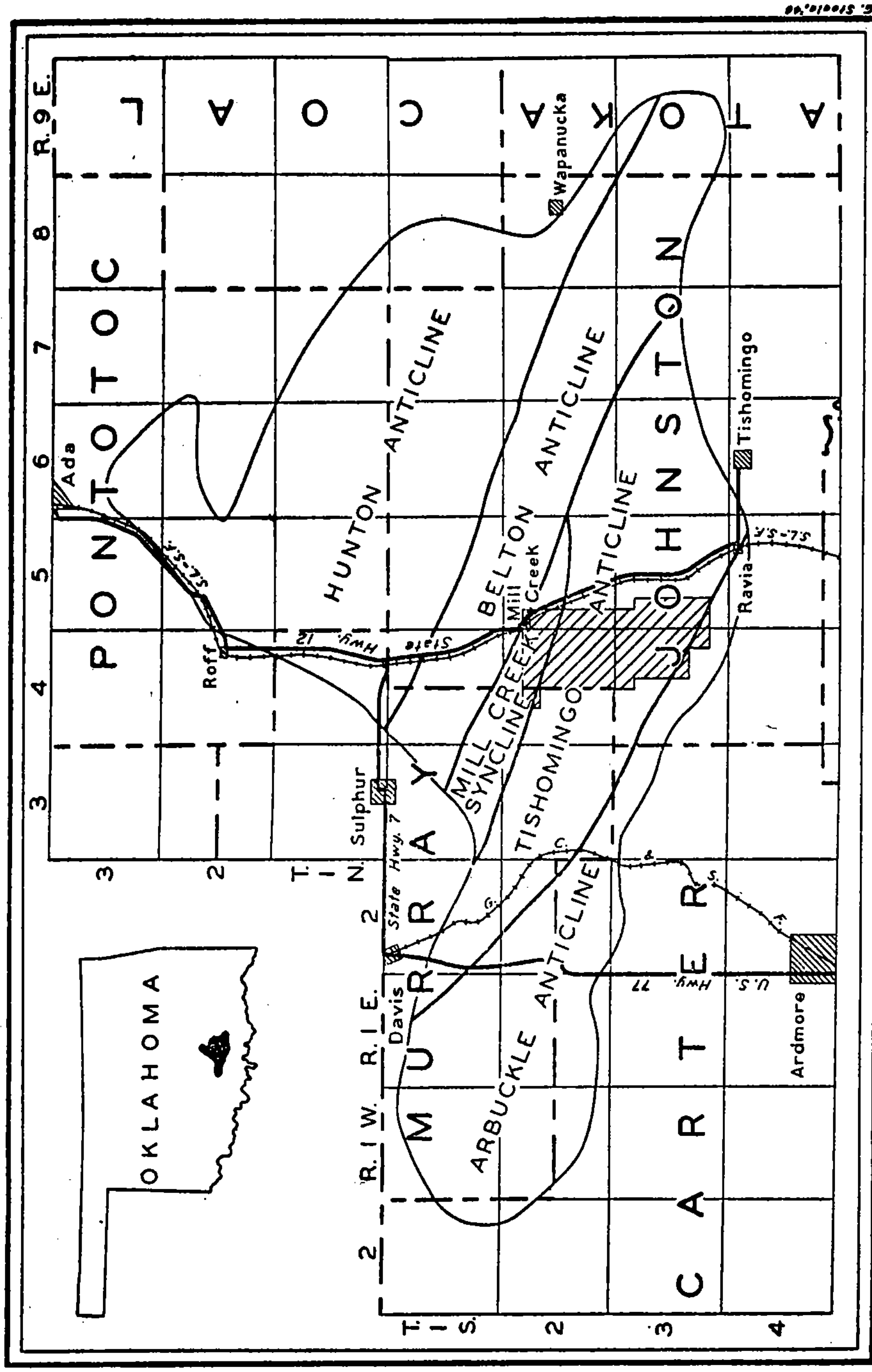


FIG. 1. INDEX MAP OF ARBUCKLE MOUNTAINS SHOWING MAJOR STRUCTURAL UNITS AND LOCATION OF MILL CREEK-RAVIA AREA.

INTRODUCTION

Purpose of report. Beginning in 1942 the Geological Survey received many requests concerning deposits of high grade dolomite in Oklahoma. These requests resulted from interest in the use of dolomite as an ore of magnesium metal, as fluxing stone for iron smelting in east Texas, and in the possibilities of using Oklahoma dolomite for glass-making and refractories.

Up to 1948 no dolomite had been quarried in the State for purposes other than railroad ballast and agricultural or structural stone, and but little information was available on the quality and extent of the known deposits. Petrological information in 1928, together with a few more recent analyses, indicated the possibility of large deposits of dolomite in the lower part of the Arbuckle limestone in the Arbuckle and Wichita Mountains. Field reconnaissance in the Arbuckle region revealed that large deposits of high-quality dolomite, accessible to railroad transportation, are centered in the vicinity of the villages of Mill Creek and Ravia, Johnston County, and this area was investigated in detail. The present report describes the geology of the Cambrian rocks in the Mill Creek-Ravia area and gives chemical analyses of high grade Royer dolomite. Included is a map of the area which shows for the first time the outcrop of the Royer and associated strata, and from which a readily accessible reserve of 150,000,000 tons of high grade dolomite is indicated.

Location of area. The area mapped for this report lies near the southern edge of the central part of the Arbuckle Mountains, in south-central Oklahoma (fig. 1). It covers, roughly, the eastern half of T. 2 S., R. 4 E., together with 3 tiers of sections along the east line of T. 3 S., R. 4 E., all in the west-central part of Johnston County. The strip is 10 miles long north-south, 1 to 3 miles wide, and includes a total of about 15 square miles. Mill Creek, Ravia, and Troy are the nearest villages and from the first two the area takes its name.

The St. Louis-San Francisco (Frisco) Railroad runs between Mill Creek and Ravia, about 2.5 miles east of the mapped area (Pl. I). A graveled highway, Oklahoma State Highways 12 and 22, parallels the railroad. A network of paved roads surrounds the area and provides easy access to the general region. From Mill Creek, by road, it is 12 miles to Sulphur, 30 miles to Ada, and 40 miles to Ardmore. It is 91 miles, airline, from the center of the area to Oklahoma City, 137 miles to Tulsa, Oklahoma, and 120 miles to Dallas, Texas.

The roads into and within the area itself are those used chiefly by ranchers. The best road leads from Mill Creek to the South and Daube ranch-houses. This road is graded, drained, and easily passable except immediately after heavy rains. Another is a well-marked trail entering the area from the north, from the Farm-Market road 3.0 miles west of Mill Creek. Also there are many secondary trails, made by the ranchers and used to truck cattle feed in the winter. There are no roads leading eastward toward Ravia from the southern part of the area.

In June, 1948, a narrow-gauge rail and paralleling truck road were completed by the Rock Products Manufacturing Company, Ada, Oklahoma, from a siding on the Frisco Railroad 1 mile north of Troy, to outcrops of the Royer dolomite in the NW¼ SW¼ sec. 36, T. 2 S., R. 4 E. The distance by rail is 3 miles. With completion of these roads and the opening of a quarry at the rail terminus, the high-grade Royer dolomite is now being produced and is currently being shipped as fluxing stone to the blast furnace at Daingerfield, Texas.

Topography. The typical surface expression of the Arbuckle Mountains is a peneplaned upland surface developed on the tilted and eroded edges of the sedimentary rocks of the region, and dissected to slight or moderate relief by small streams. On a small scale this topography is characteristic of the Mill Creek-Ravia area. The dominant feature is a broad upland, sloping almost imperceptibly from a maximum altitude of about 1,150 feet in the northern part of the area to 900 feet at its southern edge.[1] The

[1] *U. S. Geol. Survey, Topographic Map,* Tishomingo Quadrangle, Oklahoma, 1903.

lowest altitudes are along the channel of Mill Creek, which descends from about 950 feet at the north edge of the map to 675 feet at the south edge. Mill Creek is a perennial stream flowing near the east margin of the Paleozoic sedimentary rocks and emptying into Washita River 3 miles south of the area. Many spring-fed streams flow eastward to Mill Creek from the upland divide. These streams have cut into the broad margin of the divide several widely flaring valleys 100 or more feet deep. Many of the smaller streams and ravines have narrow, V-shaped valleys in which there are numerous small falls and rapids. The outcrops of Royer dolomite are located along this dissected margin of the upland and many natural quarry sites have been formed.

The upland is almost devoid of trees and has many bare rock outcrops of limestone and dolomite, so that it is locally known as the "rock prairie". There is a very thin covering of soil, except in the swales or meadows where prairie grasses thrive. The land is used mainly for pasturing beef cattle and is sparsely settled by ranchers, there being only three ranch houses in the mapped area. The area covers parts of the Penner, South, Chapman, and Daube ranches.

The "rock prairie" extends about 3 miles west of the mapped area to the valley of Oil Creek, where the topography is more rugged, there is less grass for pasture, and good roads or trails are lacking.

In the eastern part of the area oak and hickory trees grow in profusion on the outcrop of the Reagan sandstone, Honey Creek sandy dolomite, and granite. The sedimentary beds generally form an east-facing escarpment, increasing in height southward along Mill Creek, that overlooks the rolling granite plain. On the granite plain there is little relief except for one hill that forms a prominent landmark about 100 feet high in the SE¼ sec. 14, T. 2 S., R. 4 E. In the same general locality, in parts of sections 14, 15, 22, and 23, two small topographic basins have been eroded into Cambrian dolomites on the upland divide, exposing the peaks of buried granite hills.

Previous work. The first detailed geological investigations of the Arbuckle Mountains were those of J. A. Taff,[2] published in 1902, 1903, and 1904. Taff's Tishomingo Folio (1903) covers the area of the present report and its map, although somewhat generalized, is remarkably good, showing accurately many of the contacts and faults found by the present writer in his later work with aerial photographs.

The principal geologic maps published since Taff's that show the Mill Creek-Ravia area are by Reeds[3] and Decker.[4] Both followed Taff's geology without revision, except that Decker's map erroneously shows Reagan sandstone surrounding the granite inlier in secs. 22 and 23, T. 2 S., R. 4 E. Decker has, however, measured and described the stratigraphic section of the Arbuckle limestone in this area.[5]

Considerable information has been published on the Arbuckle limestone, its subdivision, and the position within it of the Cambrian-Ordovician boundary. Most of the information relates to other parts of the Arbuckle Mountains or to the Wichita Mountains but is considered in the following discussion of stratigraphy.

The occurrence of dolomites in the Arbuckle limestone was revealed first by Taff,[6] who stated: "A sample from approximately the middle of the formation (Arbuckle limestone) yielded 29.4 per cent of lime and 19.2 per cent magnesia, showing it to be a nearly normal dolomite. A sample from the lower part of this dolomitic zone showed contents of 33.1 per cent of lime and 14.3 per cent of magnesia."

[2] Taff, J. A., *U. S. Geol. Survey Geol. Atlas*, Atoka Folio (No. 79) 1902.
Taff, J. A., *U. S. Geol. Survey Geol. Atlas*, Tishomingo Folio (No. 98) 1903.
Taff, J. A., "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma": *U. S .Geol. Survey Prof. Paper* 31, 1904 (Reprinted as *Okla. Geol. Survey Bull.* 12, 1928.)

[3] Reeds, C. A., "A Report on the Geological and Mineral Resources of the Arbuckle Mountains, Oklahoma": *Okla. Geol. Survey Bull.* 3, Plate XXIV, 1910.

[4] Decker, C. E., and Merritt, C. A., "The Stratigraphy and Physical Characteristics of the Simpson Group": *Okla. Geol. Survey Bull.* 55, Plate I, 1931.

[5] Decker, C. E., "Progress Report on the Classification of the Timbered Hills and Arbuckle Groups of Rocks, Arbuckle and Wichita Mountains, Oklahoma": *Okla. Geol. Survey Circular* 22, pp. 39-42, 1939.

[6] Taff, J. A., "Portland Cement Resources of Indian Territory": in *U. S. Geol. Survey Bull.* 243, p. 145, 1905.

Decker, on the basis of field examination, and Merritt, after microscopic study of samples collected by Decker, reported several hundred feet of calcite-free dolomite in the lower part of the Arbuckle limestone;[7] and preliminary chemical analyses of samples collected from the Mill Creek-Ravia area indicated the presence of high quality dolomite in the Royer.[8] Additional analyses of the Royer dolomite from this area appear in later publications.[9]

Present investigations. The writer began field work in the Mill Creek-Ravia area in the fall of 1943 and continued intermittently for a total of about 3 months until the project was completed in December, 1945. Aerial photographs (scale, about 3.2 inches per mile) were used for mapping the formations and by using stereoscopic pairs it was possible to obtain geologic details as well as accurate horizontal control.

Besides the mapping, many representative samples of high grade dolomite were collected for chemical and mineralogical analysis and three detailed stratigraphic sections of the Cambrian beds were measured and sampled for insoluble residue study. A brief description of the insoluble residues is included in the present report. This study is part of a broad, comprehensive investigation of the Arbuckle limestone as exposed in the Arbuckle and Wichita Mountains, and found in wells drilled for oil and gas in Oklahoma. It was undertaken in collaboration with the Fuels Section of the U. S. Geological Survey, under its expanded program of regional geologic studies for oil and gas, initiated in 1943. One map and one chart have been issued.[10]

[7] Decker, C. E., and Merritt, C. A., "Physical Characteristics of the Arbuckle Limestone": *Okla. Geol. Survey Circular* 15, pp. 34-37, 51-53, 1928.

[8] Beach, J. O., and English, S. G., "Dolomite and Magnesian Limestone (Oklahoma)": *Okla. Geol. Survey Mineral Rept.* 6, 1940.

[9] Burwell, A. L., "The Possibility of Magnesia from Oklahoma Oil Field Brines": *Okla. Geol. Survey Mineral Rept.* 14, Table IV, 1942.
Burwell, A. L., and Ham, W. E., "New Facts Regarding Oklahoma Raw Materials for the Ceramic Industries": *Bull. Am. Ceramic Soc.*, Vol. 24, no. 8, pp. 293-295, 1945.

[10] Ireland, H. A., and Wishart, A. P., "Correlation and Subdivision of Subsurface Lower Ordovician and Upper Cambrian Rocks in Northeastern Oklahoma": *U. S. Geol. Survey, Oil and Gas Investigations, Preliminary Chart* 5, 1944.
Ireland, H. A., and Warren, J. H., "Maps of Northeastern Oklahoma and Parts of Adjacent States Showing the Thickness and Subsurface Distribution of Lower Ordovician and Upper Cambrian Rocks Below the Simpson Group": *U. S. Geol. Survey Oil and Gas Investigations, Preliminary Map* 52, 1946.

STRUCTURAL GEOLOGY

The Arbuckle Mountain region is composed structurally of five major elements, each of which is dominantly anticlinal or synclinal. The five elements, as originally named by Taff, listed from southwest to northeast, are: Arbuckle anticline, Tishomingo anticline, Mill Creek syncline, Belton anticline, and Hunton anticline (fig. 1). Each structural element is separated from adjoining ones by major faults that strike uniformly N. 60°-70° W., and the traces of these faults in most places are rather straight, indicating high angles of dip. Many faults and structural units of lesser magnitude and of diverse orientation occur within the major elements.

As interpreted by Dott, the first deformation regionally affecting the Arbuckle Mountain region began in early Pennsylvanian time, forming the broad anticlinal and synclinal trends.[11] More intense deformation in late Pennsylvanian time further compressed the beds into close folds, some of which were overturned, and produced overthrust faults. Evidence for late Pennsylvanian overthrusting near Sulphur has been presented in two recent publications.[12]

TISHOMINGO ANTICLINE

The Tishomingo anticline, the central portion of which constitutes the area of the present report, is a northwest-trending folded fault block containing in its eastern part extensive outcrops of pre-Cambrian granite and, in its western part, a thick sequence of Cambrian through Mississippian sedimentary rocks that dip generally westward away from the granite. Only the core and west limb of the anticline are known in surface outcrops, the rest of the fold being covered by a veneer of Trinity sandstone (Lower Cretaceous).

The fault block in most places is upthrown with respect to structural units on either side, having stratigraphic displacement

11 Dott, R. H., "Overthrusting in Arbuckle Mountains, Oklahoma": *Bull. Am. Assoc. Petrol. Geol.*, Vol. 18, No. 5, pp. 567-602, 1934.

12 Lehman, R. P., "Thrust Faulting in Arbuckle Mountains, Oklahoma": *Bull. Am. Assoc. Petrol. Geol.*, Vol. 29, pp. 187-209, 1945.
Ham, W. E., "Geology and Glass Sand Resources, Central Arbuckle Mountains, Oklahoma": *Okla. Geol. Survey Bull.* 65, pp. 41-48, 1945.

of at least 7,500 feet near Mill Creek, where pre-Cambrian granite is in contact with middle Ordovician (Simpson) beds of the Mill Creek syncline. Displacement of similar magnitude is indicated along the south fault of the block near Ravia.

Within the Tishomingo anticline in the mapped area the structure is homoclinal and is characterized by westward dip ranging generally between 10° and 20°. In the northern part of the area Cambrian strata have peripheral dips around granite inliers but the dips are not the result of tectonic deformation.

The principal modification of the homoclinal structure is by faulting. Faults are most abundant in the central faulted area of the anticline, where they offset beds a maximum distance of about 0.5 mile and have a throw of 400 feet or less. These faults are high-angle and probably normal, developed from stresses set up in the axial part of the anticline.

Two northwest-trending faults of considerably greater magnitude and evidently of different origin are found in the southern third of the Mill Creek-Ravia area. One of these is a branch of the south fault of the Tishomingo anticline. It trends northwest through the central part of sec. 30, T. 3 S., R. 5 E. and presumably dies out as a strike fault or bedding plane fault in sec. 24, T. 3 S. R. 4 E. The stratigraphic displacement is greatest, about 6,500 feet, in the SE¼ sec. 30 and adjoining part of sec. 31, where pre-Cambrian granite is in contact with Oil Creek limestone (Simpson group) in a small graben of complex structure. In the N½ sec. 30 the outcrop of north-striking Cambrian formations in the main part of the Tishomingo anticline is abruptly terminated against vertical beds of upper Arbuckle age.

A second fault that trends northwest through secs. 12 and 13, T. 3 S., R. 4 E. and secs. 18 and 19, T. 3 S., R. 5 E., may be a branch from the south fault of the anticline, but cannot be traced through an exposure of granite that separates the known fault traces. In the SW¼ sec. 18, Fort Sill limestone is in fault contact with granite, indicating stratigraphic displacement of at least 700 feet. Northwestward from this locality the displacement decreases and the fault dies out along the strike of the Honey Creek formation in sec. 12. Steeply dipping and overturned beds are found along this fault in sec. 13.

STRATIGRAPHY

GENERAL STATEMENT

The exposed rocks in the Mill Creek-Ravia area consist principally of a sequence of Upper Cambrian and Lower Ordovician sedimentary rocks, the base of which rests unconformably upon an irregular surface of pre-Cambrian igneous rock. The igneous rock, named the Tishomingo granite, apparently was a land mass during late pre-Cambrian time as well as during the early and middle epochs of the Cambrian period, for the Upper Cambrian Reagan sandstone is the oldest sedimentary rock deposited on it in the Arbuckle Mountains. No deposits of Lower or Middle Cambrian age are known in Oklahoma.

The Cambrian deposits of the mapped area are 1,875 feet thick and consist of a basal sandstone followed upward by sandy dolomite, limestone, and finally a thick unit of dolomite. The overlying Lower Ordovician beds are 4,400 feet thick and consist principally of limestone.

With the exception of the basal sandstone, the Upper Cambrian and Lower Ordovician strata of the Arbuckle Mountains were grouped together by Taff in 1902[13] as the Arbuckle limestone, a term which has gained wide acceptance in other areas, particularly in Oklahoma and Kansas where rocks of this age produce oil and gas. Taff also gave the name Reagan to the basal sandstone.[14]

Later modifications and subdivisions have expanded the nomenclature very considerably. Ulrich in 1911 and 1932[15] applied the name Honey Creek to glauconitic limestones that had been assigned by Taff to the top of the Reagan sandstone, and the fossiliferous Honey Creek formation has since been found to have wide distribution in the Arbuckle and Wichita Mountains. Decker in

13 Taff, J. A., *U. S. Geol. Survey Geol. Atlas*, Atoka Folio (No. 79) p. 3, 1902.
14 Taff, J. A., *op. cit.*, and *U. S. Geol. Survey Geol. Atlas*, Tishomingo Folio (No. 98), 1903.
15 Ulrich, E. O., "Revision of the Paleozoic Systems": *Bull. Geol. Soc. Am.*, Vol. 22, p. 624, 1911.
.............................., "Preliminary Description of the Honey Creek, Fort Sill, Royer and Signal Moutain Formations of Oklahoma": *Bull. Geol. Soc. Am.*, Vol. 43, no. 3, pp. 742-743, 1932.

1939[16] elevated the Arbuckle limestone to rank of group and divided it into eight principal formations, four in the Cambrian and four in the Ordovician, and combined the Reagan and Honey Creek into the Timbered Hills group. Frederickson in 1942[17] classified the four Cambrian formations of the Arbuckle limestone into the Blue Creek Canyon group. Thus the Cambrian beds as now recognized are placed into two groups, the Timbered Hills group below, consisting of the Reagan and Honey Creek formations, and the Blue Creek Canyon group above, consisting in ascending order of Fort Sill limestone, Royer dolomite, Signal Mountain limestone, and Butterly dolomite. It is with these Cambrian formations that the present report on the Mill Creek-Ravia area is concerned.

CAMBRIAN STRATA

Within the mapped area the two lower Cambrian formations offer no difficulties of mapping and correlation. The Reagan sandstone is easily recognized by its lithology and position on the pre-Cambrian granite. No fossils have been found in the sandstone but it can be unmistakably identified by lithology alone, as no other similar arkosic sandstones occur in the Lower Paleozoic succession of the Arbuckle Mountains.

The Honey Creek formation is a mappable unit of dolomite that is sandy and glauconitic in its lower part. Lithologically it is different from the type Honey Creek glauconitic limestone of the western Arbuckle Mountains (Arbuckle anticline), and the difference is accentuated in the Mill Creek-Ravia area where solution locally has removed dolomite from the lower sandy beds so that on the outcrop the strata appear to be sandstones. Ulrich[18] correlated

16 Decker, C. E., "Progress Report on the Classification of the Timbered Hills and Arbuckle Groups of Rocks, Arbuckle and Wichita Mountains, Oklahoma": *Okla. Geol. Survey Circular* 22, pp. 15-16, 1939.
Decker, C. E., "Two Lower Paleozoic Groups, Arbuckle and Wichita Mountains, Oklahoma": *Bull. Geol. Soc. Am.*, Vol. 50, pp. 1311-1322, 1939.
17 Frederickson, E. A., "Cambrian Stratigraphy of the Arbuckle and Wichita Mountains, Oklahoma": *University of Wisconsin Unpublished Ph. D. Dissertation*, 1942.
18 Ulrich, E. O., "Preliminary Description of the Honey Creek, Fort Sill, Royer, and Signal Mountain Formations of Oklahoma": *Bull. Geol. Soc. Am.*, Vol. 43, No. 3, pp. 742-747, 1932.
Ulrich, E. O., and Cooper, G. A., "Ozarkian and Canadian Brachiopoda": *Geol. Soc. Am. Special Paper* No. 13, Plate 58, 1938.

these sandy beds with the Cap Mountain formation of Texas. Correlation of these beds with the Honey Creek could not be confidently made until the discovery by the writer of brachiopods and trilobites that are characteristic of the Honey Creek elsewhere in the Arbuckle and Wichita Mountains. The most abundant and widespread fossils are brachiopods that occur in a conspicuous bed 68 feet above the base and 165 feet below the top of the sequence, in well-exposed outcrops in the NE¼ sec. 1, T. 3 S., R. 4 E., as well as in adjoining sections to the north and south. The bed contains chiefly *Billingsella* and *Eoorthis*. The *Eoorthis* was identified by C. E. Decker as very close to or identical with *E. remnicha,* a guide fossil in the Honey Creek, and the *Billingsella* was identified by P. E. Cloud, Jr, as B. cf. *coloradoensis*. According to E. A. Frederickson, *B. coloradoensis* occurs in the Honey Creek in the Wichita Mountains.

Trilobite fragments also are locally present in leached sandy strata below and above the brachiopod zone. Several well-preserved specimens, however, were found on weathered sandstone slabs that were lying loose on a modified dip slope and whose position in the sequence is not known. These were examined by Frederickson, who states that the forms are *Taenicephalus* and *Crepicephalus,* both of which are characteristic Honey Creek fossils.

Overlying the Honey Creek formation are Cambrian strata of the Arbuckle group, consisting of about 1,350 feet of carbonate rocks. The sequence is similar to but does not conform entirely with the succession west of U. S. Highway 77, which has been considered standard for the Arbuckle Mountains. The Highway 77 succession, measured by the writer in September, 1944, and shown graphically in fig. 2, consists in ascending order of the following formations: Fort Sill limestone, 126 feet thick; Royer dolomite, 734 feet; Signal Mountain limestone, 365 feet; and Butterly dolomite, 297 feet. This section is suitable for a standard because the formations, consisting of thick units of limestones alternating with thick units of dolomite, are easily recognized by lithology and stratigraphic position. Fossils served to correlate the limestone units with at least certain parts of the Fort Sill and Signal Mountain formations, which have their respective type localities in the Wichita

Mountains; but the two dolomite formations, which are not typically developed in the Wichitas, were named from the good exposures of the Highway 77 section.

In the Mill Creek-Ravia area, on the other hand, the fossiliferous limestone formations, which elsewhere serve as a key to placing the unfossiliferous dolomite formations in their proper stratigraphic position, have graded entirely or partly into dolomite. This results in a thick sequence of dolomite in which limestone equivalents are difficult or impossible to recognize in the field. The sequence can be subdivided and mapped, however, by observing details of lithology and particularly by distinguishing one kind of dolomite from another. It was found that three mappable units may be recognized: (a) a lower unit of limestone that grades laterally into impure dolomite, (b) a middle unit of high-purity dolomite, and (c) an upper unit of rather impure dolomite. These units are here called Fort Sill formation, Royer dolomite, and Butterly dolomite, with which formations of the Highway 77 section they are most nearly equivalent in lithology and stratigraphic position. The correlations, based on a comparison of detailed measured sections, are shown in fig. 2.

That the gradation of limestone into dolomite is a facies change, and not the result of unconformable stratigraphic relations, is indicated by the fact that the Cambrian beds of the Arbuckle group in the Arbuckle Mountains show little deviation from a total thickness of 1,400 feet; and this is substantiated by the conclusions of earlier investigators, who found little physical or paleontologic evidence to suggest major unconformities within Cambrian strata of the Arbuckle and Wichita Mountains.

The probability that the limestones grade into dolomite of equivalent age also is strengthened by the knowledge that such stratigraphic relations are well known from many examples throughout the world. Limestone-dolomite facies have been demonstrated recently by detailed mapping of the "Ellenburger limestone" of central Texas,[19] the formations there being of the same lithologic

[19] Cloud, P. E., Jr., Barnes, V. E., and Bridge, J., "Stratigraphy of the Ellenburger Group in Central Texas—A Progress Report": *University of Texas Publication* 4301, pp. 133-161, 1945.

types and the same general age as the Arbuckle Mountain beds here discussed. Within the Mill Creek-Ravia area specific evidence is furnished by the Fort Sill formation, which grades along strike from limestone into dolomite, and where, in one locality, the gradation is so abrupt that it may be observed directly by walking beds a few hundred feet. The Honey Creek formation is likewise a well-authenticated example, being limestone in the western part of the Arbuckle Mountains and dolomite in the eastern part. The lateral passage of limestone into dolomite is in fact very common within all carbonate rock facies of Cambrian strata in the Arbuckle Mountains.

Correlation with the U. S. Highway 77 section. The correlation from measured sections between the Tishomingo anticline and Highway 77 of the Arbuckle anticline are shown in fig. 2. The datum for correlation is an horizon in the McKenzie Hill formation, at the base of a distinctive sequence of conglomeratic limestone containing porous, tripolitic chert in reticulate masses and nodules. Graptolites were found in this sequence in the Mill Creek-Ravia area by C. E. Decker, who has also found them in the same stratigraphic position and in similar lithology at the Highway 77 section. In the mapped area this sequence crops out in a conspicuous low ridge, easily identified in the field.

The Butterly dolomite as mapped in the Tishomingo anticline correlates in stratigraphic position as well as in details of lithology with the Butterly near its type section on Highway 77. The base of this formation, which was mapped at the base of the lowest bed of laminated, cream-colored dolomite, and which appears to be a reliable marker, is correlated with the base of the Butterly along U. S. Highway 77. The thickness of the formation also is reasonably constant in spite of the fact that its contact with the overlying McKenzie Hill limestone is erratically gradational. Although composed in part of indistinctive coarse- and medium-crystalline dolomite, the Butterly is characterized lithologically by thin beds of laminated, cream-colored dolomite and small aggregates of quartz druse, both of which seem to be restricted mainly to this formation in the two areas.

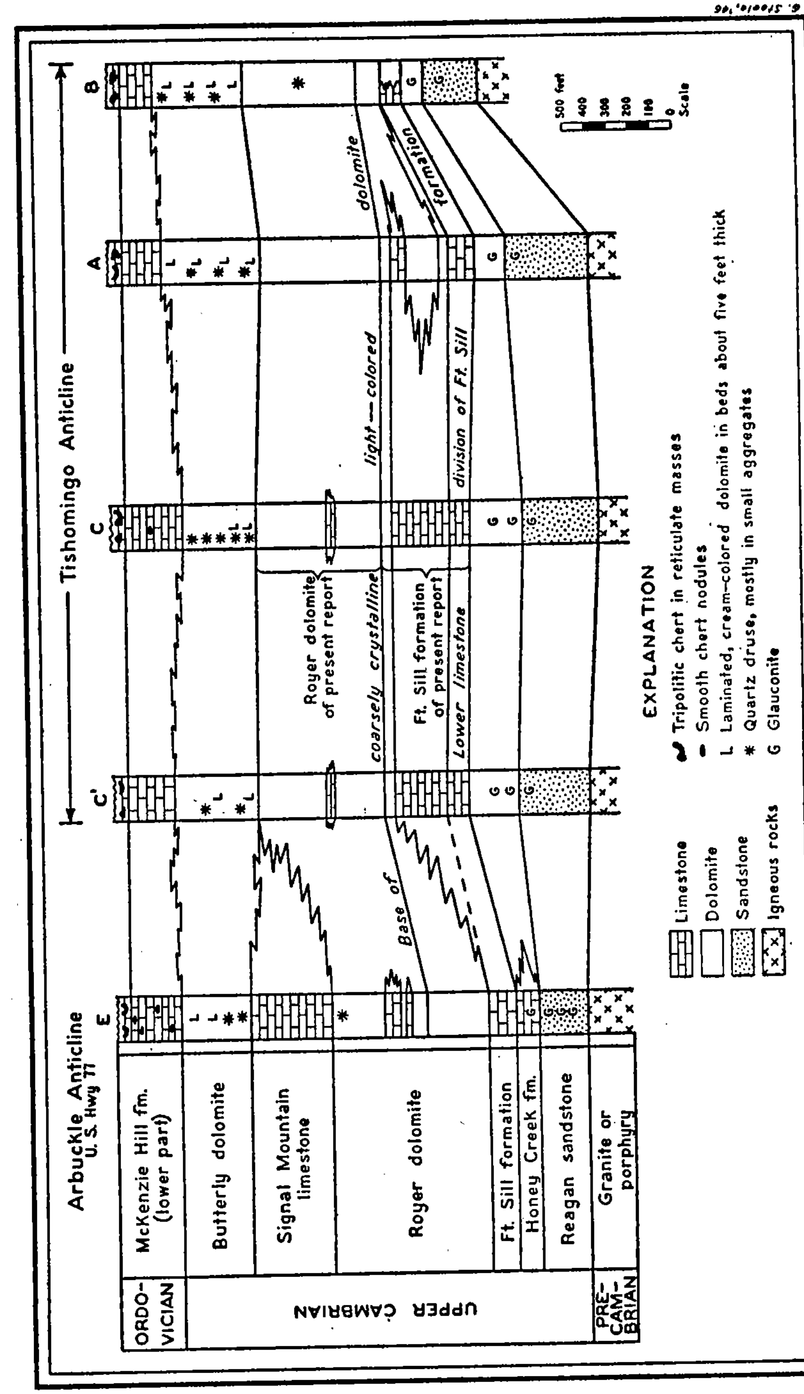


FIG. 2. CORRELATION OF MEASURED OUTCROP SECTIONS OF CAMBRIAN STRATA IN THE TISHOMINGO ANTICLINE WITH THE SECTION ON U. S. HIGHWAY 77.

A. S½ sec. 22 and S½ sec. 23, T. 2 S., R. 4 E.

B. Secs. 14 and 15, T. 2 S., R. 4 E.

C. N½ sec. 1 and NE¼ sec. 2, T. 3 S., R. 4 E.; SW¼ sec. 36, T. 2 S., R. 4 E.; and NW¼ sec. 6, T. 3 S., R. 5 E.

C'. NW¼ sec. 13 and NE¼ sec. 14, T. 3 S., R. 4 E., and N½ sec. 30, T. 3 S., R. 5 E.

The term Fort Sill is used in the Tishomingo anticline in a slightly broader interpretation than was originally given. It includes limestone and dolomite of equivalent age. This usage conforms essentially to the established concept, however, for over most of the mapped area the Fort Sill formation is predominantly limestone and is the basal stratigraphic unit of the Arbuckle group, underlain by the Honey Creek formation and overlain by the Royer dolomite.

Owing to gradation of limestone into dolomite between the Arbuckle anticline and the Tishomingo anticline, only the lower part of the beds mapped with the Fort Sill for this report, namely, the lower limestone division, is equivalent to the Fort Sill limestone on Highway 77. The middle and upper parts, which locally contain yellowish-gray, thin-bedded dolomite, correlate with similar lithology in the lower part of the Royer formation on Highway 77.

The sequence of strata lying above the Fort Sill formation and below the Butterly dolomite in the Tishomingo anticline is composed almost exclusively of light-colored, mostly coarsely crystalline, high-purity dolomite. These features identify it as a mappable unit and at the same time distinguish it from the thinner bedded, yellowish dolomite beds in the underlying Fort Sill formation, and from the cream-colored and siliceous dolomites of the overlying Butterly. Its potential economic value as a source of large quantities of high-purity dolomite makes it the most important unit mapped for the present report. This unit is here mapped as the Royer dolomite.

It is evident from the measured sections in fig. 2 that the Royer dolomite of the Tishomingo anticline correlates only in part with the Royer of the Highway 77 section, where the type locality was established by Decker. As a result of limestone-dolomite facies, the Royer in the mapped area (a) represents in its upper part the time equivalent of nearly all the Signal Mountain limestone along Highway 77, and (b) in its lower part it is equivalent in age and type of dolomite to the upper part of the Royer at the type locality. The upper part of the Royer at the type locality contains mostly light-colored, coarsely crystalline dolomite whose base may be correlated satisfactorily with the base of the Royer as mapped in the Tishomingo anticline.

Cambrian-Ordovician boundary. The position of the Cambrian-Ordovician boundary in the Arbuckle Mountains probably lies within or near the top of the Butterly dolomite. At its type section on the Chapman Ranch, immediately west of U. S. Highway 77, the Butterly dolomite is overlain by the McKenzie Hill limestone which contains, according to Bridge, a Lower Ordovician fauna (Van Buren and Gasconade of the Ozark region in Missouri). The underlying Signal Mountain limestone contains "... a typical Upper Cambrian assemblage characterized by the genera *Eurekia, Stenopilus, Euptychaspis,* and *Plethometopus*".[20] The exact position of the Cambrian-Ordovician boundary lies at some unknown horizon within the intervening unfossiliferous sequence, which includes the Butterly dolomite. As this horizon could not be determined from the available evidence, the Cambrian-Ordovician boundary was arbitrarily placed by Bridge at the top of the Butterly.

It is now known that the top of the Butterly is gradational into limestone along strike and therefore that the top of this formation is not everywhere of the same age. In the Tishomingo anticline the top of the Butterly ranges through slightly more than 100 feet of strata, and detailed work elsewhere may show an even greater range.

The Butterly dolomite in the Mill Creek-Ravia area is approximately the time equivalent of the Butterly at the type locality (fig. 2) and, in accordance with Bridge's interpretation, the Cambrian-Ordovician boundary is placed at the gradational contact between the Butterly dolomite below and the McKenzie Hill limestone above.

Post-Cambrian Strata

Other sedimentary rocks which crop out near the margins of the mapped area, mostly Ordovician formations of the Arbuckle

20 Bridge, J., "Position of Cambrian-Ordovician Boundary in Section of Arbuckle Limestone Exposed on Highway 77, Murray County, Oklahoma": *Bull. Am. Assoc. Petrol. Geol.*, Vol. 20, p. 983, 1936.

group, bear little relation to the purpose of this report and accordingly they were not mapped or investigated in detail. The McKenzie Hill and Cool Creek formations, for example, crop out westward from the Butterly dolomite; and the Kindblade and West Spring Creek limestones were found south of the south fault of the Tishomingo anticline in secs. 23 and 25, T. 3 S., R. 4 E.

Formations of the Middle Ordovician Simpson group, together with younger beds, lie in the Mill Creek syncline north of the mapped area and in the small, down-dropped fault block near the SW cor. sec. 29, T. 3 S., R. 5 E. The fault block also contains outcrops of dark-colored fissile shales with siderite concretions belonging to the Springer formation (Lower Pennsylvanian).

CAMBRIAN SYSTEM

Reagan Sandstone

The term Reagan sandstone as used in this report is applied to a unit of arkosic sandstone and conglomerate 31 feet to 381 feet thick, that lies with an unconformity of great magnitude on pre-Cambrian granite and is overlain with sharply defined contact by the Honey Creek dolomite.

Distribution. The outcrop of the Reagan sandstone in this area is a series of disconnected narrow bands that trend north to northwest for about 9 miles across the Tishomingo anticline. The outcrop is terminated abruptly on the north and south by major northwest-trending faults. Whereas the normal outcrop width is 500 to 800 feet, the range is 0 to 1,700 feet, these extremes resulting chiefly from transverse faulting within the anticline. This faulting and its accompanying drag folding, besides changing the trend of the different outcrop bands, has displaced and offset the beds a maximum distance of 1 mile; it has caused omission of outcrop in the SW¼ sec. 18 T. 3 S., R. 5 E., where the Reagan has been upthrown and completely eroded; and it has caused narrow outcrop width in sec. 13, T. 3 S., R. 4 E., and sec. 36, T. 2 S., R. 4 E., where the dips are abnormally steep (Pl. I).

The differences in outcrop width that are well shown in secs. 14 and 23, T. 2 S., R. 4 E. are related solely to differences in thickness of the Reagan formation as originally deposited on the irregular granite surface.

Thickness. The Reagan sandstone is consistently about 350 feet thick through the southern 7 miles of the Mill Creek-Ravia area and it is remarkably inconstant in the northern 1.5 miles, where the formation ranges from 31 feet to 289 feet within a distance of 1,000 feet along the strike. The irregularities in thickness are owed chiefly to the irregular configuration and moderately strong relief of the granite floor upon which the Reagan was deposited. Taff in his earlier work had gained this concept, stating: "The Reagan sandstone is of variable thickness, due to its having been deposited on the eroded and uneven surface of the granite. . . The thinning is due to the loss of successive beds from the base upward. In its thinnest part only the uppermost calcareous beds are present."[21]

Measurements made by the writer in the area under discussion show that the formation is 325 feet thick in sec. 30, T. 3 S., R. 5 E., at the southern edge of the Tishomingo anticline, and that it maintains nearly the same thickness northward for 4 miles to sec. 6, T. 3 S., R. 5 E. and sec. 1, T. 3 S., R. 4 E., (measured section C), where it is 348 feet. Between measured section C and a locality 2.5 miles northward, along the south line of sec. 23, T. 2 S., R. 4 E., the formation increases in thickness to 381 feet, this being the maximum thickness of the Reagan in the mapped area. Nearly 1 mile north, in the S½ NW¼ NE¼ of the same section, the formation is 289 feet thick. At the N¼ cor. sec. 23, and again near the center of sec. 14, T. 2 S., R. 4 E., the Reagan is only 31 feet thick; and at the northern edge of the Tishomingo anticline, in the north-central part of sec. 14, it is 251 feet thick.

Character. The Reagan is a sandstone formation composed principally of quartz grains with irregular distribution of pink feldspar and glauconite. It is poorly sorted and poorly cemented except for local zones indurated by quartz cement that presumably was deposited from circulating ground waters. Bedding surfaces in general are obscure, irregular, or cross-laminated, although locally

21 Taff, J. A., *U. S. Geol. Survey Geol. Atlas*, Tishomingo Folio (No. 98), p. 3, 1903.

the beds are evenly stratified and well defined (Pl. II). The color is predominantly buff but ranges through different shades of brown and red. It is non-calcareous in most exposures, the only notable exception being a local pink dolomitic sandstone bed 29 feet thick at the top of the formation near the center S½ sec. 23, T. 2 S., R. 4 E.

The basal beds normally are somewhat conglomeratic and contain pebbles of granite, rhyolite porphyry, and vein quartz in a matrix of sand. The texture of the overlying beds and of the formation as a whole is medium- to coarse-grained, with numerous thin pebble layers of sandy quartz conglomerate. The following sieve analysis representing the upper 243 feet of the Reagan from measured section C, NE¼ sec. 1, T. 3 S., R. 4 E., shows the wide range of grain size (poor sorting) as well as the predominance of coarse sand. A cumulative frequency curve plotted from this analysis shows the median diameter is 0.52 mm and the sorting coefficient (So) is 1.89.[22]

TABLE I

SIEVE ANALYSIS OF REAGAN SANDSTONE

Screen opening (mm)	Percent by Weight Retained	Cumulative	Designation (Wentworth Scale)
4.0	0.4	0.4	pebble
2.0	6.3	6.7	granule
1.0	18.4	25.1	very coarse sand
0.5	26.6	51.7	coarse sand
0.25	27.1	78.8	medium sand
0.12	16.5	95.3	fine sand
0.06	3.0	98.3	very fine sand
Pan	1.6	99.9	silt

Examination under a binocular microscope shows that feldspar uniformly is a prominent constituent, even though it is not distinguishable by the naked eye in all outcrops, and the typical rock should be classed as a feldspathic sandstone or true arkose. Detailed grain counts under a petrographic microscope of the above 243-foot sample gave a ratio of 27 percent feldspar to 73 percent quartz in the medium, coarse, and very coarse sand fraction, and a

[22] Krumbein, W. C., and Pettijohn, F. J., "Manual of Sedimentary Petrography": *Appleton Century*, pp. 229-233, 1938.

ratio of 39 percent feldspar to 61 percent quartz in the fine and very fine sand fraction. The weighted average ratio of feldspar to quartz in all sand sizes of the Reagan sandstone is 30:70, i.e., the sand contains 30 percent feldspar. Thin section photomicrographs are shown in Plate IX, A-D.

The microscopic examination also reveals that the quartz grains are subangular to subrounded, pitted, and frosted, and many have partial crystal faces of secondary growth. Some of the feldspars likewise have secondary crystal faces. Glauconite in small, rounded, green pellets is of uncommon occurrence and apparently is localized in the upper part of the formation.

Doubtless the Reagan sandstone in the Mill Creek-Ravia area was deposited along the shore line of an advancing sea, deriving its granitic materials from residual detritus of the granite mainland. The mineral composition alone offers ample evidence for this statement, because the abundance of feldspar and granite fragments in the sandstone clearly shows granite to be the source rock, and glauconite is indicative of a marine environment. Field relations, specifically the erosional, overlapping contact of sandstone on granite, indicate a local source of the sand. It is clear also that the granitic material had been subjected to prolonged decomposition, for a considerable part of the feldspar now present in the Reagan sandstone is altered and clouded with numeous streaks of sericite. The poor sorting of the sand particles, together with the cross-bedding that is observed locally, indicates rapid deposition from swiftly moving currents of the kind that are common in shallow water along marine beaches.

Field identification. The coarse-textured, arkosic sandstones of the Reagan are quite unlike any other strata in the mapped area, and ordinarily lithology alone is adequate for field identification, even in isolated exposures. The typical outcrop of the formation is an east-facing, forest-covered escarpment that rises above the low-lying, gently undulating surface of the granite. Although the escarpment locally is rather inconspicuous, particularly where the Reagan is thin, over much of the area its total height is at least 50 feet. The topographic break at the base of the escarpment as a general rule marks the base of the formation.

Where a well-defined escarpment is lacking, some difficulty may be encountered in locating the sandstone-granite contact, as both weather to an arkosic sandy soil which covers the outcrops. In a few such localities it is possible to determine the boundary where dikes of fine-grained igneous rock (rhyolite porphyry or diabase) can be found. These dikes weather less rapidly than the granite and form low ridges that are traceable to the base of the sandstone, where the topographic ridges disappear. Near the north fault of the Tishomingo anticline, in the north-central part of sec. 14, T. 2 S., R. 4 E., the lower part of the Reagan sandstone is somewhat harder than normal and stratification in it is indefinite. Its general appearance is so much like granite that close scrutiny with a hand lens must be resorted to, relying on the rounded outlines of quartz grains to indicate sandstone.

The top of the Reagan formation is marked by the contact of its coarse-grained sandstones with fine-grained sandy dolomite of the overlying Honey Creek formation. (See Honey Creek formation.)

Stratigraphic relations. The Reagan sandstone rests unconformably on the underlying pre-Cambrian granite. The time interval represented by the unconformity is of very considerable magnitude, including all of Lower and Middle Cambrian time as well as an unmeasured part of the pre-Cambrian.

Relief on the granite floor, and its accompanying effect on the thickness of the Reagan sandstone, differs from place to place in the Mill Creek-Ravia area. In the southern 8 miles the floor was relatively smooth and sand was deposited uniformly on it. In the northernmost mile of the area, however, the Reagan was deposited on the sides of a granite hill that was about 260 feet high. The oldest beds of the formation were deposited at the base of the hill as it existed at the beginning of Reagan time, and successively younger overlapping beds were laid down along its flanks. Eventually the hill was submerged and covered by sands in the upper 31 feet of the Reagan formation. The overlapping relation of sandstone on granite is conclusively demonstrated by field mapping as well as by projecting strike of the sandstone beds directly into granite outcrop. This relation can be seen directly in the field by looking northward from the road at a point 1,900 feet west and 1,200 feet south of the NE cor. sec. 23, T. 2 S., R. 4 E. Careful search precludes the possibility of a fault at this locality.

The configuration of the granite hill is reflected in the thickness of the sandstone and its rate of overlap. On the north flank of the hill, in the north-central part of sec. 14, T. 2 S., R. 4 E., the Reagan is 251 feet thick only 2,000 feet horizontally from the peak of the hill where the sandstone is 31 feet thick. This indicates sedimentary overlap at the rate of 580 feet per mile, or an average slope on the granite floor of about 6 degrees. The south flank of the hill, in the north-central part of sec. 23, is even steeper, for on it the thickness of the sandstone is 31 feet at the crest of the slope and 289 feet about 1,000 feet farther south. Here the rate of overlap is slightly more than 1,300 feet per mile and the calculated slope of the granite is 14° 28′. From this point southward the granite floor is comparatively smooth and the Reagan has a nearly uniform thickness of about 350 feet. These relations are shown graphically in fig. 3.

Whether the contact of the Reagan with the overlying Honey Creek dolomite represents a break in sedimentation is a debatable matter. There is no evidence of erosional or angular unconformity at this contact, yet the pronounced contrast in lithology above and below, and the sharp line of demarcation between the two formations, indicates a sudden change in sedimentary environment from one in which coarse clastics of the Reagan were deposited, to an environment in which dolomite and very fine-grained clastics of the Honey Creek were deposited. Such relations suggest that an hiatus may be present, probably a non-depositional period of short time duration.

Honey Creek Formation

The Honey Creek formation in the Mill Creek-Ravia area consists of sandy and non-sandy dolomite 63 to 234 feet thick, overlying the Reagan sandstone and underlying, with slight disconformity, the Fort Sill limestone.

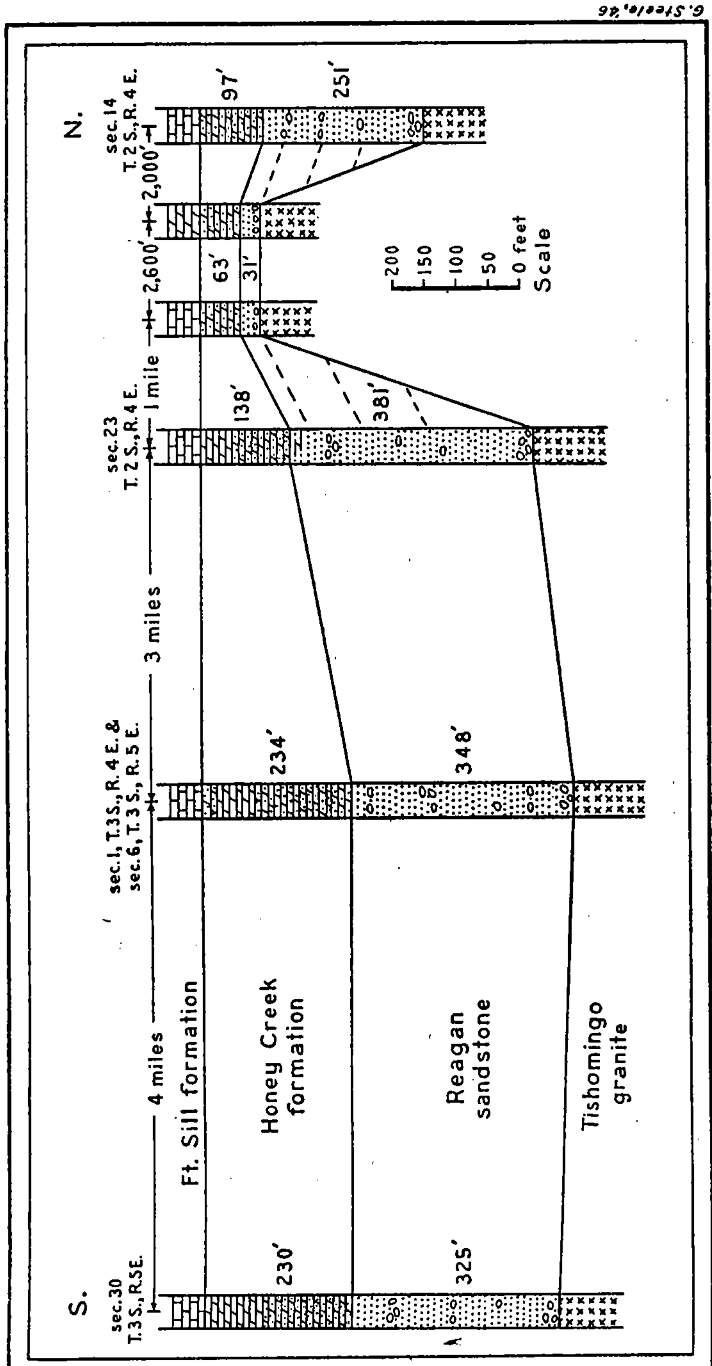
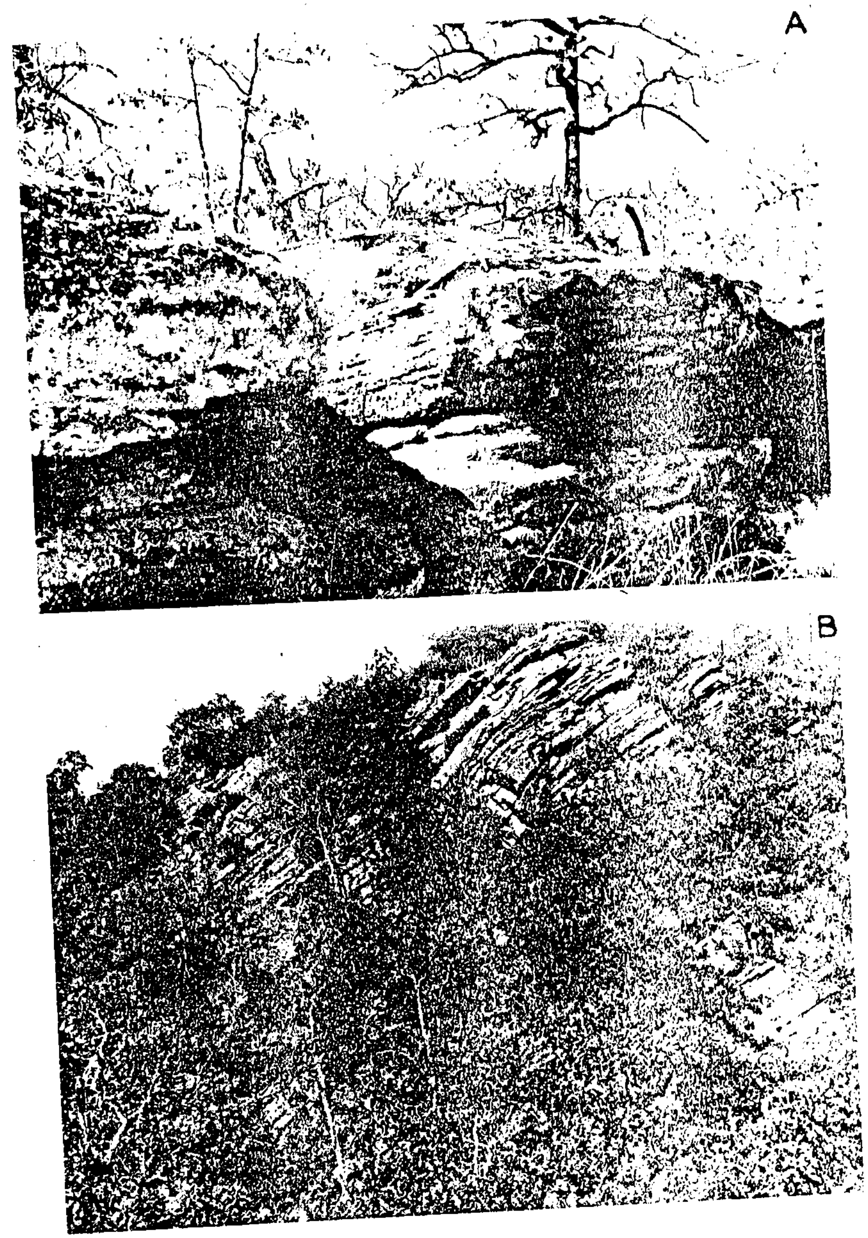


FIG. 3. STRATIGRAPHIC SECTION OF REAGAN AND HONEY CREEK FORMATIONS SHOWING MARKED THINNING OVER A GRANITE HILL IN NORTHERN PART OF MILL CREEK-RAVIA AREA.

PLATE II.

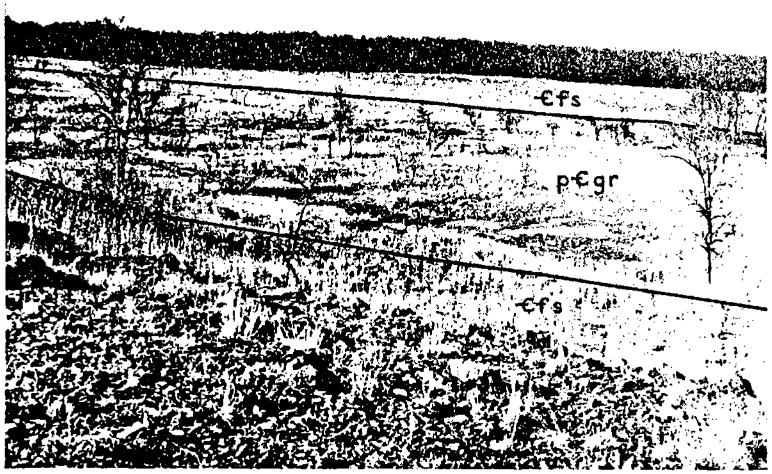


OUTCROPS OF REAGAN SANDSTONE.

A. Basal conglomeratic sandstone showing indistinct parallel bedding; 900 feet west and 2,000 feet north of the SE cor. sec. 23, T. 2 S., R. 4 E.

B. Well-bedded sandstone strata in middle part of the formation. Bluff about 75 feet high; 1,500 feet west and 750 feet south of the NE cor. sec. 30, T. 3 S., R. 5 E.

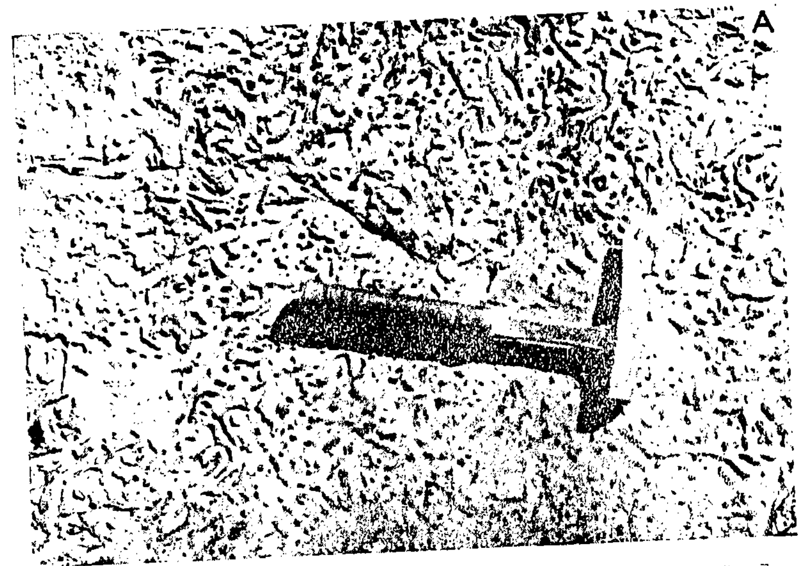
PLATE III.



A. Laminated, sandy dolomite in lower division of Honey Creek formation; 3,000 feet east and 1,000 feet south of the NW cor. sec. 30, T. 3 S., R. 5 E.

B. Inlier of pre-Cambrian granite surrounded with unconformable contact by dolomite of the Fort Sill formation. In foreground the dolomite dips 40° toward observer; in small scarp across flat surface of granite the dolomite dips 6° away from observer. Tree line in background marks approximate position of fault between the Tishomingo anticline and Mill Creek syncline. View toward northeast, in the NW¼ NW¼ sec. 14, T. 2 S., R. 4 E.

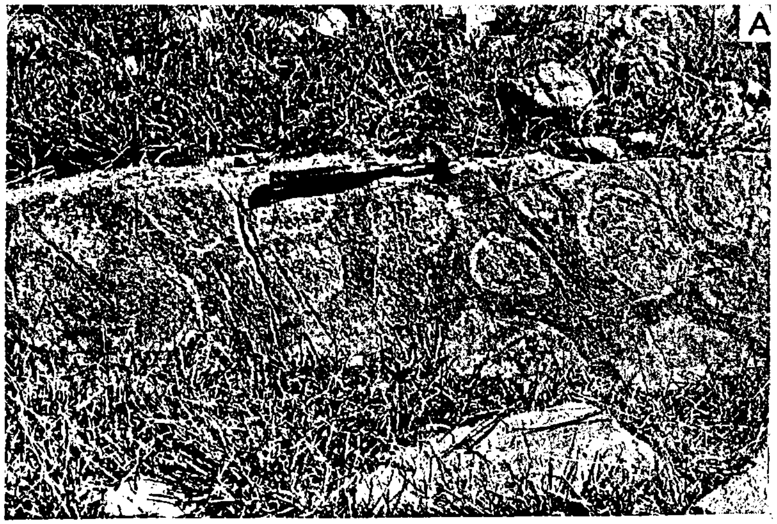
PLATE IV.

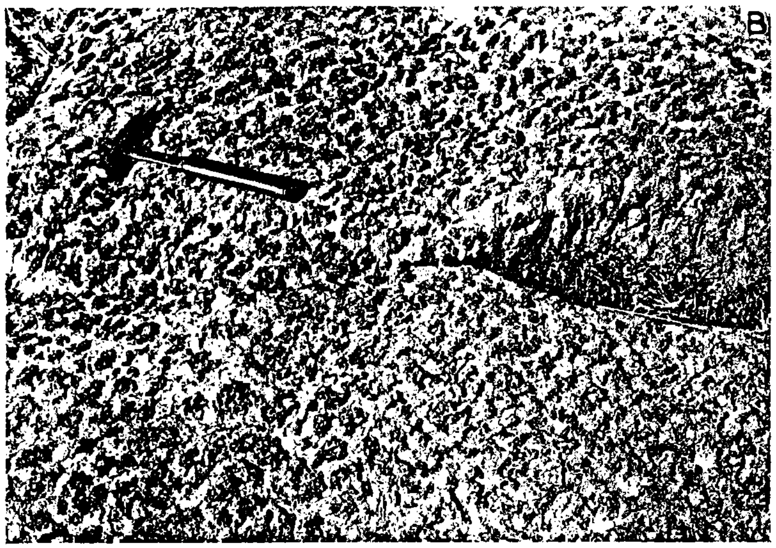


DOLOMITIC LIMESTONES IN MIDDLE DIVISION OF FORT SILL FORMATION.

A. Anastomosing stringers of dolomite weathering into relief along bedding surface of fine-grained limestone. Dolomitization possibly related to worm trails. Hammer is 13 inches long. The outcrop is 200 feet south of the NW cor. sec. 12, T. 3 S., R. 4 E.

B. Mottled dolomitic limestone with lens of dolomite (below hammer); 1,000 feet east of the SW cor. sec. 1, T. 3 S., R. 4 E.





DOLOMITIC ALGAL LIMESTONES IN MIDDLE DIVISION OF FORT SILL FORMATION.

A. Bedding surface view showing *Cryptozoon* algal colonies, slightly dolomitized, set in a calcite-dolomite matrix. Largest colony is about 10 inches in diameter; 2,100 feet east and 700 feet south of the NW cor. sec. 30, T. 3 S., R. 5 E.

B. Oblique view on bedding surface showing crudely circular areas of dolomite in calcitic limestone. Along eroded joint crack at right center may be seen dim outlines of vertically oriented cylindrical algae, composed of fine-grained calcite, with dolomite filling the inter-algal space. NE¼ SE¼ SW¼ sec. 26, T. 2 S., R. 4 E.

Distribution. The outcrop of the Honey Creek formation parallels that of the Reagan sandstone. It trends northward as a band generally about 200 to 1,300 feet wide along the eastern part of the mapped area and, in the central part, it is offset by several diagonal faults. The outcrop is cut by a strike fault of considerable displacement that trends northwestward through sec. 13, T. 3 S., R. 4 E. and adjoining sections, locally reducing the outcrop width to 50 feet or less. Fort Sill limestone is in contact with granite in the SW¼ SW¼ sec. 18, T. 3 S., R. 5 E., the Honey Creek and Reagan having been eroded from the upthrown side of a fault. The outcrop is widest (1,300 feet) in sec. 1, T. 3 S., R. 4 E. and sec. 36, T. 2 S., R. 4 E., because the formation here is thickest, it has a relatively low dip, and the upper half of the formation crops out on a modified dip slope.

Thickness. The Honey Creek formation ranges in thickness from 63 to 234 feet, being thinnest in the northern part of the area. It is 63 feet thick near the center sec. 14, T. 2 S., R. 4 E. and 2,000 feet north, practically at the north fault of the Tishomingo anticline, it is 97 feet thick. Southward there is a progressive increase to 138 feet in the southern part of sec. 23, T. 2 S., R. 4 E., and then to 234 feet in sec. 1, T. 3 S., R. 4 E. This thickness remains virtually constant to the south edge of the Tishomingo anticline, in sec. 30, T. 3 S., R. 5 E., where the formation is 230 feet thick.

From a cross-section diagram of the Honey Creek and Reagan formations in the mapped area, in which the top of the Honey Creek is used as datum (fig. 3), it may be seen that at the beginning of Honey Creek time there was substantial relief on top of the Reagan sandstone, attaining a maximum of 171 feet in the 4-mile distance between sec. 1, T. 3 S., R. 4 E. and sec. 14, T. 2 S., R. 4 E. The relief was caused chiefly by the influence of the pre-Reagan granite hill in sec. 14 which, although just previously covered by a thin veneer of Reagan sandstone, still was topographically high beneath the sea. This locality apparently remained high throughout Honey Creek time, so that here the sea was shallower and the sediment deposited in it was thinner than at other parts of the area. Thicker sediment was deposited in deeper parts of the basin, and at the close of Honey Creek time the sea floor, for the first time in the Paleozoic depositional history of the Tishomingo anticline, was built up to a nearly level surface. The irregularities of the granite floor had not yet been completely obviated in the entire region, however, for there still remained islands of pre-Cambrian granite in the open sea to the west.

Character. The Honey Creek formation of the Mill Creek-Ravia area consists of a lower division of sandy dolomite (Pl. III, A) and an upper division of relatively pure dolomite. The two divisions are readily distinguishable over most of the area, but in the NW¼ sec. 14, T. 2 S., R. 4 E. nearly the entire 97-foot thickness of the formation is coarsely crystalline dolomite with erratic distribution of coarse-grained arkosic sand, obviously derived from adjacent granite hills.

Lower division: The lower division is 80 to 150 feet thick. In it the dolomite beds contain approximately 50 percent very fine sand and silt and are characterized by a noticeable content of glauconite. The percentage of sand is inconstant, however, and those beds with relative scarcity of sand weather to massive-bedded ledges 0.5 to 3 feet thick or to rounded blocks with smooth to slightly pitted, light brown to nearly black surface. Beds with abundant sand may have much or all of their dolomite leached by surface waters and appear on the outcrop, if not covered by soil, as intervals of loose sand or thin beds of laminated, buff-colored, porous sandstone. That the sandstone beds on the outcrop are sandy dolomites beneath the surface is proved by churn drill cuttings from wells in sec. 1, T. 3 S., R. 4 E. and sec. 36, T. 2 S., R. 4 E. Three wells, drilled in the Honey Creek to a depth of 100 feet and bottomed at or near the top of the Reagan sandstone, penetrated a uniform section of sandy dolomite without any suggestion of interstratified beds of sandstone.

On a fresh surface of most outcropping beds the color ranges from light gray to brownish-gray, and to greenish-gray in beds having high glauconite content. The dolomite is uniformly of fine-crystalline texture, but the individual crystals are large enough to reflect light from cleavage surfaces and to give a distinct crystalline appearance. The detrital constituents also are of fine size, and

in some specimens they are so evenly distributed and inconspicuous in the dolomite that one is mistakenly led to suspect a relatively pure dolomite. In other beds sand and glauconite are conspicuous on a weathered outcrop as interlaminations with dolomite. In general the laminated strata are even-bedded but locally they are cross-bedded on a small scale. Certain of the laminated beds contain well preserved brachiopods and trilobite fragments.

A chemical analysis of a composite sample taken from outcropping ledges (excluding covered strata which probably are higher in sand) in the lower half of the Honey Creek formation, SE¼ SE¼ sec. 36, T. 2 S., R. 4 E., is given in Table II.

TABLE II

CHEMICAL ANALYSIS OF HONEY CREEK SANDY DOLOMITE
A. C. Shead, Analyst

SiO_2	32.28	K_2O	3.01
Al_2O_3	4.88	Na_2O	0.15
Fe_2O_3	1.13	H_2O (—105°C.)	0.21
CaO	18.68	Loss on ignition	27.93
MgO	11.66	Total	99.72

This sample, tested in the experimental rock wool plant at the research laboratory of the Oklahoma Geological Survey, produced without blending an excellent commercial grade of rock wool, suitable for insulation. A plant to utilize sandy dolomite from the Honey Creek formation of the Mill Creek-Ravia area has been planned for construction at Ada.

An examination of three thin sections under the petrographic microscope reveals that dolomite, the dominant mineral, occurs in sub-rhombic to highly irregular crystals, generally about 0.1 mm in diameter. Associated with dolomite are the detrital minerals orthoclase, microcline, quartz, glauconite, zircon, and shreds of clear mica (sericite), named in order of abundance (Pl. IX, E-F). These minerals have random distribution but prevailingly they are concentrated in laminae about 0.3 to 1.0 mm thick. The feldspars and quartz are of very fine sand and silt size, ranging mostly from about 0.04 to 0.07 mm in diameter.

Grain counts of the detrital constituents show about 60 percent feldspars, generally as rhombic cleavage fragments or subangular grains that are partly clouded by incipient alteration products, and about 35 percent quartz, occurring as subrounded to angular clear grains. Glauconite, occurring as bright green rounded pellets or irregular fibers, ranges from less than 1 percent to about 15 percent in different samples. Zircon and sericite together contribute about 1 percent.

A sieve analysis of the insoluble residue portion of the lower 115 feet of the Honey Creek formation, representing practically the entire thickness of the lower division, was made from samples obtained from churn drill holes in the NE¼ sec. 1, T. 3 S., R. 4 E. Fifty-one percent of the composited sample was insoluble residue, chiefly detrital quartz and feldspar. The analysis as given in Table III shows the predominance of silt (62.6 percent) and the fine size of even the coarsest fragments. The median diameter calculated from a cumulative frequency curve is 0.052 mm.

TABLE III

Sieve Analysis of Detrital Constituents in Lower Division of Honey Creek Formation

Screen opening (mm)	Percent by weight retained	Percent by weight cumulative	Designation (Wentworth Scale)
0.246	0.2	0.2	medium sand
0.177	0.2	0.4	fine sand
0.124	1.0	1.4	
0.088	12.9	14.3	very fine sand
0.061	23.0	37.3	
0.043	39.6	76.9	silt
Pan	23.0	99.9	

The percentage of insoluble residue ranges between 35 and 60 percent, averaging very close to 50 percent. In general the lower part of the lower division of the Honey Creek contains more insoluble residue (sand) than dolomite, but this ratio is reversed in the upper part, so that there is a gradation into the upper, relatively pure dolomite beds of the Honey Creek formation.

Upper division: The upper division of the Honey Creek formation ranges in thickness from about 60 to 80 feet. It is composed of gray, tan, or pink, medium- to coarse-crystalline dolomite in beds 2 to 6 inches thick that weather light brown to dark gray. The dolomite contains much less sand and glauconite than the lower member of the formation, the insoluble residue ranging between 6 and 12 percent over most of the area. The sand is poorly sorted arkose distributed in thin layers and the glauconite has the form of green, waxy flakes instead of rounded pellets. The glauconite is observable only in the insoluble residue under a microscope. At the top is a bed 6 to 22 feet thick that contains abundant coarse-grained arkosic sand.

The beginning of deposition of Honey Creek sediments in the Mill Creek-Ravia area shows a marked change in sedimentary environment over that which previously existed in Reagan time. The Honey Creek formation is composed dominantly of carbonate rock (dolomite) with conspicuous glauconite and rather abundant fossils in its lower part, whereas these three elements either are inconspicuous or completely lacking in the Reagan sandstone. This condition represents a change from deposition of granite-derived coarse clastics in shallow water near the beach, to precipitation of non-clastic dolomite from marine waters farther offshore, this being the normal sequence of deposition in a sea that is advancing on a submerging land mass. The environment appears to have been modified quite suddenly, for there is little or no gradation of typical Reagan lithology into the Honey Creek rocks.

That the shore line in Honey Creek time was advancing continually over a submerging land mass is indicated by the abundance of very fine sand, about 50 percent, in the lower division of the formation and its nearly complete absence in the upper division. The upper division is composed of dolomite that was deposited too far from shore to receive significant contributions of clastic material from the mainland.

Field Identification. The most distinctive lithology in Honey Creek strata of the Mill Creek-Ravia area is the fine-grained, sandy to silty, glauconitic dolomite that occurs in about the lower half of the formation. No similar beds were found in any of the other Cambrian formations examined in the area, and accordingly this lithology has been a valuable element in field identification of the Honey Creek. A brachiopod zone (*Billingsella*) and a zone of abundant trilobite fragments, both in the lower part of the sandy dolomite unit, are also helpful.

It is a comparatively simple field problem to map the contact of the Honey Creek with the underlying Reagan sandstone because of the sharp lithologic contrasts. The coarse-grained, arkosic, thick-bedded sandstones of the Reagan are easily distinguished from the fine-grained, thin-bedded, laminated, glauconitic dolomites of the Honey Creek which crop out as black-weathering boulders or rounded pedestals. That the Honey Creek contains about 50 percent very fine sand and silt probably would not be suspected from field examination alone, except that surface weathering locally has leached the dolomite and produced a laminated, friable, buff sandstone. Such sandstone need not be confused with the Reagan, as it is much finer grained than typical Reagan lithology. The topographic expression and vegetative cover of the Reagan formation and the lower part of the Honey Creek are essentially the same, however, for both normally crop out in a single scarp face which is covered indiscriminately by a thick growth of oak and hickory trees.

Approximately the upper half of the Honey Creek formation is composed of an indistinctive medium- to coarse-crystalline dolomite, of a type that occurs also in the Fort Sill, Royer, and Butterly formations, and which has little value as a stratigraphic guide. For mapping the top of the Honey Creek, reliance was placed chiefly on the base of the fine-grained, algal-containing limestones of the overlying Fort Sill formation.

Stratigraphic relations. The contact between the Reagan and Honey Creek formations is quite sharply defined at a point 1,500 feet north of the S¼ cor. sec. 23, T. 2 S., R. 4 E. The sharp contact, together with the abrupt, non-gradational change in lithology from massive-bedded, coarse-grained sandstone to thin-bedded, fine-textured sandy dolomite, indicates a sudden change in depositional environment and may be indicative of an hiatus.

The few exposures available in the mapped area show that the upper contact of the Honey Creek formation is disconformable. This contact is well exposed in a small ravine about 2,100 feet west and 1,000 feet south of the NE cor. sec. 1, T. 3 S., R. 4 E. Here the basal limestone bed of Fort Sill has channeled 1 foot into the upper dolomite beds of the Honey Creek along a horizontal distance of 25 feet. The channeling represents relatively slight erosion and possibly is of local significance only.

Fort Sill Formation

The Fort Sill formation as used in this report is a mappable unit of limestone, dolomitic limestone, and dolomite that overlies with slight unconformity the Honey Creek formation and underlies conformably the Royer dolomite. The thickness ranges between 193 feet and 425 feet. At one locality in the central part of the area (N½ sec. 1, T. 3 S., R. 4 E.) the formation is composed of a lower limestone unit 105 feet thick, a middle dolomitic limestone unit 252 feet thick, and an upper dolomite unit 44 feet thick. Mapping has shown that the dolomitic limestone in the middle unit and the limestone in the lower unit grade into dolomite in the northern part of the area.

Distribution. The Fort Sill formation crops out in the Tishomingo anticline as a north-trending band 500 to 3,000 feet wide, parallel to and between the outcrops of the Honey Creek formation on the east and the Royer dolomite on the west. In the central part of the anticline the Fort Sill and other formations are offset by several transverse faults. Northward from sec. 1, T. 3 S., R. 4 E. the regional dip to the westward is normally between 10° and 15°, giving greater breadth of outcrop than in the southern third of the area where the dip is between 25° and 90°.

The peculiar distribution of the Fort Sill in the northern part of the area is caused partly by the overlapping deposition of this formation against the sides of three granite islands. The islands now are exposed as inliers that are surrounded by the Fort Sill and Royer formations. The granite inliers crop out as topographic basins in an upland plateau of dolomite, so that the outcrop of the sedimentary beds is curved down dip, westward, around the sides of the basins. The curve is accentuated by a northwest-plunging syncline between the largest inlier in secs. 22 and 23, T. 2 S., R. 4 E. and the smaller inliers to the north.

Thickness. Throughout most of the Tishomingo anticline the Fort Sill formation has a thickness of about 400 feet. There is a slight increase in thickness from 380 feet at the south edge of the anticline, in sec. 30, T. 3 S., R. 5 E., to 401 feet in the N½ sec. 1, T. 3 S., R. 4 E., and to 425 feet in the SW¼ sec. 23, T. 2 S., R. 4 E. Northward the thickness decreases to 193 feet in the NW¼ sec. 14, T. 2 S., R. 4 E., where the formation was deposited on and around two small granite islands.

Character. A reconnaissance survey in the Mill Creek-Ravia area by the writer, early in the field investigations, revealed that strata in the stratigraphic position of the Fort Sill limestone are represented by two different facies of essentially contemporaneous age. One facies, cropping out in the southern and central parts of the area, constitutes the bulk of the outcrop and may be considered typical. It consists of limestone and dolomitic limestone, with subordinate beds of dolomite, aggregating about 400 feet in thickness.

In contrast, the northern facies consists predominantly or entirely of dolomite. That the northern dolomite facies is equivalent to the southern limestone facies is clearly demonstrated by field mapping, chiefly by tracing the base of the Royer dolomite and the top of the Honey Creek formation. The basal limestone division of the Fort Sill formation, so well developed in the southern part of the area, also can be traced into the area of dolomite facies; and in one locality, the gradation of limestone into dolomite can be observed directly by walking beds a few hundred feet or less.

SOUTHERN AREA

In about the southern 7 miles of the Mill Creek-Ravia area the Fort Sill consists of three recognizable lithologic divisions: a basal division of fine-grained, massive-bedded limestone; a middle division of interbedded dolomitic limestone and dolomite; and an upper division of fine-grained, yellowish-gray dolomite. These divisions, exemplified in measured section C, are characteristic of the area south of the north line of sec. 26, T. 2 S., R. 4 E. (See fig. 4 and Appendix.)

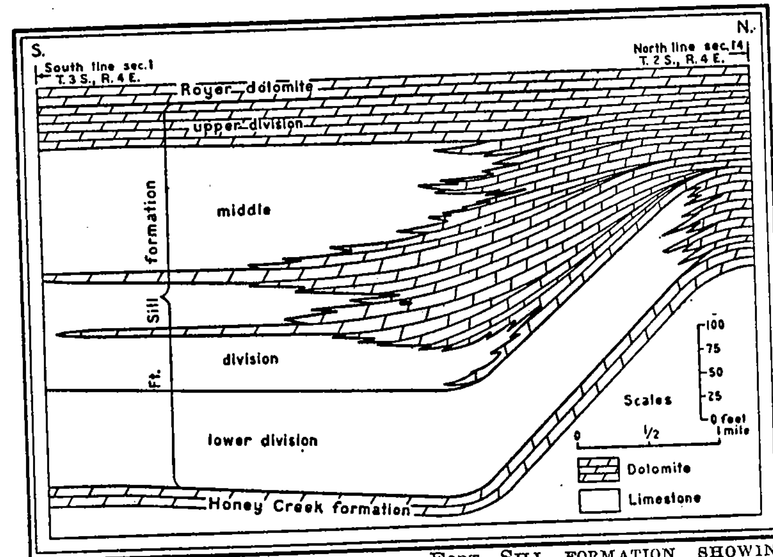


FIG. 4. GENERALIZED SECTION OF FORT SILL FORMATION SHOWING MAJOR DIVISIONS AND GRADATION OF LIMESTONE INTO DOLOMITE.

Lower division: The lower division is about 100 feet thick and makes up approximately the lower fourth of the formation (measured section C, zones 29-36). The entire unit normally is composed of massive-bedded, fine-grained limestone that contains a small, almost unnoticeable, amount of dolomite. In a few places, and particularly at the base of the division, the limestone beds grade along strike into light-weathering, coarse-crystalline dolomite.

Most of the beds consist of fine-grained calcite of light gray, white, or greenish color, and locally small crystals of cream to pale orange dolomite are scattered through the rock, giving a mottled appearance. A compact structure and smooth, sub-conchoidal fracture are typical. On scarp faces the strata crop out as massive-bedded ledges 1 to 2 feet thick; and on gentle slopes they commonly weather to rounded boulders of dove-gray, pale green, or white color.

Close examination with a hand lens reveals that the rocks are made up of very fine-grained limestone in rounded pellets 0.5 to 2 mm in diameter, embedded in a matrix of fine- to medium-crystalline calcite (Pl. IX, G-J). It is believed that the pellets are rounded fragments derived by fragmentation of algae, for *Girvanella*-type algae are abundant in the same beds farther north.

The lower division of the Fort Sill of this area contains the thickest sequence of nearly pure limestone of all the Cambrian formations examined in the mapped area.

Middle division: The middle division is about 250 feet thick and makes up approximately two-thirds of the Fort Sill formation in the southern part of the area (measured section C, zones 37-57). It is composed of dolomitic limestone and dolomite, interstratified mostly but also intergrading along the strike. The dolomitic limestone typically is composed of dark gray, fine- to medium-crystalline calcite which is cut by many irregular stringers of medium-crystalline, light brown dolomite, the rock containing 10 to 40 percent dolomite. The dolomite stringers have characteristic anastomosing and reticulate patterns, easily observed on a weathered surface because the dolomite is etched into positive relief, but in some beds these stringers coalesce to form irregular knots of nearly pure dolomite in an otherwise dolomitic limestone. Knots of this type range in diameter from a few inches to lenses 15 feet long and 2 feet thick. *Cryptozoon* algal colonies about 1 foot in diameter, and composed of extremely fine-grained calcite, are prominent in some beds. Outcrop photographs of dolomitic limestone from the middle division of the Fort Sill are shown in Plates IV and V.

Most of the dolomitic limestones are massive-bedded and weather to ledges 1 to 3 feet thick. A few units of thin-bedded shaly limestone that weather to grass-covered benches, and a few thin beds of limestone conglomerate, are intercalated with the thicker, hard beds. The weathered color prevailingly is light yellowish-gray or brownish.

The few beds of relatively pure dolomite in the middle division of the Fort Sill are persistent along strike. The dolomite beds are non-calcitic and gray to yellowish-gray, with even-grained, medium-crystalline texture. They crop out as thin-bedded, slightly pitted, brownish beds in layers mostly 5 to 10 feet thick.

Of the entire 252-foot thickness of the middle division, 236 feet is dolomitic limestone and 16 feet is dolomite.

Upper division: The upper division of the Fort Sill formation in the southern part of the Tishomingo anticline is about 50 feet thick (measured section C, zones 58-60). It is composed of medium-grained, brownish, relatively thin-bedded dolomite of the same type that occurs interbedded with dolomitic limestone in the middle division of the formation.

The insoluble residues of the three divisions of the Fort Sill are essentially alike in containing a mixture of angular, arkosic silt and very fine sand, together with silt aggregates of irregular shape, tiny euhedral crystals of glassy feldspar, and green waxy flakes of a material that may be glauconite. The feldspar is the adularia variety of orthoclase, of the type described by McKnight from the Everton dolomite in northern Arkansas.[23] The crystals typically are about 0.01 to 0.05 mm in diameter and have 6 equally developed faces, the unit prism (110) and basal pinacoid (001), the combination of which produces a rhombohedral form (Pl. XI, E). In a few elongated or flattened crystals the clinopinacoid (010) is present. The perfectly clear euhedral faces and sharp edges and corners of the crystals unmistakably prove that the feldspar was not transported as detrital fragments, and clearly point to their authigenic origin.

NORTHERN AREA

The Fort Sill formation in the northern part of the Tishomingo anticline, in the 2 mile distance northward from the south line of sec. 23, T. 2 S., R. 4 E., is characterized by the predominance of dolomite over limestone. The lithologic divisions recognizable in the southern area, discussed above, can be traced to the southern part of sec. 23 with little change except that the middle member contains more dolomite than dolomitic limestone; but in the northern part of secs. 14 and 15, T. 2 S., R. 4 E., the Fort Sill formation is

[23] McKnight, E. T., "Zinc and Lead Deposits of Northern Arkansas": *U. S. Geol. Survey Bull.* 853, pp. 32-33, 1935.

composed entirely of dolomite, and individual members are indistinguishable.

No measured section in the northern area can be called typical. The section measured in the SW¼ sec. 23 (measured section A) contains a lower limestone division (zones 24-26), a middle dolomite and dolomitic limestone division (zones 27-46), and an upper dolomite division (zones 47-50).

The lower division, 116 feet thick, is composed of fine-grained, white-weathering limestone, mottled with orange dolomite crystals and containing spherical algae of the *Girvanella* type about 1 inch in diameter. Interstitial filling between the algae consists of rounded pellets, probably fragmented parts of algae, that are set in a matrix of medium-crystalline calcite (Pl. IX, G-J). A chemical analysis representing 40 feet of the *Girvanella* beds, NE¼ SW¼ sec. 23, showed 92.29 percent $CaCO_3$ and 5.23 percent $MgCO_3$.

The middle division, 258 feet thick, is composed of alternating units of dolomite and dolomitic limestone. A conspicuous sequence of dolomite 144 feet thick occurs in the middle part of the division. The dolomite mostly is yellowish-gray, fine- to medium-crystalline, and arkosic. It crops out as thick, slightly pitted ledges or as thin-bedded layers a few inches thick. The limestone invariably is dolomitic, of light to dark gray or yellowish-gray color, and fine grained; it crops out in thick- to thin-bedded strata. Much of the limestone is of clastic origin, containing abundant granules and pebbles of fine-grained limestone set in a matrix of calcite, dolomite, and arkosic sand.

In the middle division, 179 feet or 69.4 percent is dolomite and the remaining 79 feet is limestone.

The upper division of the Fort Sill formation in measured section A is 51 feet thick. It consists of yellowish-gray, finely crystalline dolomite, occurring in tough, compact beds about 3 to 5 inches thick.

The upper and middle divisions contain about 10 percent arkosic sand, derived from a granite hill that now is exposed as an inlier about 1,000 feet north of the line of measured section A.

A measured section in the SW¼ NW¼ sec. 14, T. 2 S., R. 4 E., (measured section B), near the north boundary of the Tishomingo anticline, reveals that the Fort Sill formation is abnormal both in thickness and lithology, as compared with other parts of the mapped area. The differences probably are explainable at least partly by the fact that in this locality the formation was deposited on and around two small granite islands. Almost certainly the decrease in thickness to 193 feet, which is less than half the average of 400 feet, resulted from deposition of thinner sediments in shallow water around the islands, and not from unconformities or overlapping relations at the top, base, or within the formation itself.

The upper 110 feet of the Fort Sill at measured section B is dolomite of fine- to coarse-crystalline texture and gray, yellowish-gray, greenish, or lilac color. Many of the beds are highly arkosic. The coarse-textured dolomites are unlike the prevalent type occurring in the formation elsewhere. The lower 83 feet of the formation is composed of fine-grained, greenish-gray, compact limestone in beds a few inches to 1 foot thick. Traced northward a few hundred feet to the granite inliers, the limestone beds grade into coarsely crystalline, pale green dolomite. On the north side of the inliers, in the vicinity of the NW cor. sec. 14, the Fort Sill formation is composed exclusively of dolomite.

Geologic history. The Fort Sill formation in the Tishomingo anticline was deposited in two strongly contrasting geological environments. One environment, represented by strata in the southern 7 miles of the mapped area, may be considered that of normal marine limestone deposition on a comparatively smooth floor. The second environment, represented by rocks in the northern 2 miles, was characterized by deposition of dolomite, or limestone later converted to dolomite, on a highly irregular sea floor above which granite islands were projecting.

The normal sequence, which consists of a basal unit of nearly pure limestone, a middle unit of dolomitic limestone, and an upper unit of dolomite, is persistent in lithology and thickness in the area south of the north line of sec. 26, T. 2 S., R. 4 E. Such characters indicate a stable, gradually subsiding basin in which the type of rock formed was governed chiefly by the relative supply of calcium and magnesium in the sea water. Algae grew in profusion and contributed significantly to rock building. The remains of these colonial plants are preserved virtually intact in some beds, whereas in other beds the colonies were broken into pellets or pebbles, probably by strong currents developed during storms. In the middle division of the Fort Sill the interstratification of hard (algal) and soft (shaly) beds suggests cyclic deposition, whereby algal growth was interrupted periodically by the influx of clay and production of muddy water. The clay became mingled with the lime muds which later were consolidated into thin-bedded limestone. From the absence of arkosic sand in most of the carbonate rocks it may be inferred also that the shore line lay far away, with the result that very little land-derived, coarse clastic material was contributed to the depositional basin, except that derived from localized granite islands.

Quite dissimilarly, the rocks in the northern part of the area, in secs. 14, 15, 22, and 23, T. 2 S., R. 4 E., were deposited around granite islands that now are exposed as inliers surrounded by strata of Upper Cambrian age (Plate I and Frontispiece). Four inliers, all of crudely elliptical outline, are known at present. The largest of the inliers covers about 80 acres in the eastern part of sec. 22 and the western part of sec. 23. On the southwest margin it is covered by Royer dolomite, elsewhere by the Fort Sill formation. The other three inliers, which lie in an east-west line about a mile north, in secs. 14 and 15, have a combined outcrop area of about 50 acres; the westernmost, with an area of 30 acres, is the largest. They are surrounded by beds of the Reagan, Honey Creek, Fort Sill, and Royer formations (Pl. III, B.).

Although the three northern inliers are isolated as separate areas now, it is clear that each is a peak on a larger granite mass. The strips of sedimentary rocks on either side of the middle inlier are so narrow and thin that both will be removed by erosion in

relatively short geologic time, exposing one large granite outcrop of irregular outline.

The complete history of the granite islands involves many interesting features of sedimentation, and embraces more geologic time than that of the Fort Sill alone. It is evident, for example, that all the exposed inliers were present as hills on the granite mainland just prior to the first invasion of the Upper Cambrian sea, and with the advance of the sea the hills became islands. Sedimentation kept pace with regional submergence and the islands gradually were covered, chiefly by overlapping deposition.

Whereas sedimentation in the southern part of the mapped area was continuous in areal extent, areal continuity around the granite inliers was interrupted because of non-deposition on those parts of the granite which projected as islands above sea level. Regional tilting in Pennsylvanian time, plus erosion to the present surface, has produced an outcrop pattern wherein the strata are disconnected linear bands separated by granite outcrops.

Where beds overlap granite inliers, they contain abundant arkosic sand of medium and coarse size, and the sand disappears in less than 1,000 feet from the contact. The presence of sand and the absence of granite cobbles and boulders indicate that the slopes of the granite hills were too steep for the accumulation of coarse-textured detritus.

An accurate index to the minimum height of these granite islands at the beginning of Reagan time may be gained from the thickness of sediments deposited before they were covered. The height of the southern island, which was covered uniformly by the basal beds of the Royer dolomite, may be determined from the combined thickness of pre-Royer sediments deposited nearby, which total 944 feet (Reagan, 381; Honey Creek, 138; and Fort Sill, 425).

Judging from present exposures, the north island was irregular in profile and had three peaks of different elevation. The easternmost, represented by the smallest inlier (Plate I), was lowest and was covered first, by Honey Creek dolomite. The middle peak, intermediate in height, was covered in mid-Fort Sill time; and the highest, or westernmost, was covered in mid-Royer time. Its maximum height was approximately the same as that of the southern island.

PERIPHERAL DIPS AROUND GRANITE INLIERS

It is of interest to note here that the dolomites of the Honey Creek, Fort Sill, and Royer formations which surround the granite inliers show peripheral dips, that is, the formations dip away quaquaversally from the buried hills. Such relation, according to Bridge and Dake,[24] are common in the St. Francois Mountains of southeastern Missouri, where Upper Cambrian dolomite and sandstone beds rest with 10° to 30° peripheral dips on pre-Cambrian porphyry hills. In the Tishomingo anticline the peripheral dips show a range between 4° and 40°, the steeper ones being on the west and the gentler ones on the east sides of the inliers. Whereas the observed dips in the St. Francois Mountains are believed to be the initial depositional dip, the Arbuckle Mountain dips have been modified by regional tilting, so that the present recorded dip is greater or less than that ascribable to initial deposition. The regional tilting of the Tishomingo anticline that took place in Pennsylvanian time, and resulted in the present dip of the rocks, averages about 15° westward for the area of granite inliers. To restore the correct initial dip it is necessary, therefore, to deduct 15° from all west dips and to add 15° to all east dips. For example, a 30° W. recorded dip becomes 15° W. initial dip and 8° E. recorded dip becomes 23° E. initial dip; and similarly a 4° W. recorded dip becomes 11° E. initial dip because the subtraction is algebraic and in this instance the dip direction is reversed. When corrected for regional tilting in this manner it is evident that the initial dips around the pre-Cambrian hills invariably are peripheral and range between 1° and 25°, averaging about 10°. The irregularities in magnitude of dip undoubtedly are owed to the irregular configuration of the surface of the granite hills at the time the sedimentary beds were deposited.

Field identification. The most distinctive lithology in the Fort Sill of the Mill Creek-Ravia area is in the lower limestone division

[24] Bridge, J., and Dake, C. L., "Initial Dips Peripheral to Resurrected Hills": *Missouri Bureau of Geol. and Mines*, 55th Biennial Report, Appendix I, 1929.

of the formation. The fine-grained, compact, light-colored, *Girvanella*-bearing limestone does not occur in any other Cambrian formation in the area. This lithology also is valuable in mapping the lower contact of the Fort Sill, for the light-weathering limestone beds are quite in contrast to the dark gray and brownish dolomites of the underlying Honey Creek formation. Locally the color contrast can be used in mapping the contact from aerial photographs.

Reticulated and mottled dolomitic limestones, commonly in association with colonial algae (Pls. IV and V), also are useful for field identification in the mapped area because they are restricted to the middle division of the Fort Sill formation. Similar lithology has been observed by the writer in the Fort Sill of the Wichita Mountains, in sec. 26, T. 6 N., R. 14 W., Kiowa County, about 12 miles southwest of Carnegie.

The dolomite beds of the Fort Sill, persistent throughout the area in the upper division, as well as composing most of the formation in the vicinity of the granite inliers, are typically thin-bedded, fine- to medium-crystalline, and brownish or dark gray in color. They weather to slightly yellowish-gray, pitted, thin slabs. These are dominant characters in any given sequence of Fort Sill dolomite strata, although individual beds show a wide range in color, texture, and bedding, particularly around the inliers.

Using the dominant characters, it is possible to map the contact of the Fort Sill with the overlying Royer dolomite, the basal beds of which are light-colored, coarsely crystalline, thick-bedded, and weather to massive, honeycombed, nearly black crags. With a little experience this contact, in most places, can be mapped with confidence. The general differences in lithology and outcrop character between the Fort Sill and Royer formations are well displayed in the NE¼ SW¼ sec. 26, T. 2 S., R. 4 E., where the main trail to the South ranch house passes practically along the contact for about 1,500 feet (Pl. VI, A).

Stratigraphic relations. The contact between the Fort Sill formation and the underlying Honey Creek formation in most places is partly or wholly obscured, so that exact details are lacking. At one locality of exceptionally good exposure, 2,100 feet west and

1,000 feet south of the NE cor. sec. 1, T. 3 S., R. 4 E., the basal sandy limestone bed of the Fort Sill has channelled 1 foot into upper Honey Creek dolomite along a horizontal distance of 25 feet, suggesting minor unconformity. Considered regionally, however, the uniform thickness of the lower limestone division of the Fort Sill, together with correlations from measured sections, indicate that the beds are essentially conformable and parallel.

The peripheral dips and overlapping relations at the granite inliers, occurring within the stratigraphic boundaries of the Fort Sill, have been described on a previous page.

The Fort Sill-Royer contact has been shown by mapping to represent virtually a time horizon and the beds are believed to be conformable.

Royer Dolomite

As mapped for this report, the Royer consists mostly of massive-bedded, coarsely crystalline, nearly pure dolomite about 550 feet thick, having apparently conformable contacts with the Fort Sill formation below and with the Butterly dolomite above. A unit of fine-grained limestone about 50 feet thick occurs locally in the middle part of the formation in the southern half of the mapped area.

Distribution. The Royer is the thickest formation mapped in the Mill Creek-Ravia area and accordingly it has the greatest breadth of outcrop. Like the other formations, the Royer crops out for a distance of about 9 miles in a northerly direction across the Tishomingo anticline and is terminated on the north and south by major faults. The outcrops can be divided conveniently into northern, central, and southern geographical units of approximately equal area, the central unit being characterized by faulting and an eastward offsetting of the formations. For the Royer the outcrop width in most places ranges between 1,000 and 1,500 feet and reaches extremes of 700 and 3,000 feet. The total outcrop covers an area of about 1,400 acres.

In the northern geographical unit the outcrop of the Royer dolomite is a north-trending band averaging about 1,500 feet in width that extends northward from the SW¼ sec. 26 to the southern part of sec. 10, T. 2 S., R. 4 E. There is a pronounced curvature in the outcrop in secs. 22, 15, and 10, caused by (1) irregularities of deposition around the isolated granite outcrops, to the contours of which the strike of the beds originally conformed in a general way, (2) erosion around the topographically low granite masses, which tends to increase curvature by swinging the outcrops downdip to the west, and (3) a small anticline and syncline between the two granite areas, chiefly in sec. 15.

The Royer outcrops in the central faulted area, mostly in secs. 35 and 36, T. 2 S., R. 4 E., and secs. 1 and 2, T. 3 S., R. 4 E., occur in discontinuous, offset bands of slightly different orientation in which the normal dip is about 11° westward. The exceptionally wide outcrop of 3,000 feet in secs. 35 and 36 results from the low dip of the beds and relative flatness of the ground surface.

The Royer dolomite crops out in the southern unit as a northwest-trending, slightly curved strip about 1,500 feet wide that extends from the NW¼ sec. 30, T. 3 S., R. 5 E. to the SE¼ sec. 2, T. 3 S., R. 4 E. The diversity of dip, which ranges between 12 and 30 degrees, results from proximity to the large fault in sec. 30 and to a similar fault in sec. 13, T. 3 S., R. 4 E.; the width of outcrop is in turn determined largely by steepness of dip.

Thickness. In the Mill Creek-Ravia area the thickness of the Royer dolomite ranges between 513 feet and 567 feet and averages about 550 feet. It is 551 feet in the NW¼ sec. 13, T. 3 S., R. 4 E.; 567 feet in secs. 35 and 36, T. 2 S., R. 4 E.; 559 feet in secs. 22 and 23, T. 2 S., R. 4 E., about 0.3 mile southwest of the largest granite inlier; and 513 feet in the east-central part of sec. 15, T. 2 S., R. 4 E.

Character. The Royer formation in the Mill Creek-Ravia area is composed almost exclusively of dolomite, the few beds of limestone making up only a trivial part of the formation. The entire thickness of about 550 feet is essentially similar in being non-cherty, non-sandy, and non-argillaceous, and like most dolomites in the Arbuckle Mountains the beds have a conspicuous crystalline texture. Despite these similarities there are sufficient differences in degree of crystallinity and outcrop characters that textural types may be recognized. The textural classifications here adopted for field identification of dolomite crystallinity, in which a 10X hand lens was used, is as follows:

Diameter (mm)	Crystallinity
>1.0	very coarse
1.0 -0.5	coarse
0.5 -0.25	medium
0.25-0.12	fine
<0.12	very fine

One kind of dolomite clearly predominates. It is typically coarse-crystalline, the individual crystals of which range in diameter from 0.5 to 1.0 mm in most beds and locally reach the exceptional coarseness of 5.0 mm (Pl. VII, B). The prevailing color is very light gray to white, grading into beds that are mottled in shades of gray, pink, lilac, or yellow. A few beds are dark gray to light chocolate. The dolomite occurs in poorly defined, massive beds that weather to dark-colored, honeycombed crags standing 2 to 3 feet above the ground surface (Pl. VI). Where the dip of the rocks is 15° or less the outcropping beds are eroded into low, pinnacle-like blocks by solution along widely spaced joints. The rock is compact but not tough, and readily crushes to powder under the hammer, owing to the relative softness, coarse texture, and excellent cleavage of the dolomite crystals.

Thin sections show that the rock is virtually pure, calcite-free dolomite, the dolomite occurring in subhedral to irregular crystals containing dark-colored, dust-like inclusions (Pl. X, A-D). In hand specimen the texture appears equigranular, and most thin sections show similar uniform-grained texture with sharp crystal boundaries, but in some an inequigranular texture is evident. In these the crystals have sutured, interlocking boundaries and show indistinct mortar structure,[25] both of which indicate recrystallization (Pl. X, B). Such features appear to be of local development.

One noteworthy optical character is that nearly all the large crystals have fan-shaped or flamboyant extinction, caused by the

25 Grout, F. F., "Petrography and Petrology", *McGraw-Hill*, pp. 353-354, 1932.

distortion during crystal growth of the kind that produces the familiar saddle-shaped crystal form of dolomite.

The solution cavities and pits visible on weathered outcrops are in part aligned along bedding planes (Pl. VII, A), but in greater part they have no apparent relation to bedding structures. They are believed to result from differential solution of the rock, the cavity formation being governed chiefly by differences in texture rather than differences in mineral composition. In some of the cavities there is a thin encrustation or partial filling of fibrous calcite (Pl. X, D-E). The fibrous form and occurrence of the calcite exclusively in solution pockets on the outer, weathered surfaces of the outcropping beds proves that it is a deposit from surface waters. Probably no calcite of secondary origin will be found below a depth of a few feet over most of the area, and none was encountered in the new quarry.

The insoluble residue from this dolomite is very small, that from most of the 30 gram samples used being so small that it can hardly be weighed on an ordinary trip-scale laboratory balance, which is supposed to be accurate to about 0.1 gram. The insoluble residue consists of milky silt aggregates, finely granular to smooth, with impressions or molds from which dolomite crystals have been leached and which have been termed dolocasts by McQueen,[26] and dolomolds by others.[27] Associated with the silt aggregates is loose material of coarse silt (about 0.01 to 0.05 mm) size that consists of angular, detrital arkose; euhedral crystals of orthoclase feldspar of the glassy or adularia type, undoubtedly authigenic (Pl. XI, E); and a few small, waxy flakes of a green, micaceous mineral.

Strata of the coarsely crystalline type constitute the typical high-grade dolomite in the Mill Creek-Ravia area. Chemical analyses given on a following page show a uniform, close approximation to

26 McQueen, H. S., "Insoluble Residues as a Guide in Stratigraphic Studies": Appendix I in *Missouri Bureau Geol. and Mines*, 56th *Bienn. Rept.*, p. 9, 1931.

27 Crowley, A. J., and Hendricks, Leo, "Lower Ordovician and Upper Cambrian Subsurface Subdivisions in North-Central Texas": *Bull. Am. Assoc. Petrol. Geol.*, Vol. 29, p. 417, 1945.

Ireland, H. A., "Terminology for Insoluble Residues": *Bull. Am. Assoc. Petrol. Geol.*, Vol. 31, pp. 1479-1490, 1947.

theoretically pure $Ca,Mg(CO_3)_2$ with low percentages of the common impurities.

A second type of dolomite is of common distribution, although subordinate to strata of the coarsely crystalline type. It is characterized by light cinnamon-brown color, close to Ridgeway's 15'.Y-O. K;[28] even-grained, medium-crystalline, sugary texture; and occurrence in beds 4 to 10 inches thick that weather non-pitted and brownish-gray, with a rough surface. In thin section the individual crystals are seen to be subhedral rhombs about 0.2 to 0.5 mm in diameter, arranged in interlocking mosaic but showing no evidence of recrystallization (Pl. X, A). The crystals are slightly to moderately clouded with minute inclusions. Beds of this type have no other visible constituent except very thin seams or encrustations of secondary calcite. The insoluble residue and chemical composition are like that of coarsely crystalline dolomite. A chemical analysis of a 55-foot section of these beds is given in table V, laboratory number 9294.

Least extensive of the dolomites in the Royer is a type that is dark blue-gray, locally mottled with yellowish or brownish patches, and of medium-crystalline to fine-crystalline texture. The beds are 2 to 6 inches thick and weather to yellowish or dark gray, slightly pitted slabs and blocks. They are tough and resistant to the hammer and to a certain extent resemble quartzites. The stone has a little argillaceous material and slightly more insoluble residue than the other types. The residue itself, however, is indistinguishable from the others.

In addition to the dolomites, there are a few outcrops of limestone in the Royer of the Mill Creek-Ravia area. One outcrop of limestone 42 feet thick and 187 feet above the base of the formation was observed near the center SW¼ sec. 36, T. 2 S., R. 4 E. Another, of similar thickness and in about the same stratigraphic position, was noted in the SW¼ sec. 19, T. 3 S., R. 5 E., but none was found between these outcrops and none in the northern part of the area. These limestones are lenses that grade laterally into dolomite. The limestone is dark gray, fine-grained and compact and contains a

[28] Ridgeway, Robert, "Color Standards and Color Nomenclature": Washington, *published by author*, 1912.

small amount, probably 10 percent or less, of dolomite in lacy, crystalline aggregates. The beds are about 6 to 12 inches thick and weather to light blue-gray, thin-bedded slabs.

The Royer formation at the type locality in the Arbuckle anticline is composed of strata similar to those described in the area of the present report, with the exception that limestone and dolomitic limestone are more abundant in the type locality. The formation is well exposed in the SW¼ sec. 1, T. 2 S., R. 1 E. Murray County, where it is 735 feet thick, according to the writer's measurements. Near the middle of the formation are two units, aggregating 100 feet in thickness, of fine-grained, french-gray limestone in which the calcite crystals are about 0.01 to 0.02 mm in diameter. Certain beds grade irregularly into mottled dolomitic limestone containing about 50 percent dolomite in the form of coarse-crystalline, orange-colored aggregates; and some of the dolomitic limestones grade further into pure dolomite of very coarse-crystalline texture, in which individual crystals, as shown in thin sections, are 3.0 to 5.0 mm in diameter. Such relations are significant because they suggest very strongly that the dolomite originated by replacement of limestone. It also is evident that the crystallinity of the dolomite is related to some process other than metamorphism because the associated limestone is only slightly if at all re-crystallized. The dolomites are not metamorphic in origin and therefore they are not marbles within the geologic meaning of the word.

Origin. Enough evidence has been accumulated to point out with reasonable assurance the probable origin of the Royer and most other dolomites in the Arbuckle Mountains. The dolomites, particularly those that are coarse- to medium-crystalline, probably are of exclusively secondary origin because field and textural relations show that they have replaced limestones. The dolomite strata are so thick and so extensive, however, that it is difficult to conceive of them having been formed by hydrothermal solutions of magmatic origin, for no adequate source of such tremendous quantities of magnesium is believed to have been available. On the other hand the sedimentary rocks of the Arbuckle group were deposited in a typical marine environment, as shown by the presence of trilobites, brachiopods, graptolites, and other fossils, so that the magnesium normally present in sea water would be sufficient for the precipitation of almost any amount of dolomite.

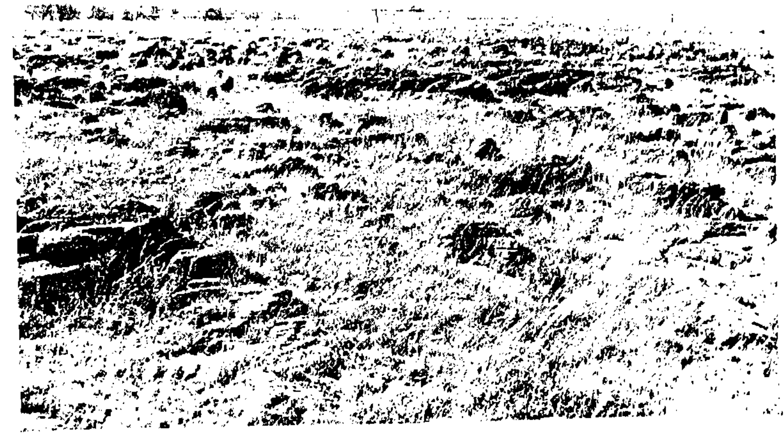
The dolomitization probably took place syngenetically, in marine water of normal temperature a short time after the limestone was deposited and lithified, and before the ocean floor was uplifted above sea level. Although replacement was virtually complete for the Royer and Butterly formations, locally and at certain times there was insufficient magnesium in the sea to cause complete dolomitization and this resulted in partial replacement and the production of dolomitic limestone.

The size of the dolomite crystals probably depended more than any other factor on the rate of deposition from the sea and the rate of replacement of the limestone, the larger crystals being deposited at a slower rate. The large crystal size does not indicate metamorphism because there is very little evidence of recrystallization. The slight amount of recrystallization that was noted probably occurred in localized areas of intense fracturing where the rocks were partly granulated, at a time when the strata were deeply buried and therefore under comparatively high pressure and somewhat elevated temperature. Under these conditions dolomite may be dissolved at loci of granulation and precipitated in the form of irregular patches or to a lesser extent in veins.

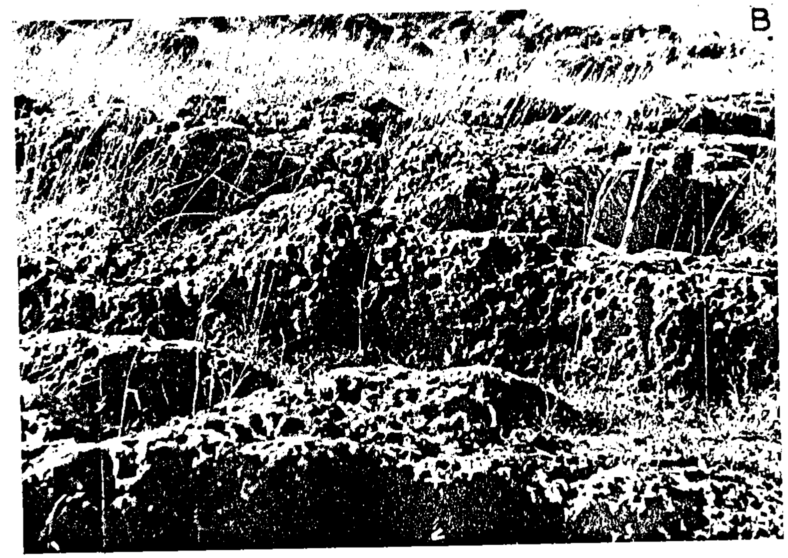
The bedding features of the dolomite probably are determined by the original characters of the limestone, that is, thick beds of limestone will yield similar thick strata of dolomite and thin-bedded limestone will be converted to thin-bedded dolomite. This conclusion can not be relied upon with complete confidence, however, because the coarse crystallinity of the dolomite obliterates many of the primary textures and structures of the limestone and this tends to make dolomite strata appear thick-bedded and massive regardless of bedding in the stone which the dolomites replaced.

The formation of calcite in surface cavities of dolomite strata is explained by the fact that sub-aerial solution of dolomite yields bicarbonates of calcium and magnesium. The two salts are not reprecipitated together as dolomite at surface temperatures and pres-

A



B

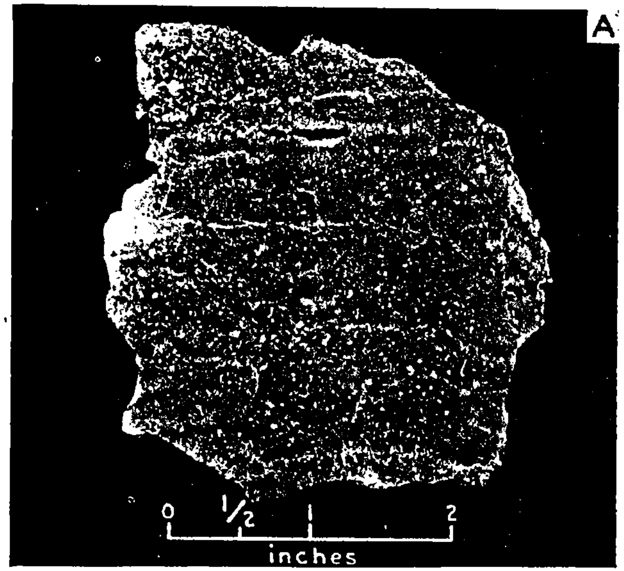


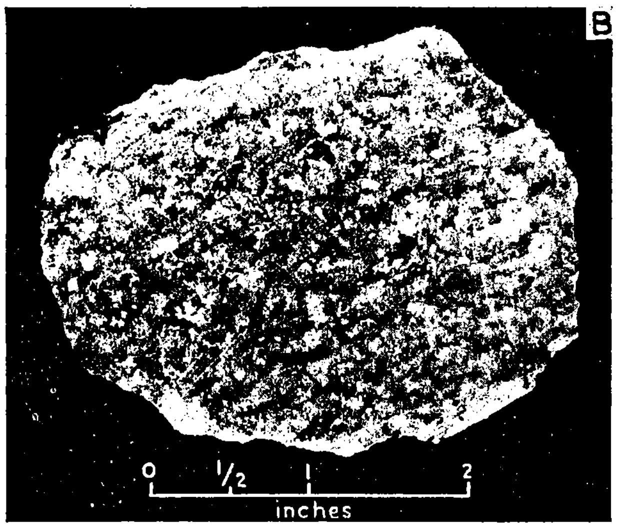
OUTCROPS OF ROYER DOLOMITE.

A. Typical exposure on the "rock prairie". Contact in foreground of dark-weathering, pitted crags of coarsely crystalline dolomite in lower part of the Royer, with light-weathering, non-pitted dolomite at the top of Fort Sill formaion. View toward northwest, in the NW¼ SW¼ sec. 26, T. 2 S., R. 4 E.

B. Detail of pitted surfaces characteristic of coarsely crystalline Royer dolomite. Same locality as above.

PLATE VII.



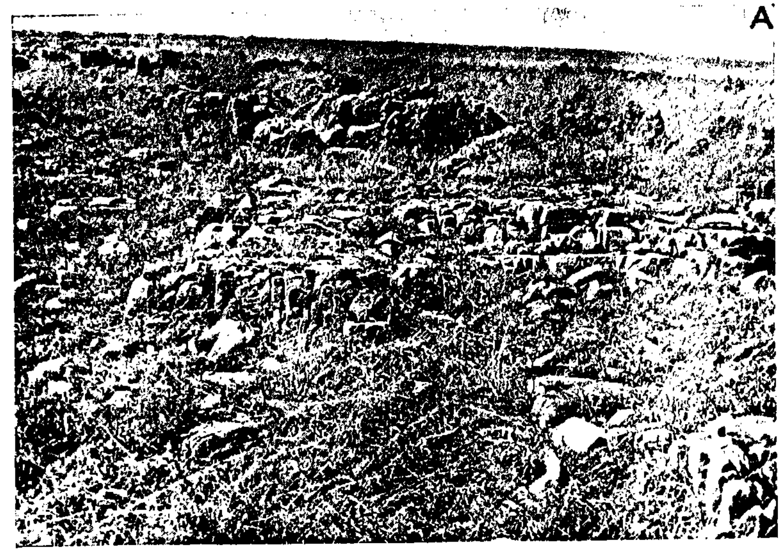


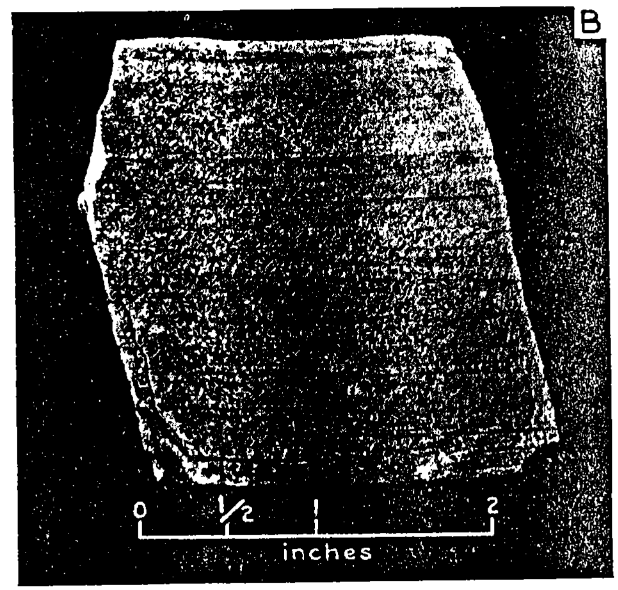
POLISHED SURFACES OF ROYER DOLOMITE.

A. Coarsely crystalline dolomite showing tendency for alignment of cavities along bedding planes.

B. Very coarsely crystalline dolomite from middle part of Royer formation near type locality in Arbuckle anticline, NW¼ SW¼ sec. 1, T. 2 S., R. 1 E., Murray County.

PLATE VIII.



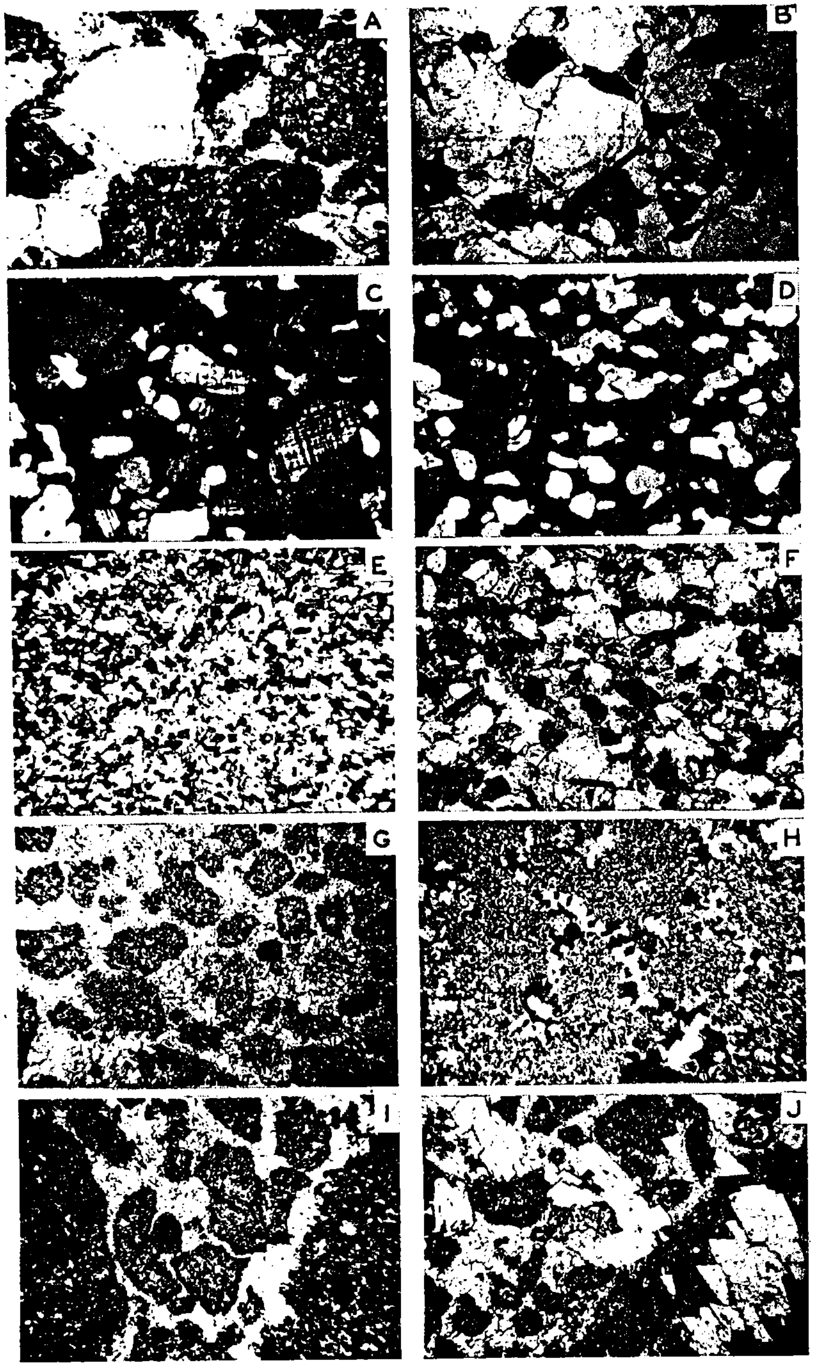


LAMINATED DOLOMITE IN BUTTERLY FORMATION.

A. Surface exposure illustrating light color and typical weathering of beds to smooth blocks or "flags". Thickness of bed is 5 feet. Base of Butterly dolomite, looking west from a point 600 feet west and 400 feet south of the NE cor. sec. 2, T. 3 S., R. 4 E.

B. Detailed view of weathered specimen, showing strongly developed laminations.

PLATE IX.



PHOTOMICROGRAPHS OF REAGAN SANDSTONE (A-D), HONEY CREEK SANDY DOLOMITE (E-F), AND FORT SILL LIMESTONE (G-J).

PLATE IX.

A, B. Coarse-grained phase of Reagan sandstone, poorly sorted, showing subrounded quartz (light gray) and partly decomposed orthoclase feldspar (nearly black). In upper right corner of A is a grain with micrographic intergrowth of quartz and feldspar. Plain light, 17X.

C. Medium-grained phase, illustrating wide range in size of particles and abundance of unaltered microcline feldspar (grid pattern). Crossed nicols, 17X.

D. Fine-textured phase, an uncommon type in the Reagan formation. The grains are predominantly quartz. Crossed nicols, 17X.

E. Typical sandy dolomite from lower member of Honey Creek formation. Angular fragments, mostly less than 0.07 mm in diameter, of quartz and feldspar (white), and rounded pellets of glauconite (black) in a matrix of dolomite (dark gray). Plain light, 17X.

F. Subangular quartz (white), angular cleavage fragments of feldspar (dark-gray), rounded grains of glauconite (black), and zircon (grain with high relief in lower right), all surrounded by mottled dolomite. Plain light, 40X.

G. Pellet limestone typical of lower limestone division of Fort Sill formation. Plain light, 17X.

H. Same lithology as G, but pellets of larger size. Pellets of fine-grained limestone, probably rounded fragments of algae, cemented by medium-crystalline calcite. Crossed nicols, 17X.

I. Parts of *Girvanella* algae, shown at right and left, are composed of fine-grained calcite. Pellets of similar composition, probably fragmented algae, occur between them in a matrix of coarser grained calcite. Plain light, 17X. Compare with pellets in G. and H.

J. *Girvanella* algae, pellets, and cement partly replaced by rhombohedrons of dolomite. Plain light, 17X.

PLATE X.

A. Typical coarsely crystalline, even-textured dolomite from middle part of Royer formation. Subhedral crystals about 0.5 mm in diameter, some of which are partly clouded with dust-like inclusions. Plain light, 100X.

B. Coarsely crystalline dolomite with irregular, sutured boundaries, probably recrystallized in part. Crossed nicols, 17X.

C. Fine-grained, local phase of high-grade dolomite in Royer formation. Plain light, 40X.

D. Feathery calcite, probably a ground-water precipitate, in cavity of coarsely crystalline Royer dolomite. The central part of the well-formed dolomite crystals is clouded with dark-colored particles, whereas the outer part is colorless. Plain light, 17X.

E. Fibrous structure of calcite in dolomite cavity. Crossed nicols, 17X.

PLATE XI.

A. Laminated, finely crystalline dolomite characteristic of the Butterly formation (see Pl. VIII, B). Two laminae are shown by concentrations of dark-colored clay extending horizontally across photograph. Plain light, 17X.

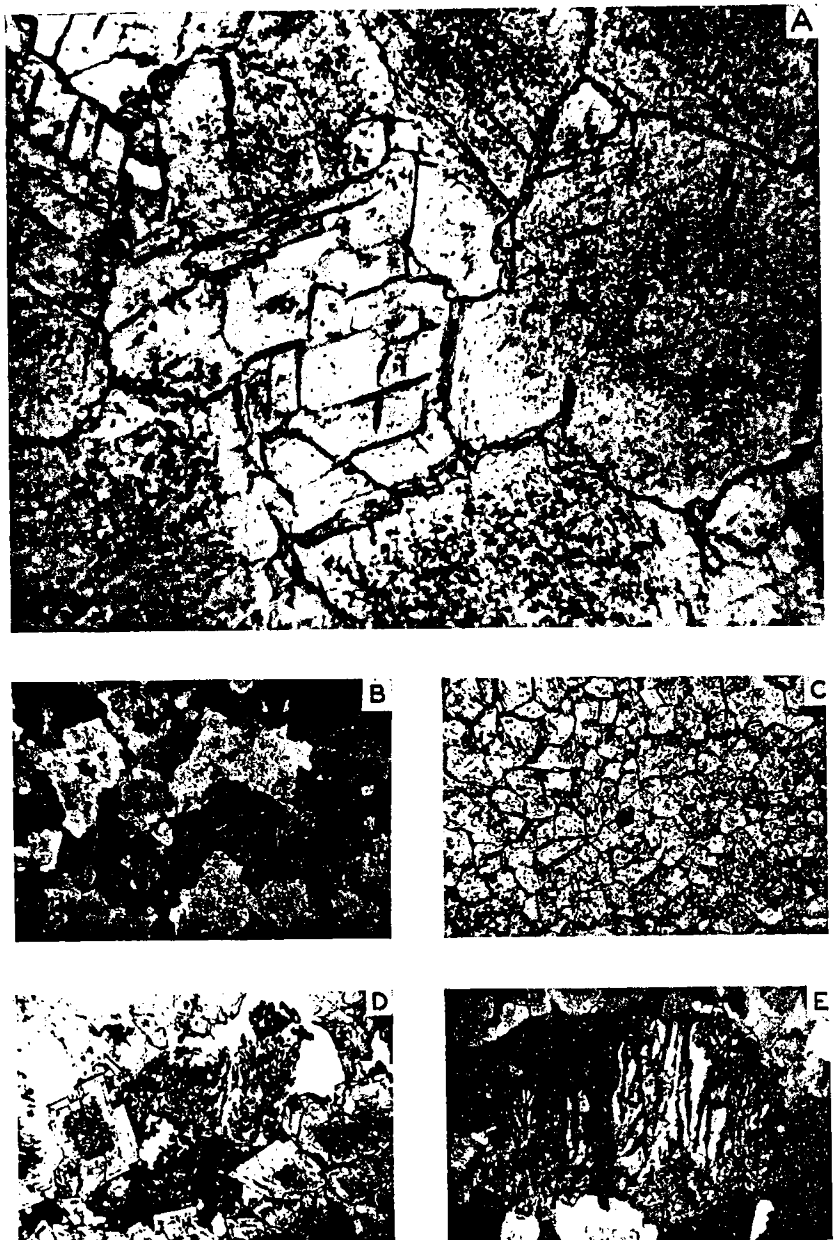
B. Same as A, 40X, illustrating sub-rhombic outline of dolomite grains.

C. Siliceous oolite from upper part of Butterly formation, cut by vein of dolomite in upper left corner. Dark circles and wavy bands contain reddish-brown iron oxide. Plain light, 17X.

D. Same as C, crossed nicols. Note growth rings of fibrous chalcedony and cavity filling of granular quartz.

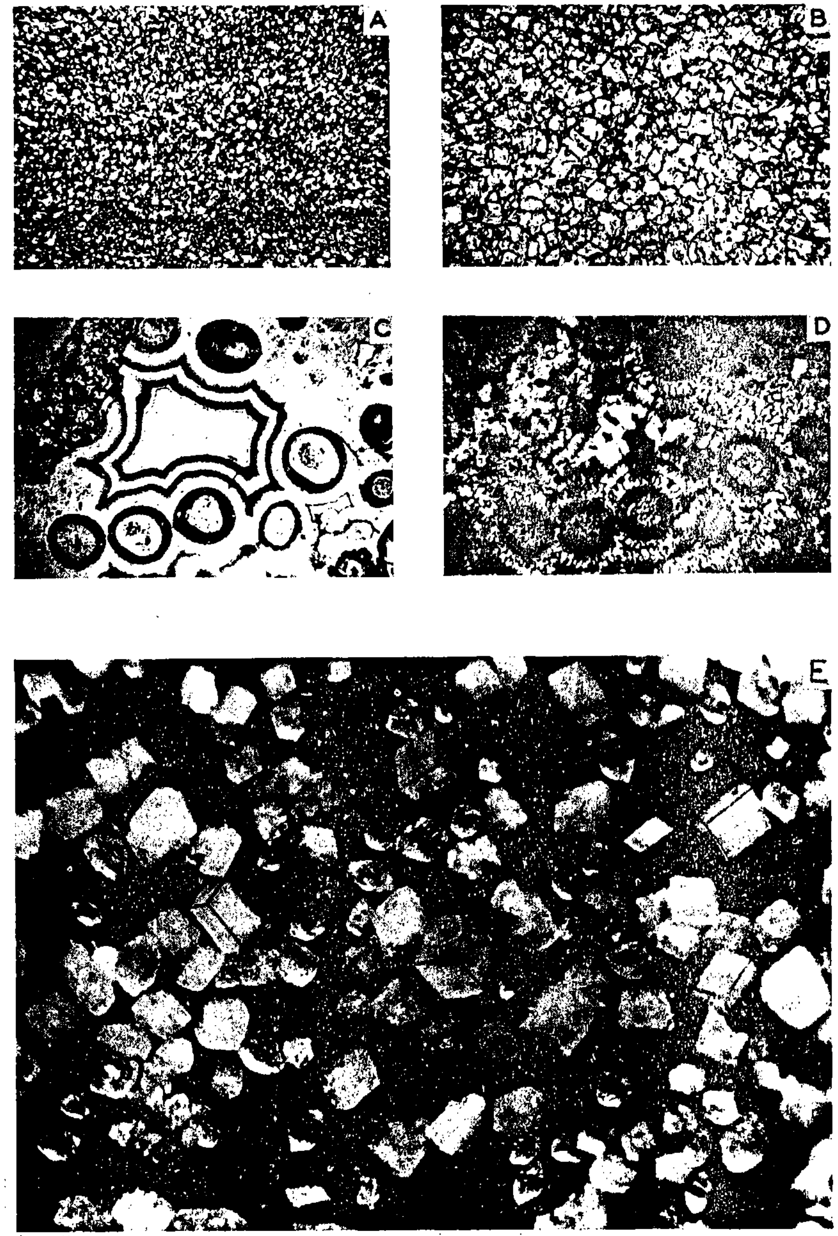
E. Insoluble residue from Butterly dolomite, containing feldspar (adularia) of authigenic growth in six-sided euhedral crystals, and a few doubly terminated crystals of quartz. Crystal form of the adularia consists of the basal pinacoid (001) and prism (110). Similar crystals are found in the Fort Sill and Royer formations, both in limestone and dolomite. 45X.

PLATE X.

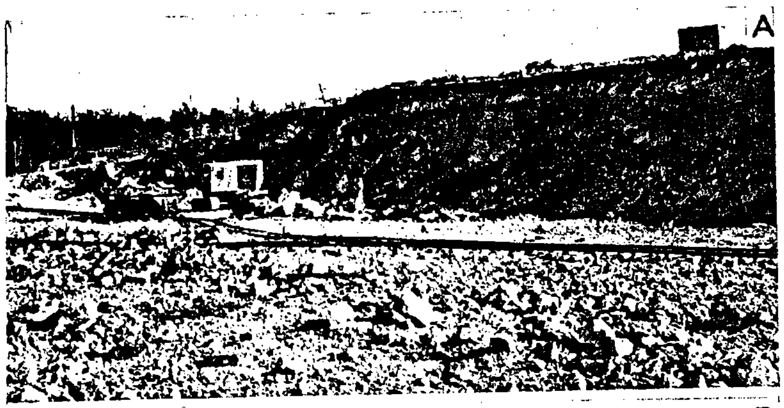


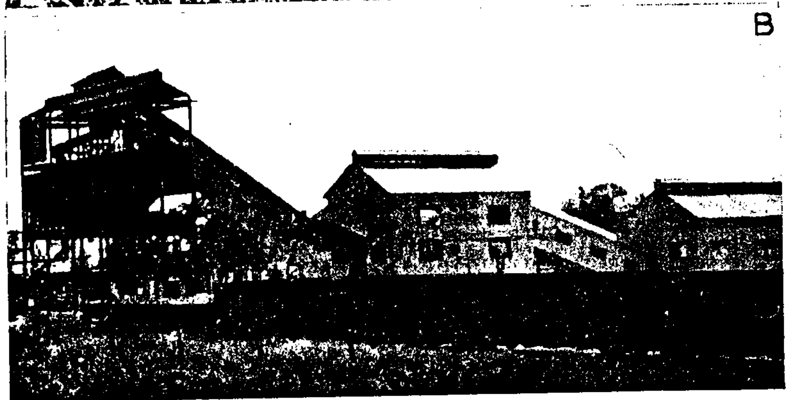
PHOTOMICROGRAPHS OF ROYER DOLOMITE.

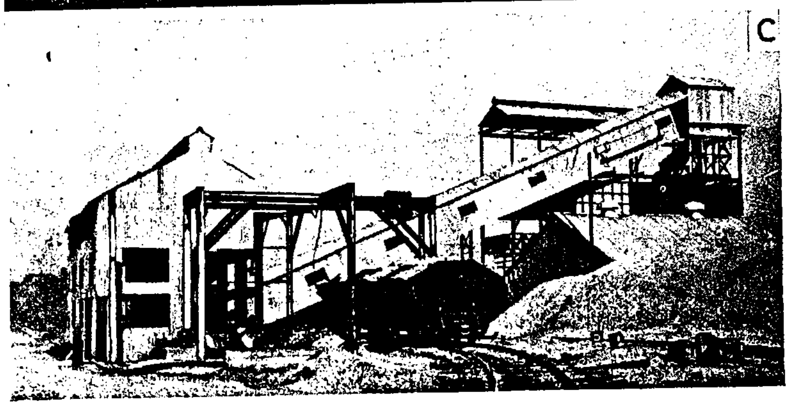
PLATE XI.



PHOTOMICROGRAPHS OF DOLOMITE, SILICEOUS OOLITE, AND EUHEDRAL FELDSPAR FROM BUTTERLY FORMATION.







A. The Rock Products Manufacturing Corporation's quarry in Royer dolomite, cen. N½ SW¼ sec. 36, T. 2 S., R. 3 E., Johnston County.

B, C. Crushing plant of The Rock Products Manufacturing Corporation, one mile north of Troy.

sures and the magnesium salt is carried away in solution. Calcium carbonate, however, is stable under surface conditions and is precipitated as calcite in rock openings upon evaporation of the solution.

Field identification. The Royer formation in the Mill Creek-Ravia area is composed almost exclusively of dolomite. As there are several kinds of dolomite in the Royer, based on details of texture, bedding characters, impurities, and weathering effects, and because each of these kinds may be found in other Cambrian formations of the area, only mass characters as a whole are valuable in identifying the Royer as a formation. The Royer consists *typically* of light-colored, coarsely crystalline, massive-bedded dolomite, without quartz druse and lacking detrital sand in most beds. A sequence of this lithology 200 feet or more in thickness almost certainly could be identified safely as Royer. Coarsely crystalline dolomites occur likewise in the Butterly, but such beds are likely to be less than about 50 feet in total thickness, and in addition they are likely to contain quartz druse or sand, or both. Moreover, the Butterly is characterized by interbedded thin strata of laminated, finely crystalline dolomite, a type which is lacking in the Royer.

Coarsely crystalline, light-colored dolomite also has been observed in the Honey Creek and Fort Sill formations in the mapped area, but in each of them it occurs in units less than about 25 feet thick, interbedded with finer-grained and thinner-bedded dolomites.

In mapping, the base of the Royer was placed at the base of the massive-bedded, coarsely crystalline, rough-weathering dolomites which crop out above the relatively thin-bedded, yellowish-brown dolomites at the top of the Fort Sill formation (Pl. VI, A). In most places the lower massive beds of the Royer are 100 feet or more in thickness, and this is the first thick sequence of massive-bedded dolomite encountered above the Reagan sandstone. The top of the Royer has been mapped at the base of the lowest (oldest) dolomite bed that is laminated, cream-colored, and finely crystalline, this bed being regarded as the base of the Butterly dolomite (Pl. VIII, A). The bed is a convenient mappable unit and is believed to be a single time horizon in the Mill Creek-Ravia area.

Stratigraphic relations. The Royer dolomite as delimited in this area has conformable contacts with the underlying Fort Sill formation and with the overlying Butterly dolomite. There is no evidence of unconformity from field observations and the formation consistently is of uniform thickness within the mapped area. At two localities in the northern part of the area, however, the Royer rests not on Fort Sill strata but on buried hills of pre-Cambrian granite. In the eastern part of sec. 22, T. 2 S., R. 4 E. the base of the Royer is unconformable on granite; and in the NE¼ sec. 15 of the same township, beds in about the lower half of the formation overlap and cover a similar granite island.

Butterly Dolomite

The Butterly formation in the Mill Creek-Ravia area includes strata of dolomite 333 to 435 feet thick that lie conformably on the Royer dolomite below and grade upward into limestone beds of the McKenzie Hill formation. The differences in thickness are caused by irregular gradation into limestone at the top of the formation.

The Butterly in the Mill Creek-Ravia area is underlain by Royer dolomite, the Signal Mountain limestone being unrecognizable because of facies change. The recognition of the Butterly in the area of the present report was established through lithologic similarities with the Butterly dolomite of the type area in the Arbuckle anticline; and measured section correlation indicates the probable time equivalency of the Butterly in the two areas (fig. 2).

Though subordinate in aggregate thickness, beds of laminated, cream-colored, finely crystalline dolomite, about 5 feet thick, constitute the most distinctive lithologic feature of the formation. These are interstratified with much thicker units of medium to coarsely crystalline gray dolomite. Many beds contain quartz druse or sand.

Distribution. The Butterly formation, like the other Cambrian formations of the area, crops out in a series of disconnected, northward-trending, narrow bands across the Tishomingo anticline. These bands range in width from 800 to 2,000 feet. The outcrop

pattern is comparatively simple, consisting of a north and a south segment, each about 3 miles long, and a group of three smaller offset blocks in the central faulted area of the anticline.

Thickness. Four measurements of the Butterly formation in the Mill Creek-Ravia area show a range in thickness from 333 feet to 435 feet and an average of about 400 feet. Inasmuch as the base probably is conformable on the Royer, as here recognized, all variations are believed to take place in the upper part of the formation, chiefly by erratic dolomitization of limestone beds in the lower part of the overlying McKenzie Hill formation. There is no reason to believe that the thicknesses of the Butterly were influenced by deposition over the granite hills which affected the thicknesses of pre-Royer strata. The irregular topographic surface developed on the granite was completely covered by mid-Royer time, so that the Butterly sediments were deposited on a comparatively flat surface at a low initial dip.

The greatest thickness, 435 feet, is in the north-central part of the area, in sec. 22, T. 2 S., R. 4 E. (measured section A). About 1 mile northward, in sec. 15, near the northern edge of the Tishomingo anticline, the Butterly is 423 feet thick (measured section B). The thinnest section, 333 feet, was measured in the central part of the area, in sec. 2, T. 3 S., R. 4 E. (measured section C), this being about 2.5 miles southward from the locality of greatest thickness. Two miles farther southward, in sec. 14, T. 3 S., R. 4 E., the thickness is 376 feet.

In the Arbuckle anticline the thickness of the Butterly formation is rather consistently about 300 feet, being 286 feet at the type locality in sec. 18, T. 2 S., R. 2 E.,[29] and 297 feet in sec. 1, T. 2 S., R. 1 E., about 2 miles northwestward along the strike. In this area both the upper and lower contacts of the Butterly are erratically gradational into limestone.

Character. Strata here referred to the Butterly formation include interbedded layers of crystalline-textured dolomite. Thin

[29] Decker, C. E., "Progress Report on the Classification of the Timbered Hills and Arbuckle Groups of Rocks, Arbuckle and Wichita Mountains, Oklahoma": *Okla. Geol. Survey Circular* 22, p. 22, 1939.

beds of very finely crystalline, laminated, cream-colored dolomite are characteristic but these constitute only about 10 percent of the total thickness of the formation and the remaining dolomite types are very similar to those of the underlying Royer formation. In general, however, dolomite in the Butterly is more impure and contains more quartz druse and sand than the Royer.

The characteristic beds of laminated dolomite, of which 4 to 7 are exposed throughout the area, range in thickness from 5 to 8 feet. The lowest marks the base of the formation. They weather either to platy "flags" or to smooth partly rounded blocks showing prominently developed parallel laminae 1 mm or less in width (Pl. VIII, B). These beds are conspicuous in the field because of the contrast between their pale cream to dead-white color, and the prevailing dark colors of the other rocks (Pl. VIII, A).

The texture of the laminated dolomites is uniformly very finely crystalline and equigranular. As seen in thin section under the petrographic microscope, the dolomite grains are rhombic in outline and have an average diameter of about 0.05 mm. The lamination is caused principally by slight differences in size of the dolomite grains, by thin layers containing detrital quartz grains, and to a lesser extent by thin streaks of dark-colored clay material (Pl. XI, A). The rock nevertheless is nearly pure, as the insoluble residue is only about 1 percent. It consists of an indistinctive suite of granular quartz druse, silt aggregates, and silt-sized quartz grains.

About 60 percent of the total thickness of the Butterly is composed of dolomite that is massively bedded, coarsely crystalline, light in color, and weathers to dark gray honeycombed crags. These strata are virtually indistinguishable from the Royer except that they are likely to contain 1 to 10 percent of quartz druse. Throughout most of the formation dolomite of this type occurs in units about 10 to 50 feet thick, interbedded with finer textured dolomite.

Beds of fine and medium-crystalline dolomite are predominant in about the upper third of the formation. The fine-crystalline dolomite normally is compact and tough, dark gray to yellowish gray in color, and crops out in slightly pitted beds 2 to 6 inches

thick, whereas the medium-crystalline dolomite has a sugary texture and occurs in beds about 4 to 10 inches thick. Many of these beds contain a small amount of arkosic sand and disseminated quartz druse. Strata of similar lithology but with less impurities are present in the Royer formation.

A bed of siliceous oolite (Pl. XI, C-D) about 6 inches thick occurs locally in the upper part of the Butterly formation. It is a useful marker in the northern part of the mapped area but in the southern half, southward from sec. 26, T. 2 S., R. 4 E., no evidence of this bed could be found.

Field identification. Beds of laminated, cream-colored dolomite 5 feet to 8 feet thick constitute the most useful lithologic type in field identification of the Butterly. They are fully distinctive of the Butterly, for no similar type was found in other formations of the mapped area. Laminated dolomite beds in the lower member of the Honey Creek formation resemble them superficially, but can be distinguished by their greater thickness, gray-green color, and high content of fine sand and glauconite.

A comparison of dominant lithologic characters in the Royer, Butterly, and McKenzie Hill formations of the Mill Creek-Ravia area is shown in Table IV. The various distinctions may be used together to typify any of the given formations.

TABLE IV

LITHOLOGIC CHARACTERS OF ROYER, BUTTERLY, AND MCKENZIE HILL FORMATIONS

	Royer	Butterly	McKenzie Hill
Laminated, cream-colored dolomite	absent	common	absent
Coarsely crystalline dolomite	abundant	common	absent
Fine- or medium-crystalline dolomite	uncommon	common	uncommon
Limestone	rare	absent	abundant
Finely granular quartz druse	very rare	common	common
Smooth or tripolitic chert	absent	absent	abundant
Siliceous oolite	absent	6-inch bed locally in upper part	uncommon, in nodules only

In mapping, the base of the Butterly was placed at the base of the lowest beds of laminated, cream-colored dolomite. From detailed field work it appears that the same bed has been mapped in all places, and thus represents a single stratigraphic unit. On aerial photographs the outcrop of this basal bed, and others like it within the Butterly formation, can be distinguished as narrow, light-colored bands.

The top of the Butterly is mapped at the contact of the sequence of dolomite strata containing the laminated, cream-colored dolomite, with the first overlying persistent strata of limestones, the limestones being assigned to the McKenzie Hill formation.

Stratigraphic relations. The Butterly dolomite in the Mill Creek-Ravia area is conformable on the underlying Royer dolomite as here mapped, and grades upward into limestone of the overlying McKenzie Hill formation. In sec. 1, T. 2 S., R. 1 E., near the type section of the Butterly in the Arbuckle anticline, the Butterly dolomite is erratically gradational into limestone at both its upper and lower contacts.

ORDOVICIAN SYSTEM

McKenzie Hill Formation

The McKenzie Hill formation, of Lower Ordovician age, is composed mostly of dark-colored, fine-grained limestone. It crops out as units of massive-bedded, hard, compact strata alternating with thin-bedded, marly limestone. Many beds contain a small percentage of dolomite in disseminated crystals; and a few beds of nearly pure dolomite have been found, particularly in the northern part of the mapped area.

Nodules of smooth chert occur in some beds, but much of the chert in the formation is in porous, light-colored aggregates. The porous chert is a weathering product, much like tripoli, derived by leaching calcium carbonate from an intimate mixture of calcite and fine-grained silica. As a general rule the porous, tripolitic chert occurs in a distinctive unit of conglomeratic limestones, and fills

the interstitial matrix between pebbles. The conglomerate itself is the intraformational, flat-pebble type.[30]

The cherty conglomeratic limestone crops out in the Mill Creek-Ravia area as a low ridge that is readily identifiable in the field as well as from aerial photographs. It contains graptolites, which, according to C. E. Decker,[31] are found in similar lithology and in about the same stratigraphic position in the McKenzie Hill formation of the Arbuckle anticline. It has been a valuable key bed in mapping, and it is equally valuable as a datum for correlating measured sections of the Cambrian beds in the Arbuckle anticline with corresponding strata in the Tishomingo anticline (fig. 2).

The McKenzie Hill formation is underlain with gradational contact by the Butterly dolomite and is overlain by the Cool Creek formation. The Cool Creek is composed of limestones and dolomites which contain much chert in the form of boulders, nodules, and oolite. No well-defined boundary has been established between the McKenzie Hill and Cool Creek and no attempt was made to map this boundary for the present investigation.

[30] Walcott, C. D., "Paleozoic Intra-formational Conglomerates": *Bull. Geol. Soc. Am.*, Vol. 5, pp. 191-198, 1894.
[31] Decker, C. E., personal communication.

ECONOMIC GEOLOGY OF THE ROYER DOLOMITE

Physical Properties

The Royer dolomite in the area of the present report is characterized by a crystalline texture, which is readily observable on a broken surface by its "sparkle", or reflection of light from the many cleavage surfaces of the individual dolomite crystals. These crystals normally range between 0.5 and 1.0 mm in diameter, and are packed together in random and uniform distribution. Although crystal shape is difficult to determine from hand specimens, a subrhombic to irregular outline can be seen in thin section with medium-power magnification of the petrographic microscope.

The stone is easily sawed and takes a high polish. One common lithologic type of the Royer dolomite in particular bears a very close resemblance to commercial marbles and possibly could be used for this purpose. It occurs in light brown beds 4 to 10 inches thick and consists of uniform-textured dolomite crystals 0.2 to 0.4 mm in diameter.

The Royer is compact and has high crushing strength, which results from the interlocking contacts of its randomly oriented dolomite crystals. There is no true cementing material and practically no impurities such as chert or clay. A 100-pound block of typical, coarse-crystalline dolomite from the outcrop (not a freshly quarried specimen), tested in 1942 for the Lone Star Steel Co., Daingerfield, Texas, was found to have a compressive strength of 27,100 pounds per square inch.

Despite its high compressive strength the stone can be crushed by commercial grinding equipment, owing to the coarse-crystalline texture and the excellent rhombohedral cleavage of the dolomite crystals. The ease of crushing is an advantage to producers of crushed and ground stone for glass plant and agricultural use, and its compactness is such that it could be quarried for crushed stone without excessive loss of fines.

The prevailing color is nearly white to light drab-gray, somewhat lighter than Ridgway's "pale drab-gray" designated 17''''.O-Y.f. A pale pink, lilac, or very light brown shade is a common overtone, being superimposed uniformly over the prevailing color. A very faint mottled or banded effect is noticeable in some outcrops. Invariably, the color is somewhat lighter when the stone is powdered.

Extensive observations on the outcrop, together with thin section examination and chemical analyses, indicate that minerals like pyrite and marcasite are present only in very small traces, so that there is no likelihood of undesirable staining resulting from the decomposition of such minerals.

Typical coarsely crystalline Royer dolomite crops out in most places as massive-bedded strata that weather to pitted or honeycombed masses. The pitting is thought to have resulted from differential solution of the dolomite by surface waters in small localized areas of coarser-than-normal grain size. Such surface pitting is common in coarse-textured limestones, a good example being in the Fernvale (Ordovician) limestone at its outcrop near Lawrence, Pontotoc County, Oklahoma. Quarries in the coarsely crystalline Fernvale limestone at Lawrence, however, show that the fresh stone is only slightly pitted a few feet below the surface. This limestone is known from chemical analysis and mineralogical examination to consist of nearly pure calcite; therefore, the surface pitting is not caused by solution of different minerals, but probably results from textural differences in the calcite of the limestone. It may be inferred by analogy that the coarse-textured Royer likewise has been pitted by selective dissolving of different-sized crystalline grains of dolomite.

The dolomite occurs generally in beds about 2 to 3 feet thick, being separated by bedding planes that are distinct but not sharply defined. Except at the quarry opened near a major fault, it is not known to what extent these bedding planes will be present in fresh rock, nor to what extent they would aid in quarrying the rock for such purposes as dimension stone. Locally, bedding planes are very poorly developed, even at the outcrop, and it is suspected that a quarry face would show a homogeneous surface without prominent separation planes.

In very few places near large faults the Royer is much brecciated and closely jointed. Elsewhere it is not shattered into small blocks, but shows a system of widely spaced vertical joints that trend about at right angles to the strike of the dolomite. The joints are spaced irregularly, distances between them ranging from about 5 to 20 feet. Again, this observation is based on examination at the outcrop, where joints, however slight, have been widened and brought into prominence by dissolving action of water, whereas in subsurface the joints might well be insignificant.

A partial check on the inferences regarding subsurface pitting, jointing, bedding, and staining is made possible by observations at the newly opened quarry of the Rock Products Manufacturing Corporation in sec. 36, T. 2 S., R. 4 E. Here the Royer dolomite exposed in the 25-foot face is in part compact and free from noticeable cavities, but certain of the coarse-textured beds contain abundant cavities that range in diameter downward from about 1 inch. These cavities are encrusted with euhedral dolomite rhombohedrons that project from the walls and nearly fill some of the voids. The botryoidal calcite common in vugs on surface outcrops is not present in the fresh stone. No staining by decomposition products of iron minerals was observed.

The dolomite in the quarry face is much jointed, bedding planes are obscure, and some crush breccia is present. The closely spaced joint pattern and the crush breccia undoubtedly are the result of readjustment during faulting, for the quarry was opened less than 50 feet away from a fault on which the stratigraphic displacement is about 700 feet. Because of this tectonic disturbance, observations in the Rock Products quarry, as opened in mid-1948, may not be safely applied in less-faulted portions of the Mill Creek-Ravia area.

Chemical Composition

Significance of sampling method. Samples of Royer dolomite for chemical analysis were taken in the field from natural rock outcrops. The outcrops in the Mill Creek-Ravia area are exceptionally good, and where sampled at least 95 percent of the stone actually is exposed. Thus the samples have a high order of integrity and they

are believed to be fair representations of the dolomite. Analysis of dolomite from the recently opened quarry confirms this supposition.

According to the sampling method adopted, a sequence of rock outcrop was examined with the aid of a hand lens for visible impurities like chert or sand. If this preliminary inspection revealed insignificant amounts of these impurities, the thickness of the rock was calculated and the stone sampled with an ordinary geologists' steel hammer-pick.

Each sample, in detail, is a close approximation to a channel sample, being a composite of chips taken at right angles to the strike of the beds. It was intended that every inch of the exposed rock be represented. The sample contains about 6 cubic inches of chips per stratigraphic foot of stone, each chip being carefully trimmed of weathered surfaces that contain lichens and surface soil. To sample about 100 feet of stone in this manner requires approximately 1 day for a geologist working alone.

In spite of the precautions in trimming the chips, it is inevitable that some contaminating materials were included, leading to the conclusion that fresh rock beneath the surface probably would be even lower in impurities than indicated by analysis of the surface samples.

On the outcrop some of the pits in the dolomite are partly filled with encrustations of botryoidal calcite, which are responsible for the free calcium carbonate that is shown by analysis to be about 2 percent. No attempt was made to remove these encrustations, but it is known that they have been deposited at the surface by ground waters and are not present in a quarry face of fresh rock.

Chemical analyses. Detailed chemical analyses of carefully sampled outcrops invariably show that the Royer dolomite in the mapped area is a high grade stone suitable for the most exacting specifications of many chemical industries. The combined magnesium and calcium carbonates in 9 samples representing 791 stratigraphic feet average more than 99 percent, and in the best stone analyzed these carbonates total 99.51 percent. Dolomite from

TABLE V

Chemical Analyses of Royer Dolomite in Mill Creek-Ravia Area

A. C. Shead, analyst

Laboratory Number	9292	9293	9294	9295	9296	9379	9391	9262	9263	Average of outcrop samples	9821[1]
SiO_2	0.71	0.30	0.28	0.35	0.29	0.50	0.26	0.50	0.53	0.41	0.315
Al_2O_3 (et al)	0.12	0.10	0.11	0.25	0.16	0.21	0.19	0.23	0.22	0.177	0.195
Fe_2O_3	0.18	0.17	0.12	0.15	0.15	0.17	0.13	0.18	0.16	0.157	0.090
CaO	30.50	30.72	30.68	30.79	30.79	30.58	30.77	30.78	30.76	30.71	30.16
MgO	21.21	21.20	21.30	21.32	21.34	21.15	21.13	21.03	20.91	21.18	21.64
K_2O	0.067	0.067	0.028	0.044	0.040	0.063	0.030	0.049	0.075	0.051	0.059
Na_2O	0.011	0.033	0.032	0.031	0.025	0.023	0.024	0.044	0.035	0.029	0.036
SO_3	0.024	0.035	0.025	0.034	0.023	0.036	0.029	0.050	0.019	0.031	0.032
P_2O_5	0.006	0.004	0.004	0.008	0.006	0.004	0.002	0.004	0.002	0.004	0.003
H_2O at 105° C.	0.04	0.05	0.04	0.06	0.07	0.17	0.19	0.20	0.17	0.11	0.06
Loss on ignition (105°-950° C.)	47.09	47.35	47.36	47.32	47.37	47.27	47.30	47.16	47.13	47.26	47,383
TOTAL	99.958	100.029	99.979	100.357	100.264	100.176	100.055	100.227	100.011	100.219	99.970
RECALCULATION											
$CaCO_3$[2]	54.44	54.85	54.76	54.95	54.95	54.58	54.92	54.94	54.90	54.81	53.83
$MgCO_3$[3]	44.36	44.34	44.55	44.59	44.63	44.24	44.19	43.98	43.73	44.29	45.26
TOTAL	98.80	99.19	99.31	99.54	99.58	98.82	99.11	98.92	98.63	99.10	99.09
$CaMg(CO_3)_2$ (Dolomite)	97.02	96.97	97.43	97.52	97.61	96.75	96.64	96.18	95.64	96.86	98.98
Excess $CaCO_3$ (calcite)	1.78	2.22	1.88	2.02	1.97	2.07	2.47	2.74	2.99	2.24	0.11

[1] analysis by A. L. Burwell [2] calculated from CaO [3] calculated from MgO

9292. SW¼ NE¼ SW¼ sec. 36, T. 2 S., R. 4. E. 44 feet (basal Royer). Dolomite, chocolate brown to gray, medium-crystalline, sugary texture. Beds 1 to 2 feet thick, weather dark gray, slightly to deeply pitted.

9293. SW¼ NE¼ SW¼ sec. 36, T. 2 S., R. 4 E. 88 feet (lower Royer), overlying sample 9292. Dolomite, gray to pink, coarsely crystalline, massive-bedded. Weathers deeply pitted.

9294. SW¼ SW¼ SW¼ sec. 36, T. 2 S., R. 4 E. 55 feet (middle Royer); base of sample 328 feet above base of formation. Dolomite, light brown, medium-crystalline, very uniform sugary texture. Beds 4 to 10 inches thick, weather to nearly white or light gray smooth blocks.

9295. SW¼ SW¼ SW¼ sec. 36, T. 2 S., R. 4 E. 44 feet (upper Royer), overlying sample 9294. Dolomite, light gray, mottled in shades of pink and brown, coarsely crystalline. Massive honeycombed ledges 2 to 3 feet thick.

9296. NE¼ NE¼ NE¼ sec. 2, T. 3 S., R. 4 E. 66 feet (upper Royer), stratigraphically above sample 9295 but separated from it by a covered interval 33 feet thick. Lithology like 9295.

9379. C N½ SW¼ sec. 26, T. 2 S., R. 4 E. Basal 169 feet of Royer. Dolomite, gray to light pink, coarsely crystalline. Crops out in dark-colored pitted ledges 1 to 3 feet thick.

9391. SW¼ NW¼ NW¼ sec. 13, T. 3 S., R. 4 E. 125 feet (upper Royer). Dolomite, light gray, coarsely crystalline, weathers honeycombed.

9262. NE¼ SE¼ SE¼ sec. 15, T. 2 S., R. 4 E. 75 feet (lower Royer). Dolomite, gray to pink, medium-crystalline; crops out in massive, pitted beds 1 to 3 feet thick.

9263. SE¼ SW¼ SE¼ sec. 10, T. 2 S., R. 4 E. 125 feet (middle Royer). Dolomite, light gray to pink, medium- to coarse-crystalline. Weathers to dark-colored, honeycombed crags.

9821. Sample representing 500 tons of Royer dolomite loaded for shipment from quarry of Rock Products Manufacturing Corp., C N½ SW¼ sec. 36, T. 2 S., R. 4 E. Sample, taken Oct. 5, 1948, consists of 1 to 6-inch stone.

Notes on method of chemical analysis:

SiO_2	True silica, determined by the hydrofluoric acid method.
Al_2O_3	R_2O_3 minus Fe_2O_3, containing chiefly alumina but probably with traces of TiO_2 and ZrO.
Fe_2O_3	Total iron in sample reported as ferric oxide.
CaO	Determined by standard gravimetric analysis, using double precipitation.
MgO	Determined by standard gravimetric analysis, using double precipitation.
K_2O, Na_2O	Determined by standard gravimetric analysis, correcting for alkalies in reagents.
SO_3	Total sulphur reported as SO_3.
P_2O_5	Total phosphorous reported at P_2O_5.
H_2O at 105° C.	Uncombined water contained in air-dried samples.
Loss on ignition (105°-950°).	As there is practically no organic matter and very little clay in samples submitted, loss on ignition is a very close approximation to CO_2.

the quarry contains 98.98 percent theoretical dolomite. The analyses are given in Table V.

Distribution of mineral impurities. From a mineralogical examination of many samples, it is apparent that the Royer is essentially a pure dolomite. The other minerals present include calcite, quartz, feldspar (detrital orthoclase and microcline, and authigenic adularia), clay, pyrite, and limonite—all in very small quantity. Except calcite, which occurs in surface cavities, these minerals are distributed as scattered particles throughout the rock or concentrated along bedding planes. They account for the silica, alumina, sodium, potassium, sulphur, and part of the iron.

The iron reported by analysis occurs in large part as ferrous iron (Fe^{++}), which is well known as an isomorphous replacement of magnesium in the dolomite crystal. A small part of the iron occurs as dustlike inclusions of hematite in dolomite grains, as pyrite (FeS_2) in widely scattered crystals, and as limonite ($Fe_2O_3.nH_2O$), the alteration product of pyrite. Pyrite also accounts for sulphur.

Silica occurs as free quartz or in combination as silicates. Quartz itself is present as minute drusy aggregates and as detrital grains, normally of very fine sand or silt size.

Alumina, alkalies, and part of the silica are present in feldspar and clay. The feldspar consists of authigenic adularia (colorless orthoclase) together with detrital orthoclase and microcline. All have the composition ($KAlSi_3O_8$), in which Na replaces some of the K. The clay, an unidentified type occurring as micaceous slivers and aggregates, undoubtedly is a hydrous aluminum silicate with alkalies and/or alkaline earths.

COMPARISON OF ROYER DOLOMITE WITH SILURIAN DOLOMITE FROM OHIO

In order to show the high quality of the Royer dolomite from the Mill Creek-Ravia area, a comparison was made with the Silurian dolomites of western Ohio, which have long been used in large quantity and are recognized as a standard of excellence. According to one publication:

"Ohio produces more dolomite than any other state in the country. In 1940 more than 800,000 tons was used as flux and more than 100,000 tons of raw stone was sold for refractory use. This does not include the much larger volume reported. as dead-burned for refractory use. Sandusky and Seneca Counties produce more than half of the dead-burned dolomite consumed in this country. Northwestern Ohio is the most productive lime-producing area in the country, and most of this lime is high-magnesian. The lime in this region is particularly well adapted for use in finishing-coat plaster, which, because of its high plasticity, is widely used and distributed to all parts of the country. Mason's lime and prepared masonry mortar also are made here. Other large users of dolomite are nearby glass factories.

"Another large dolomite-producing area runs from Clark to Adams Counties in southwestern Ohio. The Clark County product is used as a refractory, in paper manufacture, for the manufacture of Epsom salts, and for calcining into lime. In Clinton and Greene counties the stone is used both for furnace flux and as a refractory."[32]

From a table of about 300 analyses of Ohio carbonate rocks made by the Ohio Geological Survey, 25 were selected as representative of the best grade of Silurian dolomite. The analyses selected were made from quarry face samples of operating companies that use the stone for calcining or other chemical purposes; and all these quarries are in beds of Niagaran (including Cedarville and Guelph) and Monroe age. Quarries operated for crushed stone, fluxing stone, or agstone, most of which have more than 1 percent silica, were not included. The average of the 25 analyses are compared in Table VI with the average of 9 analyses of Royer dolomite from the Mill Creek-Ravia area.

Most striking of the comparisons to be made from Table VI is the close similarity in chemical composition between Oklahoma and Ohio dolomites, both containing 0.41 percent silica and more than 98.6 percent Ca and Mg carbonates. Considered in detail, the Oklahoma dolomites contain less iron, sulphur, and phosphorous than Ohio dolomites; and the Ohio dolomites are superior in containing less alumina and alkalies. In the outcrop samples of Royer

[32] Colby, S. F., "Occurrences and Uses of Dolomite in the United States": *U. S. Bureau of Mines Inform. Circ.* 7192, p. 17, 1941.

dolomite from Oklahoma the percentage of theoretical dolomite is less than expected because free calcite present in surface cavities reduces the MgO-CaO ratio. Dolomite from the quarry of the Rock Products Manufacturing Corporation, which probably is representative of subsurface stone throughout the Mill Creek-Ravia area, contains no free calcite, it corresponds closely to the theoretical MgO-CaO ratio, and the total dolomite content is 98.98 percent. This is slightly higher than the average for Ohio dolomites.

Despite the close similarity, certain intrinsic differences may be noted in mineral composition. The Oklahoma dolomite contains small but apparently consistent amounts of authigenic feldspar which increases, relatively, the percentage of Al_2O_3 and alkalies (K_2O and Na_2O). On the other hand, the Ohio dolomites commonly contain small amounts of celestite ($SrSO_4$), which increases the percentage of SO_4.

TABLE VI

CHEMICAL ANALYSES OF OKLAHOMA DOLOMITE COMPARED WITH OHIO DOLOMITE

	Royer Dolomite from Mill Creek-Ravia, Okla. Nine analyses from Outcrop. See Table V.		High Grade Silurian Dolomite from Western Ohio. 25 analyses from quarries.[1]	
	Average	Range	Average	Range
SiO_2	0.41	0.26 -0.71	0.41	0.06- 1.70
Al_2O_3	0.177	0.10 -0.25	0.07	0.02- 0.25
Fe_2O_3			0.057	0.02- 0.25
FeO			0.155	0.09- 0.23
Total Fe as Fe_2O_3	0.157	0.12 -0.18	0.229	
CaO	30.71	30.50-30.79	30.02	29.00-30.33
MgO	21.18	20.91-21.34	21.53	20.79-21.77
K_2O	0.051	0.028-0.075	low	$<$0.01- 0.06
Na_2O	0.029	0.011-0.044	low	$<$0.01- 0.03
SO_3	0.031	0.019-0.050	0.218	$<$0.01- 1.70
P_2O_5	0.004	0.002-0.008	0.042	$<$0.01- 0.09
H_2O at 105° C.	0.11	0.04 -0.20	0.133	0.02- 0.40
Loss on ignition (105°-950° C.)	47.26	47.09-47.37	47.09[2]	45.49-47.60[2]
		RECALCULATION		
$CaCO_3$[3]	54.81	54.44-54.95	53.57	51.76-54.13
$MgCO_3$[4]	44.29	43.63-44.73	45.03	43.48-45.53
Total	99.10	98.17-99.58	98.60	95.24-99.65
$CaMg(CO_3)_2$ (dolomite)	96.86	95.64-97.61	98.47	95.09-99.57
excess $CaCO_3$ (calcite)	2.24	1.78- 2.99	0.13	0.08- 0.15

[2] CO_2 [3] calculated from CaO [4] calculated from MgO

[1] Stout, Wilbur, "Dolomites and Limestones of Western Ohio": *Geol. Survey of Ohio*, (4th ser.) *Bull.* 42, 1941. Analyses from table facing page 424, sample numbers 45, 46, 51, 52, 53, 54, 107, 108, 115, 114, 111, 112, 113, 193, 195, 182, 179, 177, 178, 180, 176, 89, 310, 309, and 311. The samples are from the Niagara-Cedarville (6), Niagara (10), Monroe (6), and Niagara-Guelph (3).

It may be said in conclusion that the very best of the Ohio dolomites are without question of very high quality and justly deserve their long-standing reputation for use as lime, refractories, fluxing stone, and in glass making. It is also true that the Royer dolomite in the Arbuckle Mountains likewise is of high quality and suitable for these same uses.

Commercial Production

The field mapping of 1943, 1944, and 1945, together with the chemical analyses of outcrop samples, enabled the Geological Survey to recommend to prospective operators the most favorable dolomite quarry sites in the Mill Creek-Ravia area. A quarry site was selected in high purity dolomite of the Royer formation, and construction of a crushing mill and 3-mile narrow-gauge rail line began in 1946. The project was completed, the quarry opened, and shipments of stone were first made in June, 1948.

Examination of the quarry has provided information on the chemical composition of the Royer dolomite that was not available from outcrop investigations. Of most significance is the improvement in quality of the dolomite below the ground surface, particularly by an increase in the ratio of MgO to CaO. The free calcite present in cavities on the outcrop disappears below, and the stone there shows close approximation to theoretically pure dolomite.

The quarry, owned and operated by the Rock Products Manufacturing Corporation of Ada, Oklahoma, is in the central part of the N½ SW¼ sec. 36, T. 2 S., R. 4 E. Stone is hauled from the quarry over the narrow-gauge railroad 3 miles east to the crusher and shipping point on the Frisco railroad 1 mile north of Troy.

In the fall of 1948 the quarry was 500 feet long and about 25 feet high (Pl. XII, A). The face is elongated east-west and is being driven southward into the side of a gently sloping hill, where the beds dip 10° SW. The height of the face gradually increases as the workings go forward and eventually will be about 65 feet. The quarry floor is maintained as nearly level as possible in order to facilitate laying and moving the rail line, which advances parallel with the face as it is worked back. No water has yet been encountered in quarrying; in fact, water must be obtained for blast-hole drilling from a nearby spring-fed stream.

The principal blast holes are 6 inches in diameter, drilled with gasoline-powered churn drill on 10-foot centers with 15-foot burden, to a depth 6 feet below the quarry floor. Along the lateral margins

of the quarry accessory blast holes are drilled with a wagon drill driven by compressed air. Stone broken by blasting is loaded by a gasoline-powered shovel with 1¼-yard dipper into 7-ton, side-dump, all-steel quarry cars and hauled to the crushing plant by gasoline-powered locomotives.

The quarry is in the lower beds, nearly at the base, of the Royer dolomite. The original opening was made very close to a fault with a displacement of about 700 feet which brings Royer dolomite into contact with Reagan sandstone. The fault contact is identified in Plate XII,A by the tree line in the left background. Trees grow on the Reagan sandstone whereas the outcrop of Royer is nearly bare. The overburden at the quarry consists of a thin covering of dark-colored soil, mostly contained between outcropping dolomite crags and extending downward 1 to 3 feet into the quarry face.

The quarried stone is nearly identical with medium-crystalline dolomite described from the outcrop, with the important exception that botryoidal calcite is lacking entirely from the voids, which instead are lined with perfectly formed rhombohedrons of dolomite. Irregular patches of crush breccia, containing angular fragments of medium-crystalline gray dolomite embedded in orange-colored microcrystalline dolomite, occur locally in the quarry face. A small amount of greenish-gray plastic shale likewise occurs locally, in places as a half-inch seam following bedding surfaces and in other places filling joints normal to bedding. The strata are closely and irregularly jointed, undoubtedly because they are here so close to a major fault.

At the crushing plant (Pl. XII, B,C) the dolomite is unloaded and crushed by a 24 by 36-inch primary jaw crusher to minus 6-inch size. This product may be marketed as such or classified into different grades which in turn may be sold or used as feed to a 24-inch cone crusher or 40 by 24-inch roll crusher for further reduction. In Plate XII,B the primary crushing house may be seen on the right, the secondary crushing and screening house in the middle, and storage bins for direct car loading on the left. Open gondolas are loaded directly from the secondary crushing house. The plant has equipment designed to handle 275 tons of broken stone per hour.

The principal use of the dolomite at the time of this writing is for flux in iron ore smelting. About 300 to 500 tons of 1- to 6-inch stone is shipped per day for this use, all shipments being made to the Lone Star Steel Company at Daingerfield, Texas, where East Texas brown iron ore is smelted to pig iron. Another product is minus ten mesh stone for glass-making, for which there is considerable market in the glass plants of Oklahoma and neighboring states. Crushed and ground products for prepared fertilizers, construction stone, and agstone also will be marketed.

The exceptional purity of the quarried stone is indicated by analysis of a sample representing 500 tons of fluxing stone taken from loaded cars ready for shipment (Table V, laboratory number 9821). A recalculation of the analysis shows 98.98 percent theoretical dolomite and 0.11 percent excess calcite. The high magnesia, together with low content of silica, alumina, iron oxide, sulphur, and phosphorus, compares favorably with the best grades of Ohio dolomite.

The Rock Products Manufacturing Corporation, which was organized with the late W. E. Ryder as president has its office in Ada, Oklahoma, P. O. Box 81. W. D. Ryder is president, and Abe C. Davis is superintendent of the quarry and mill.

Favorable Quarry Sites and Reserves

The Royer dolomite, as described on previous pages, is about 550 feet thick, it crops out in a belt 9 miles long and 700 to 3,000 feet wide, and has a surface exposure of about 1,400 acres. Analyses of outcrop samples, taken to represent the stratigraphic and geographic range of the formation, show that most of the stone is high grade dolomite; and, from geologic considerations and from observations in the recently opened quarry, it is believed that the formation in subsurface will show slight improvement over that on the outcrop. It is thus possible to make an estimate of stone available in the district. Using conservative data—45,000-foot length and 1,500-foot breadth of outcrop, and a sloping outcrop surface that is 60 feet higher at the top of the Royer dolomite than at its base—it is calculated that there is slightly more than 150,000,000 tons of dolomite readily accessible for quarrying. This estimate includes stone lying above a horizontal plane projected from the lowest point of outcrop, with no rock overburden and an insignificant amount of soil, and a maximum quarry face height of 60 feet. A very much larger additional volume, about 2,600,000,000 tons, could be obtained at lower depths if quarrying operations were carried below the assumed horizontal plane to the basal beds of the formation. Neither of these estimates considers Royer dolomite that underlies the outcrop of the Butterly formation, but the 150,000,000-ton reserve alone is sufficient to meet the largest commercial requirements.

The method of quarrying at any particular site will be governed largely by topography. Where the surface is rather level, as at certain localities in the central part of the district, pit-quarrying methods probably would be used. In the northern and southern parts, relief is greater and the surface somewhat dissected by streams, with many small bluffs and gently sloping, east-facing scarp faces. Such natural faces offer excellent sites for bluff or open-face quarries. It appears likely, furthermore, that open-face quarries would not encounter ground water in significant amounts, for the outcrop of the dolomite beds is above the level of permanently flowing streams.

Electric power for quarrying operations could be supplied conveniently from the 66,000 volt transmission line of the Oklahoma Gas and Electric Co., which crosses the dolomite outcrop in two places and is accessible to the entire area (see Plate I).

Although sites could be worked by open-face quarries along most of the ravines and intermittent stream valleys that cross the dolomite outcrop, several localities having favorable characters are worthy of brief description here.

At the southern edge of the area a maximum relief of 90 feet has been developed in the Royer by a drainage system tributary to

Mill Creek. About 155 acres of dolomite are available for open-face quarrying, including 60 acres in the SW¼ sec. 19, T. 3 S., R. 5 E., 25 acres in the NW¼ sec. 30 of the same township, and 70 acres in the E½ sec. 24, T. 3 S., R. 4 E. The beds dip 15°-25° southwest.

Brushy Creek and its tributaries cross the Royer outcrop in the NW¼ sec. 13 and the SE¼ sec. 11, T. 3 S., R. 4 E., where about 115 acres of dolomite could be worked in open-face quarries. The favorably exposed outcrop in this locality is about 5,000 feet long and 1,000 feet wide; the maximum relief is 60 feet; and the rocks dip 20° to 30° southwest. An analysis of 125 feet of dolomite from the upper part of the formation is shown in Table V, laboratory number 9391.

Three east-flowing tributaries to Mill Creek cross the outcrop of the Royer dolomite in a fault block in the east-central part of sec. 2 and the northwestern part of sec. 1, T. 3 S., R. 4 E. About 100 acres of dolomite are available for quarrying in the vicinity of these tributaries, which are V-shaped ravines with gently sloping inter-ravine divides. The height of the scarp face is about 60 feet and the formation dips 11° west.

At another fault block in the central part of the Mill Creek-Ravia area, chiefly in the SE¼ sec. 35 and the SW¼ sec. 36, T. 2 S., R. 4 E., an outcrop of Royer covering about 240 acres is dissected slightly by tributaries to Bee Creek. Maximum relief is about 75 feet and the strata dip 11° southwest. Exposures are typical of the "rock prairie", the ground surface having very little soil and few trees. Analyses representing 297 stratigraphic feet of dolomite from this locality are shown in Table V, (laboratory numbers 9292-9296, inclusive). It is in this locality that the quarry of the Rock Products Manufacturing Corporation was opened in 1948.

A north-trending band of Royer 2,000 feet wide and 1 mile long, covering about 230 acres in the western part of sec. 26, T. 2 S., R. 4 E. and parts of adjoining sections on the north and west, forms a nearly level rock plain on which there are no major tributaries. The beds dip 13° west. Quarrying in this area probably would be done by open pits. The stone is of high quality, as shown by an analysis representing the lower 169 feet of the formation (Table V, laboratory number 9379).

At the northern edge of the mapped area the Royer crops out in a curving, east-facing escarpment in a locality whose relief exceeds 100 feet. Several deep ravines increase the general ruggedness of the topography. Most of this outcrop, about 225 acres, is in the E½ sec. 15, T. 2 S., R. 4 E. The dip of the formation ranges between 13° and 30° west. Many open-face quarry sites are available in high grade dolomite, two analyses of which are given in Table V, laboratory numbers 9262 and 9263.

DOLOMITE IN OTHER PARTS OF OKLAHOMA

Although the Royer in the Mill Creek-Ravia area apparently represents the largest and most accessible deposit of high grade dolomite in Oklahoma, other deposits that are less extensive, of lower grade, or less convenient to railroad transportation are known in the state. Outcrops of Royer in other parts of the Arbuckle Mountains are more extensive than in the area mapped for the present report, but most of these outcrops are located at much greater distances from existing railroads and they have not been investigated in detail. Two analyses of the Royer at the southeastern edge of the Arbuckle Mountains, in Atoka County, 1 analysis in easternmost Johnston County, and 5 analyses from the west-central part of the Arbuckle Mountains, in Murray County, give the general character of dolomite in these areas. The analyses, given in Table VII, show higher silica and lower dolomite content than the Mill Creek-Ravia stone.

One outcrop area of Royer dolomite deserves special consideration because a relatively large though definitely limited tonnage of high-grade stone is located adjacent to a railroad. Three miles south of Wapanucka, chiefly in sec. 36, T. 2 S., R. 8 E. and sec. 1, T. 3 S., R. 8 E., Johnston County (fig. 5), a narrow block of Arbuckle dolomite and older beds is faulted on the south against pre-Cambrian granite and on the north against Caney shale. The block trends N. 70° W. and is 400 to 500 feet wide in this area although it pinches out westward at the west line of sec. 36 and becomes wider eastward beyond the east line of sec. 1.

Within the fault segment are outcrops of Royer dolomite, Fort Sill dolomite, Honey Creek sandy glauconitic dolomite, and Reagan sandstone. The structure in detail is complex, as faults are present, many beds show dips ranging from 10° to 60°, and some beds are

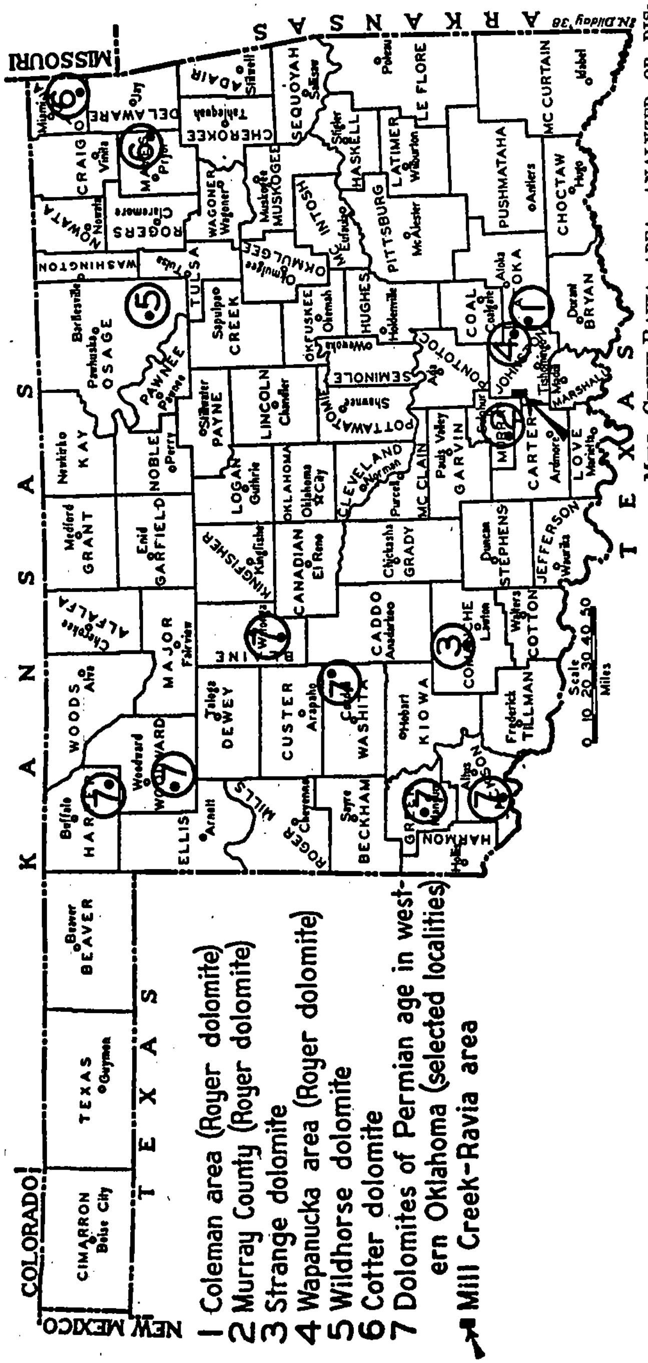


FIG. 5. INDEX MAP OF OKLAHOMA SHOWING LOCATION OF DOLOMITES, OUTSIDE THE MILL CREEK-RAVIA AREA, ANALYZED OR DISCUSSED IN THIS REPORT.

overturned. Outcrops of the Royer dolomite are limited to the northwestern third of the fault block, in the SW¼ sec. 36, whereas the older beds crop out in the southeastern part.

The Kansas, Oklahoma, and Gulf Railroad crosses the eastern edge of the Royer outcrop, and parallel with the railroad is Oklahoma Highway 48, a graveled road. The Chicago, Rock Island, and Pacific Railroad formerly operated a line across the central part of the outcrop but it is now abandoned and the rails and ties have been removed.

A quarry formerly was worked in the Royer dolomite from the Rock Island railroad northwestward to the faulted limit of outcrop. The quarry face is about 600 feet long and 35 feet high, and the quarry floor is about 200 feet wide. Nearly all the readily accessible stone has been quarried. The dolomite is much jointed and broken as the result of tectonic adjustment within the narrow fault block and no reliable dip surfaces were observed. The stone is light gray to light brown, medium-crystalline in texture, and contains no chert or sand. Apparently the quarry was worked for railroad ballast and possibly for concrete aggregate.

Between the old Rock Island roadbed and the Kansas, Oklahoma, and Gulf Railroad is a bare-rock hill of Royer dolomite that constitutes the principal reserve of high quality stone in this locality. It is about 700 feet long and 400 feet wide and covers, therefore, slightly more than 7 acres. The hill rises 50 feet above the K. O. and G. tracks but an additional 50 feet is present on the steeply sloping north flank of the hill below the railroad level. Hence there is approximately 350 acre-feet of dolomite in the hill above the lowest point of outcrop. Using 175 pounds per cubic foot or 3,800 tons per acre-foot as the weight of dolomite in the ground, a volume of 1,330,000 short tons is indicated within the hill. Little additional dolomite could be quarried conveniently in the vicinity of this hill, with the possible exception of stone present below the floor level of the abandoned quarry, which adjoins the hill on the west.

A chemical analysis of a sample consisting of about 75 chips taken from the eastern part of the abandoned quarry and from outcrops on the hill is given in Table VII. The quality of the dolomite is shown by the high percentage of total calcium and magnesium carbonates (98.89 percent), and relatively low silica, iron oxide, and alumina.

The Butterly dolomite, as well as dolomite beds in the upper part of the Arbuckle group (McKenzie Hill, Cool Creek, Kindblade, and West Spring Creek), have not been investigated in detail because preliminary examination reveals that sand, chert nodules, or quartz druse are common constituents of these beds in both the Arbuckle and Wichita Mountains. The few available analyses indicate an insoluble residue of 1 to 9 percent and MgO generally less than 20 percent.

The Strange dolomite, probably of Lower Ordovician age, crops out in 4 small hills south of the Wichita Mountains, Comanche County, in southwestern Oklahoma (fig. 5). These hills project as inliers through lower Permian shales and sandstones, and cover hardly more than 100 acres. Analyses of the Strange as given in Table VII show that the average silica content is less than 1 percent and magnesia in excess of 21 percent, thus comparing favorably with the average of high grade Royer. There is sufficient stone at these localities, convenient to railroad transportation, to warrant its exploitation for all but exceptionally large requirements.

A few other dolomites in Oklahoma are worthy of mention, notably the Pennsylvanian Wildhorse dolomite in Osage County.[33] In sec. 21, T. 22 N., R. 10 E. the Wildhorse is 18 feet thick and contains about 2.5 percent silica and 18 percent magnesia. The Cotter dolomite, probably equivalent to beds in the upper part of the Arbuckle limestone in the Arbuckle Mountains, crops out in northeastern Oklahoma (fig. 5) in widely scattered exposures, most of which are not accessible to railroads. Preliminary analyses indicate about 6 percent insoluble residue and about 20 percent MgO.

In western Oklahoma (fig. 5) there are several beds of Permian dolomite,[34] mostly less than 5 feet thick, that may be used for local consumption, but quarrying conditions are not favorable for large scale operation.

[33] Beach, J. O., and English, S. G., "Dolomite and Magnesium Limestone": *Okla. Geol. Survey Mineral Report* 6, 1940.

[34] Suffel, G. G., "Dolomites of Western Oklahoma": *Okla. Geol. Survey Bull.* 49, 1930.

TABLE VII

CHEMICAL ANALYSES OF DOLOMITE FROM ATOKA, MURRAY, JOHNSTON, AND COMANCHE COUNTIES

County	Atoka		Murray					Comanche				Johnston
Location	NE¼ SW¼ sec. 28, T. 3 S., R. 9 E., 3.5 mi. east of Coleman		NW¼ SW¼ sec. 1, T. 2 S., R. 1 E., 7 mi. south of Davis		SW¼ NE¼ section 18, T. 2 S., R. 2 E., 8 miles south of Davis			NE¼ sec. 20, T. 2 N., R. 12 W., 6 mi. NW of Lawton		SW¼ SE¼ sec. 9, T. 2 N., R. 12 W., 7 miles NW of Lawton	S½ SE¼ sec. 8, T. 2 N., R. 12 W., 7 miles NW of Lawton	Cen. SW¼ SW¼ sec. 36, T. 2 S., R. 8 E., 3 mi. south of Wapanucka
Formation	Royer (lower)		Royer (lower)	Royer (upper)	Royer (middle)	Royer (upper)	Royer (upper)	Strange				Royer
Thickness (ft.)	55	50	75	118	67	78	78	Hand Specimens				about 50 feet quarry sample
Lab. No.	9264	9265	9370	9371	9353	9354	9355	7744	7745	7746	7747	9656
Analyst	A. C. Shead		A. C. Shead		A. C. Shead			S. G. Sudduth				Sharp-Schurtz
SiO_2	0.79	1.50	0.54	1.27	1.68	1.42	2.78	0.68 [1]	0.98 [1]	1.22 [1]	0.58 [1]	0.89
Al_2O_3 (et al)	0.28	0.39	0.27	0.50	0.38	0.14	0.33	0.13	0.34	0.37	0.32	0.20
Fe_2O_3	0.11	0.12	0.31	0.27	0.25	0.43	0.35	0.36	0.29	0.21	0.29	0.145
CaO	30.78	30.54	30.99	30.55	30.36	30.35	29.98	30.98	30.69	30.59	30.78	30.62
MgO	20.96	20.74	20.84	20.43	20.73	20.53	20.20	21.18	21.38	21.20	21.76	21.15
MnO	n. d.	n. d.	n. d.	n. d.	0.03	0.035	0.04	0.03	0.03	0.02	0.03	n. d.
K_2O	0.052	0.082	0.032	0.180	0.054	0.056	0.17	n. d.	n. d.	n. d.	n. d.	0.07
Na_2O	0.031	0.028	0.030	0.028	0.039	0.037	0.051	n. d.	n. d.	n. d.	n. d.	0.04
SO_3	0.033	0.04	0.022	0.013	0.022	0.047	0.038	n. d.	n. d.	n. d.	n. d.	0.03
P_2O_5	0.003	0.011	0.005	0.005	0.009	0.034	0.015	trace	none	none	none	0.036
H_2O at 105° C.	0.20	0.13	0.24	0.17	0.05	0.05	0.06	n. d.	n. d.	n. d.	n. d.	n. d.
Loss on ignition (105°-950° C.)	47.07	46.76	47.11	46.67	46.65	46.78	45.99	47.00 [2]	46.74 [2]	46.96 [2]	46.90 [2]	46.76
Total	100.309	100.341	100.389	100.086	100.254	99.909	100.004	100.36	100.45	100.57	100.66	99.941
					RECALCULATION							
$CaCO_3$ [3]	54.94	54.51	55.31	54.53	54.19	54.17	53.51	55.29	54.78	54.60	54.94	54.65
$MgCO_3$ [4]	43.84	43.38	43.59	42.73	43.36	42.94	42.25	44.30	44.72	44.34	45.51	44.24
Total	98.78	97.89	98.90	97.26	97.55	97.11	95.76	99.59	99.50	98.94	100.45	98.89
$CaMg(CO_3)_2$ (dolomite)	95.88	94.87	95.33	93.45	94.83	93.91	92.40	96.88	97.80	97.23	99.53	96.76
excess $CaCO_3$ (calcite)	2.90	3.02	3.57	3.81	2.72	3.20	3.36	2.71	1.70	1.97	0.92	2.13

[1] insoluble residue [2] CO_2 [3] calculated from CaO [4] calculated from MgO

APPENDIX

MEASURED SECTION A

LOCATION: SECTION BEGINS AT POINT 1,300 FEET EAST AND 200 FEET NORTH OF SW COR. SEC. 22, T. 2 S., R. 4 E., AND EXTENDS EASTWARD TO BASE OF REAGAN SANDSTONE AT A POINT IN THE SE¼ SEC. 23, T. 2 S., R. 4 E. (PL. I). STRIKE N. 5° W., DIP 22° WEST AT TOP.

SAMPLE NUMBER	CALCULATED THICKNESS (ft.)	LITHOLOGY	INSOLUBLE RESIDUE PERCENT	INSOLUBLE RESIDUE DESCRIPTION
		McKENZIE HILL LIMESTONE (LOWER PART ONLY)		
144-154	115.5	Limestone, conglomeratic; gray to brownish, fine grained; chert common in nodules and reticulate patches along bedding planes. Thick-bedded strata alternating with soft marly limestone, mostly covered.	10	Chert, light gray, smooth; grades either to opalescent chalcedony or to chalk-textured tripolitic chert, partly dolomoldic or lacy. (D)* Silt aggregates, light brown, coarsely granular, dolomoldic (C). Quartz druse, milky, granular (R).
143a	161.4	Covered across meadow, probably limestone. Large boulders of limestone lying on surface.		
143	10.4	Limestone: gray with brownish mottling, microcrystalline, compact. Weathers light gray.	1	Silt, coarse-textured, with abundant euhedral quartz (D). Quartz druse, milky, granular, botryoidal (R).
		BUTTERLY DOLOMITE: 434.6 FEET THICK.		
141-142	20.8	Dolomite, sandy: gray to light brown, medium- to fine-crystalline. Beds less than 1 foot thick.	8	Silt aggregates, light brown, finely granular, highly dolomoldic (D). Arkosic sand, poorly sorted (C).
140	5.4	Dolomite: cream-colored, very finely crystalline, laminated.	2	Silt aggregates, milky coarsely granular, powdery.
139	15.4	Dolomite, sandy: gray, coarsely crystalline. Massive-bedded honeycombed ledges.	10	Arkosic sand, poorly sorted; quartz subrounded, frosted, with crystal faces of secondary growth (D). Silt aggregates, milky, granular, dolomoldic (C). Quartz druse, milky, granular botryoidal (R).

* Letter symbols are used to designate relative abundance of insoluble materials as follows:
(D) Dominant: more than 50 percent — (C) Common: 5-25 percent
(A) Abundant: 25-50 percent — (R) Rare: 1-5 percent

136-138	31.2	Dolomite: gray to light brown, medium-crystalline (sugary), sandy, cherty. Weathers to smooth beds 2-6 inches thick.	5	Quartz druse, milky, finely granular, lacy to dolomoldic (A). Silt, coarse-textured, powdery (D). Arkosic sand, poorly sorted (C).
135	7.0	Dolomite: cream-colored, very finely crystalline, laminated.	4	Silt aggregates, coarsely granular, dolomoldic.
128-134	80.0	Dolomite: gray to brownish, medium-crystalline (sugary), some beds arkosic. Strata 2-6 inches thick.	9	Arkosic sand, poorly sorted. Quartz subrounded, frosted (A). Silt, powdery or in aggregates (A). Quartz druse, milky, granular (C).
127	0.5	Oolitic chert, in a continuous mappable bed.	100	Siliceous oolites, light brown, set in a matrix of light blue chalcedony and granular clear quartz.
		Strike N. 15° W., dip 16° west.		
124-126	39.7	Dolomite: brownish-gray, medium-crystalline (sugary). Chert irregularly disseminated. Beds 2-6 inches thick, weathering smooth and non-pitted.	4	Arkosic sand and silt (D). Quartz druse, granular, milky (C).
122-123	24.4	Dolomite: gray, coarsely crystalline. Beds about 2 feet thick, weathering pitted.	1	Feldspar (adularia), euhedral, transparent to translucent (D). Silt aggregates, milky, granular, dolomoldic (A). Quartz, euhedral (R). Glauconite (?), pale green waxy flakes, dolomoldic (R).
121	8.0	Dolomite: gray to cream, very finely crystalline, laminated.	1	Silt aggregates, milky, powdery.
120	10.9	Dolomite like 122-123	3	Feldspar, euhedral (D). Silt aggregates, milky to pale green, smooth to finely granular, dolomoldic (C).
119	8.0	Dolomite: light gray weathering cream, very finely crystalline, laminated. Weathers to thin plates and flags.	1	Silt aggregates, milky, coarsely granular, dolomoldic.

109-118	111.9	Dolomite: gray, coarsely crystalline. A little disseminated chert. Weathers dark gray, pitted.	2	Chert, opalescent botryoidal crusts (D to C). Silt aggregates, milky, smooth, dolomoldic (D to C). Silt, milky, powdery (C to R). Feldspar, glassy, euhedral (R). Glauconite (?), green waxy flakes, dolomoldic (R).
108	6.0	Dolomite: laminated gray and brown, finely crystalline; in smooth beds 1-2 inches thick.	2	Silt, milky, powdery.
104-107	43.6	Dolomite: gray to brownish-gray, sugary textured, a little chert. Beds about 1 foot thick, weathering smooth.	1	Drusy quartz, milky, granular (D). Silt aggregates, smooth, milky, dolomoldic (C). Feldspar, glassy, euhedral (R).
103	5.0	Dolomite: cream colored, very finely crystalline, laminated.	4	Silt aggregates, milky, powdery (D). Quartz druse, milky, finely granular (A).
102½	9.8	Dolomite: light gray, coarsely crystalline; weathers dark-colored, massive-bedded.	4	Quartz druse, milky, finely granular, grading to translucent light blue chert.
102	7.0	Dolomite: cream-colored, very finely crystalline; weathers to laminated flags ½-2 inches thick.	4	Silt aggregates, milky, finely granular, dolomoldic.
		ROYER DOLOMITE: 560.9 FEET THICK.		
95-101	76.3	Dolomite: gray to pink, coarsely crystalline; beds 2-3 feet thick, weathering dark gray, honeycombed. Typical Royer lithology.	1	Silt aggregates, milky, smooth to granular, dolomoldic (D). Quartz druse, clear to milky (R). Glauconite (?), pale green, interstitial, waxy, dolomoldic (R). Feldspar, glassy (R).
93-94	26.8	Dolomite: gray, sugary-textured; beds 2-4 inches thick, weathering smooth.	1	Silt aggregates, interstitial, milky, smooth, dolomoldic (D). Glauconite (?), pale green, waxy, dolomoldic (R). Feldspar, glassy, euhedral (R). Quartz druse, very finely granular, milky (R).
88-92	54.5	Dolomite: gray to pink, coarsely crystalline. Typical Royer lithology.	1	Silt aggregates, interstitial, milky, smooth to granular, dolomoldic (D). Glauconite (?), pale green, interstitial, waxy, dolomoldic (C). Feldspar, glassy, euhedral (R).
77-87	119.9	Dolomite: gray to light brown, medium-crystalline. Beds about 1 foot thick, weathering to non-pitted, sugary-textured surface. Disseminated chert rare.	1	Silt aggregates, interstitial, smooth, milky, dolomoldic (D). Arkosic silt (C). Feldspar, euhedral (R).
		At SW cor. sec. 23, T. 2 S., R. 4 E. Strike N. 20° W., dip 14° west.		
51-76	283.4	Dolomite: gray ranging to mottled in shades of pink, lilac, or brown; mostly coarsely crystalline, massive bedded, pitted ledges. Typical Royer lithology.	1.5	Silt aggregates, interstitial, milky to brown, smooth to finely granular, dolomoldic (D to A). Arkosic silt (C). Feldspar, euhedral (C to R). Glauconite (?), dark to pale green, interstitial, dolomoldic (R).
		FORT SILL FORMATION: 424.8 FEET THICK.		
47-50	51.0	Dolomite: yellowish-gray, finely crystalline, tough and compact. Beds mostly 3-5 inches thick.	9	Arkosic silt and silt aggregates.
46	8.0	Limestone, dolomitic: light gray, very fine grained, sandy, compact, thick-bedded.	9	Arkosic sand and silt, poorly sorted.
45½	5.0	Dolomite like 47-50.	9	Arkosic sand and silt.
44-45	25.0	Limestone like 46.	9	Arkosic sand and silt, poorly sorted (D). Silt aggregates, dolomoldic (C). Glauconite, dark green flakes, dolomoldic (R).
43	15.0	Dolomite, arkosic: yellowish-gray, finely crystalline, weathering to yellowish beds 0.5-1.0 inches thick. At top a massive-bedded coarsely crystalline dolomite 3 feet thick.	10	Arkosic fine sand and silt (D). Quartz sand, medium-grained, subrounded, frosted (R).

42	16.0	Limestone, dolomitic: light gray, fine-grained and compact, arkosic, thick-bedded. Contains some flat-pebble conglomerate. Uneven, probably erosional contact with underlying dolomite.	13	Arkosic fine sand and silt.
30-41	144.0	Dolomite: gray to yellowish-gray. Beds that are medium-crystalline and massive-bedded alternating with strata that are fine-crystalline and thin-bedded. Arkosic sand common.	11	Arkosic sand, ranging from coarse to very fine in different beds. Quartz subrounded, frosted; feldspar subrounded cleavage fragments (A). Silt aggregates, milky, granular, dolomoldic (A). Feldspar, euhedral (C to R).
28-29	35.0	Limestone, dolomitic: light gray to yellowish-gray, fine-grained. Alternating thick- and thin-bedded strata.	5	Silt aggregates, milky, granular, dolomoldic (A). Arkosic silt (A). Feldspar, glassy, euhedral (A). Fine sand (R).
27	10.0	Dolomite: gray to buff, medium-crystalline, weathering to pitted, light-brown, thin beds.	3	Same as 28-29.
25-26	36.0	Limestone: light gray, mottled by orange coarse-crystalline dolomite crystals, very fine-grained and compact. Weathers to nearly white massive beds. A few *Girvanella* algae.	1	Feldspar, glassy, euhedral; 6-sided crystals 0.05-0.10 mm in diameter showing prism and basal pinacoid. (D). Silt aggregates, milky to pale green (C). Limonite pseudomorphous after pyrite, cube and octahedron (R).
24a	59.8	Covered by soil. Local exposures of limestone along strike.		
24	20.0	Limestone: light gray, very fine grained and compact, mottled with patches and stringers of orange, coarsely crystalline dolomite. Numerous *Girvanella* ½-1 inch in diameter. Strata weather light-colored, pitted.	1	Silt aggregates, milky to pale green, smooth to finely granular.

HONEY CREEK DOLOMITE: 138.0 FEET THICK.

23½	6.0	Dolomite: gray to pink, very coarsely crystalline, with coarse arkosic sand. Thick beds.	11	Arkosic silt (D). Medium sand; quartz subrounded, frosted; feldspar in pink cleavage fragments (C). Glauconite, dark green, dolomoldic (R).
22-23	20.0	Dolomite: gray to pink, very coarsely crystalline; thick beds weathering dark gray, moderately pitted.	11	Arkosic very fine sand and silt.
21	12.0	Dolomite, sandy: light brown, medium crystalline. A few layers ½-1 inch thick are highly arkosic.	15	Arkosic very fine sand, angular (D). Quartz sand, very coarse, subrounded, frosted (R).
19-20	15.0	Dolomite: gray to pink, very coarse crystalline, thick-bedded.	13	Arkosic very fine sand, angular (D). Glauconite, in flakes and irregular interstitial fillings (R).
18	5.0	Dolomite, arkosic: cream-colored, coarse crystalline.	32	Quartz sand, medium-grained, subrounded, frosted (D). Feldspar, pink, subrounded cleavage fragments (C). Glauconite, tiny green flakes and pellets (R).
15-17	32.0	Dolomite, sandy: gray to buff, very finely crystalline, laminated in part. Very fine sand abundant, glauconite rare.	39	Very fine sand and silt, consisting of angular quartz and feldspar (D). Glauconite, dark green pellets, chiefly of coarse silt size (R).
13-14		Numbers omitted in field.		
12	8.0	Sandstone, buff, very fine grained, slightly glauconitic. Dolomite leached.	94	Same as 15-17.
11	10.0	Dolomite, sandy: light brown, finely crystalline, slightly glauconitic, with abundant very fine sand. Smooth-weathering, thin beds.	56	Same as 15-17.
10	10.0	Sandstone, buff, very fine grained, glauconitic. Dolomite leached.	93	Same as 15-17.
8-9	20.0	Dolomite, sandy: light gray, greenish-gray or brownish, very finely crystalline and compact; thin beds weathering smooth to slightly pitted.	46	Quartz-feldspar sand, very fine, angular (D). Glauconite, dark green pellets (C).

		Reagan sandstone: 381.0 feet thick.		
7	29.2	Dolomitic sandstone: buff to bright pink, medium-grained to conglomeratic; thick beds weathering to pitted layers 2-5 inches thick.	71	Quartz sand, mostly coarse, sub-rounded, deeply frosted (A).* Feldspar, pink, subangular (A). Glauconite, dark green pellets, very fine sand size (R).
6	86.9	Arkosic sandstone: buff, medium-grained to conglomeratic, in part calcitic.	92	Quartz sand, subrounded to subangular, secondary crystal faces common (D). Feldspar, pale pink subrounded cleavage fragments (A). Glauconite, tiny pale green flakes (R).
5	62.8	Arkosic sandstone: buff to reddish-brown, medium-grained, with many thin conglomerate layers. Some cross-bedding. Indurated by silica cement.	99	Quartz sand, subangular to subrounded, pitted and frosted, some with secondary crystal faces (D). Feldspar, milky white to pale pink, is subrounded rectangular cleavage fragments (A).
4	30.9	Arkosic sandstone: buff, medium-grained; thick, poorly bedded strata. Partly covered.	98	Same as 5.
3	32.1	Arkosic sandstone: buff to pink, medium-grained, with layers 1-3 inches thick of sandy quartz conglomerate.	98	Same as 5.
2a	30.9	Covered. Sandy soil.		
2	32.5	Arkosic sandstone: buff to pink, medium-grained to conglomeratic. Quartz pebbles ½ inch diameter.	99	Same as 5.
1a	48.7	Covered. Sandy soil.		
1	27.0	Arkosic conglomerate: pink to light brown, poorly sorted and stratified. Pebbles 1 inch in diameter of quartz, coarse-grained granite, and rhyolite porphyry.	100	Arkose, coarse-grained, very poorly sorted; quartz subangular, pitted, frosted, and with secondary crystal faces; pink feldspar, mostly angular cleavage fragments. Many fragments of granite.

Base of Reagan rests unconformably on pre-Cambrian Tishomingo granite. At point 850 feet west and 2,100 feet north of the SE cor. sec. 23, T. 2 S., R. 4 E., 3 miles southwest of Mill Creek village.

* Letter symbols are used to designate relative abundance of insoluble materials as follows:
(D) Dominant: more than 50 percent (C) Common: 5-25 percent
(A) Abundant: 25-50 percent (R) Rare: 1-5 percent

MEASURED SECTION B

Location: Section begins at point 800 feet east and 1,300 feet north of the SW cor. sec. 15, T. 2 S., R. 4 E., and continues eastward to base of Reagan sandstone near the center of sec. 14, T. 2 S., R. 4 E. (See Pl. I). Strike N. 10° W., dip 16° west at top.

SAMPLE NUMBER	CALCULATED THICKNESS (ft.)	LITHOLOGY	INSOLUBLE RESIDUE PERCENT	DESCRIPTION
		McKenzie Hill limestone (lower part only)		
111-114	43.0	Limestone, conglomeratic: dark gray; micro-granular pebbles and small grains embedded in a medium-crystalline matrix; chert abundant as reticulate masses and irregular nodules in layers 1-3 inches thick. Beds 2-4 feet thick, weathering to light gray, slightly irregular layers 1-3 inches thick.	12	Chert, gray, smooth; grades to chalk-textured, smooth or porous tripolitic chert, in part dolomoldic (D).* Quartz druse, clear to milky, partly granular (R).
110a	138.3	Covered in grassy swale. Probably marly limestone.		
		Butterly dolomite: 423.1 feet thick.		
108-110	31.5	Dolomite: gray, medium crystalline, in beds 4-8 inches thick, weathering moderately pitted.	1	Quartz druse, milky, granular (A). Arkosic coarse silt (A).
107a	42.0	Covered.		
102-107	63.0	Dolomite like 108-110.	2	Silt aggregates, light brown, granular, grading to milky and smooth; dolomoldic (D). Arkosic sand, poorly sorted; quartz subrounded, frosted, with many secondary crystal faces (C). Chalcedonic chert, grading to quartz druse, milky, granular (C). Feldspar, glassy, euhedral (R). Oolitic chert in 106.
101	8.0	Dolomite: gray to yellowish, very finely crystalline, laminated, weathering cream-colored, smooth.	6	Silt aggregates, powdery, dolomoldic.
99-100	30.6	Dolomite, sandy: gray, medium-crystalline, weathering smooth to moderately pitted.	12	Arkosic sand, medium-grained, poorly sorted.

* Letter symbols are used to designate relative abundance of insoluble materials as follows:
(D) Dominant: more than 50 percent (C) Common: 5-25 percent
(A) Abundant: 25-50 percent (R) Rare: 1-5 percent

98½	4.0	Dolomite like 101.	1	Silt aggregates, porous to dolomoldic.
95-98	42.0	Dolomite: gray to chocolate brown, coarsely crystalline, weathering moderately pitted. Silicified brachiopods and gastropods at top.	1	Arkosic sand, poorly sorted (C) Botryoidal chalcedony, milky (beekite) (C). Feldspar, euhedral, clear to milky (C). Glauconite (?), pale green waxy flakes (R). Pyrite, cubic crystals, dolomoldic (R).
94	0.5	Oolitic chert in a laterally persistent bed.	100	Oolites, milky to light brown, sand-centered in part, set in a matrix of light blue chalcedony or clear crystalline to granular quartz.
92-93	26.0	Dolomite: purplish-brown, medium crystalline.	3	Arkosic sand, poorly sorted.
89-91	33.0	Dolomite: light gray, grading to purplish and brown, coarsely crystalline, massive bedded, weathering pitted.	1	Feldspar, glassy, euhedral (A). Glauconite (?), pale green waxy flakes, dolomoldic (A).
88	8.0	Dolomite: yellowish-gray, very finely crystalline, laminated.	2	Silt, powdery.
87	9.0	Dolomite: gray, coarsely crystalline.	1	Silt, powdery.
86½	5.0	Dolomite like 88.	1	Silt, powdery.
86	11.0	Dolomite: gray, coarsely crystalline.	1	Feldspar, glassy, euhedral (D). Glauconite (?), pale green waxy flakes, interstitial, dolomoldic (A).
85	7.0	Dolomite: yellowish to pinkish-gray, finely crystalline, laminated, weathering to smooth blocks.	1	Coarse silt, with some euhedral feldspar.
84	15.0	Dolomite: light purplish-gray, coarsely crystalline, in massive, pitted beds. Disseminated chert at top.	10	Quartz druse, botryoidal, milky, granular (D). Silt aggregates, milky, smooth, dolomoldic (R).
81-83	38.0	Dolomite: dominately light gray grading to pink and light chocolate brown, coarsely crystalline; in massive, pitted beds.	1	Silt aggregates (residue barely perceptible).

80	5.0	Dolomite: yellowish-gray, very finely crystalline, laminated.	1	Arkosic silt.
77-79	39.5	Dolomite: gray to light brown, coarsely crystalline, in beds 6 inches or less thick.	1	Arkosic silt (D). Feldspar, glassy, euhedral (C).
76	5.0	Dolomite: brownish-yellow, very finely crystalline, weathering to smooth flags.	2	Arkosic silt (D). Silt aggregates, golden brown to milky, granular, dolomoldic (C).
		ROYER DOLOMITE: 513.8 FEET THICK.		
75	10.9	Dolomite: gray to pink, coarsely crystalline, massive, honeycombed.	3	Quartz druse, milky, granular (D). Glauconite (?), pale green waxy flakes, interstitial, highly dolomoldic (C).
56-74	202.7	Dolomite: gray to light brown and pink, coarsely crystalline, weathering to slightly pitted beds 2-6 inches thick.	1	Arkosic silt (D). Silt aggregates, milky, smooth, interstitial, dolomoldic (C). Glauconite (?), pale to dark green, waxy, interstitial, dolomoldic (C). Feldspar, glassy, euhedral (C).
53-55	31.5	Dolomite, cherty: gray to light brown, medium-crystalline; chert disseminated and in masses 4 inches in diameter.	20	Quartz druse, milky, granular, lacy to dolomoldic.
50-52	31.5	Dolomite: brownish-gray, medium-crystalline, weathering to bluish-gray, slightly pitted beds 2-6 inches thick.	3	Arkosic fine sand (D). Quartz druse, milky, granular (A).
37-49	135.8	Dolomite: gray to pink, coarsely crystalline, massive, honeycombed.	3	Silt aggregates, brown to milky, granular to smooth, dolomoldic (C). Arkosic sand and silt (C). Glauconite (?), pale green, waxy, interstitial, dolomoldic (C). Feldspar, euhedral (C). Quartz druse, milky, granular (C).
33-36	36.0	Dolomite, sandy: gray to lilac, coarsely crystalline, in massive, honeycombed ledges. At south edge of granite inlier (Pl. I).	10	Arkosic sand and silt (D). Silt aggregates, milky, dolomoldic (A). Glauconite (?), pale to dark green, interstitial, dolomoldic (R).

27-32	65.4	Dolomite like 33-36, non-sandy.	4	Arkosic silt (A). Silt aggregates, milky, smooth to granular, dolomoldic (A). Feldspar, glassy, euhedral (A). Glauconite (?), pale green, waxy, interstitial, dolomoldic (R).
		FORT SILL FORMATION: 192.6 FEET THICK.		
21-26	93.3	Dolomite: gray, coarsely crystalline, interbedded with yellowish, medium-crystalline dolomite. Many beds very sandy.	15	Arkosic sand and silt, poorly sorted. Quartz in subrounded, frosted grains; feldspar bleached and in part apple green, perhaps an incipient stage in glauconitization (D). Silt aggregates, milky to pale green, granular to smooth, dolomoldic (C).
20	16.3	Dolomite, sandy: cream to gray, medium crystalline, weathering to thin, yellowish beds.	20	Arkosic sand, poorly sorted (D). Silt aggregates, milky, granular, dolomoldic (R).
		Strike N. 25° W., dip 13° southwest.		
17-19	50.0	Limestone: light gray to greenish-gray, fine-grained and compact, slightly dolomitic, thick-bedded, weathering to strata 1-2 inches thick. Erratically gradational into dolomite along strike. At south edge of granite inlier in the NW¼ sec. 14, T. 2. S., R. 4 E. (Pl. I).	2	Silt aggregates, pale green, granular (A). Arkosic fine sand (C). Feldspar, glassy, euhedral (C).
16	10.0	Dolomite, sandy: gray, coarsely crystalline.	15	Arkosic sand, ranging downward from grains 2 mm in diameter (D). Glauconite (?), pale green, waxy, interstitial, dolomoldic (R).
14-15	23.0	Limestone like 17-19, grading to coarsely crystalline dolomite along strike.	1	Silt aggregates, milky to pale green, smooth to granular, dolomoldic (A). Feldspar, glassy, euhedral (A). Glauconite (?), pale green, waxy, interstitial (R).
		HONEY CREEK DOLOMITE: 97.2 FEET THICK.		
5-13	97.2	Sandy dolomite: gray mottled with pink, brown, and green, coarsely crystalline, slightly pitted beds 3-10 inches thick. Coarse arkosic sand abundant in many beds.	19	Arkosic sand, poorly sorted, containing some apple-green feldspar (D). Silt aggregates, pale green, finely granular, dolomoldic (C). Glauconite (?), apple green, waxy, interstitial, dolomoldic (C).
		REAGAN SANDSTONE: 250.4 FEET THICK.		
3-4	41.0	Sandstone: yellowish to brown, coarse grained, partly covered.	95	Arkosic sand, ranging from 2 mm diameter downward to coarse silt. Quartz grains irregular, subrounded, frosted; feldspar milky, pale pink, or pale green, subrounded.
2a	43.3	Covered.		
2	37.9	Conglomeratic sandstone: reddish brown, beds poorly defined.	100	Arkosic sand, ranging from 2 mm dia- Glauconite, dark green pellets (C).*
1a	59.5	Covered. Thick sandy soil.		
1	68.7	Arkose: pink to brown, coarse-grained, poorly sorted, friable. Poorly defined, irregular beds 1 inch to 1.5 feet thick. Lower part covered.	94	Arkosic sand, poorly sorted; quartz grains irregular, frosted.

Pre-Cambrian Tishomingo granite exposed in stream bed. At point 2,500 feet east and 1,000 feet south of the NW cor. sec. 14, T. 2 S., R. 4 E., 2 miles southwest of Mill Creek village.

* Letter symbols are used to designate relative abundance of insoluble materials as follows:
(D) Dominant: more than 50 percent (C) Common: 5-25 percent
(A) Abundant: 25-50 percent (R) Rare: 1-5 percent

MEASURED SECTION C

LOCATION: SECTION BEGINS AT EAST BASE OF SCARP 1,300 FEET EAST AND 700 FEET SOUTH OF THE NW COR. SEC. 2, T. 3 S., R. 4 E., AND EXTENDS EASTWARD TO BASE OF REAGAN SANDSTONE AT A POINT IN THE NW¼ SEC. 6, T. 3 S., R. 5 E. (SEE PL. I). STRIKE N. 20° W., DIP 12° SOUTHWEST AT TOP.

SAMPLE NUMBER	CALCULATED THICKNESS (ft.)	LITHOLOGY	INSOLUBLE RESIDUE PERCENT	INSOLUBLE RESIDUE DESCRIPTION
		MCKENZIE HILL LIMESTONE (LOWER PART ONLY)		
151+	50+	Limestone, conglomeratic: dark gray to chocolate, microcrystalline pebbles set in medium crystalline matrix; chert abundant as reticulate masses, normally replacing the matrix, and as porous tripolitic nodules; thin-bedded.	15	Light gray chert, chalk-textured; grades from smooth and translucent to porous and drusy.
150a	64.0	Covered across swale.		
		Strike N. 20° W., dip 11° southwest.		
149-150	22.0	Dolomite: light brown, medium crystalline; in beds 1 foot thick.	1	Quartz druse, milky, fine granular to lacy (D).* Very fine sand (A).
146-148	36.0	Limestone: dark gray to chocolate, finely crystalline to lithographic; about 5 percent disseminated dolomite; massive beds in zones 5 to 10 feet thick, interstratified with thin-bedded, marly limestone that is largely covered.	1	Very fine sand (D). Silt aggregates, milky, fine-granular, porous (C). Quartz druse (R).
145	11.0	Similar to above. Sandy.	20	Sand, arkosic, medium- to fine-grained.
133-144	132.0	Similar to above. Zone of chert nodules along bedding planes 12 feet below top.	1	Fine- and very fine-grained sand, with many euhedral crystals of quartz and feldspar (D). Silt aggregates, finely granular, porous to dolomoldic (C). Chert, smooth, translucent (R).

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(D) Dominant: more than 50 percent (C) Common: 5-25 percent
(A) Abundant: 25-50 percent (R) Rare: 1-5 percent

132	17.0	Dolomite: gray, finely crystalline and compact; disseminated and nodular chert; beds 6 inches thick; weathers smooth, dark gray. Silicified brachiopods and cephalopods, poorly preserved.	2	Chert, milky, translucent, mottled, associated with drusy quartz (D). Fine-grained sand (A).
128-131	44.0	Dolomite: gray to yellowish, medium- to coarse-crystalline; a few beds sandy, drusy quartz; beds 6 to 12 inches thick; weathers gray to brownish.	4	Medium- to fine-grained sand (D). Granular quartz druse (C). Silt aggregates, granular (C).
127a	44.0	Covered across meadow. Probably dolomite.		
125-127	33.0	Dolomite: gray to yellowish, finely crystalline, sandy; disseminated quartz druse; mostly thin beds, 2 to 6 inches thick, that weather light gray to pale tan.	4	Medium- to fine-grained arkosic sand (D). Quartz druse, milky, granular to lacy (C). Silt aggregates, dolomoldic (R).
124	11.0	Dolomite: mottled gray and brick-red, coarse-crystalline; disseminated quartz druse; massive beds 1 to 3 feet thick; weathers dark gray, honeycombed.	10	Quartz druse, milky, granular to lacy (D). Silt aggregates, finely porous (R).
121-123	33.0	Dolomite: like sample No. 124, but lacking quartz druse.	1	Fine-grained sand (A). Euhedral feldspar, glassy (A). Silt aggregates, milky, finely granular, porous to dolomoldic (C).
120	5.0	Dolomite: gray to tan, finely crystalline, laminated; beds 2 to 4 inches thick; weathers smooth and pale cream to dead white.	1	Very fine-grained sand (A). Druse, finely granular (A).
119	12.0	Dolomite: gray, coarsely crystalline; massive beds 1 to 3 feet thick; weathers dark gray, honeycombed.	1	Very fine-grained sand with glassy feldspar (D). Silt aggregates, tan, dolomoldic (C).
118	6.0	Dolomite: like sample No. 120.	1	Silt aggregates, milky, smooth, dolomoldic to lacy.
117	25.0	Dolomite: gray finely crystalline; quartz druse; beds 6 to 12 inches thick; weathers light gray, smooth to slightly pitted.	1	Quartz druse, milky, granular to lacy (D). Silt aggregates, milky, dolomoldic (A).

112-116	55.0	Dolomite: gray, coarse-crystalline, massive beds 1 to 3 feet thick; weathers dark gray, honeycombed.	1	Fine- and very fine-grained sand, with glassy feldspar (D). Silt aggregates, milky, dolomoldic (C)
111	6.0	Dolomite: gray to tan, finely crystalline, laminated; beds 2 to 4 inches thick; weather smooth and pale cream to dead white.	1	Coarse-grained silt (D). Quartz druse, granular (C).
108-110	37.0	Dolomite: light gray, coarse-crystalline; disseminated quartz druse; massive beds 1 to 3 feet thick; weathers dark gray, honeycombed.	2	Quartz druse, milky, granular to lacy.
107	5.0	Dolomite: gray to tan, finely crystalline, laminated; beds 2 to 4 inches thick; weathers smooth and pale cream to dead white.	1	Coarse-grained silt.

ROYER DOLOMITE: 566.5 FEET THICK.

105-106	29.5	Dolomite: light gray to pink and light brown, coarse-crystalline; disseminated quartz druse, and chert; beds 2 to 3 feet thick; weathers dark gray, honeycombed.	6	Chert, smooth, milky; grades into granular, lacy, and crystalline druse.
98-104	77.0	Dolomite: like above, without quartz druse and chert.	1	Silt aggregates, milky, smooth to fine granular, dolomoldic (D). Coarse silt (A). Green waxy flakes, some dolomoldic (R). Authigenic feldspar, euhedral, glassy (R).
97a	33.0	Covered across meadow.		
94-97	44.0	Dolomite: light gray to pink and light brown, coarse-crystalline; beds 2 to 3 feet thick; weathers light to dark gray, honeycombed.	1	Coarse-grained silt with euhedral feldspar (C). Silt aggregates, milky to pale green, smooth to finely granular, dolomoldic (D). Green waxy flakes, dolomoldic (R).
89-93	55.0	Dolomite: tan to light chocolate, medium-crystalline, very uniform sugary texture; beds 4 to 10 inches thick; weathers to light gray smooth blocks with rough feel.	1	Coarse-grained silt and fine-grained sand, arkosic (D). Silt aggregates, finely granular, dolomoldic (A). Quartz druse (R).
86-88	33.0	Dolomite: gray to tan, medium-crystalline; beds 2 to 3 feet thick; weathers gray, slightly pitted to honeycombed.	1	Coarse-grained silt with glassy, euhedral feldspar (D). Silt aggregates, milky, finely granular, dolomodic to lacy (A).
80-85	66.0	Dolomite: gray to tan, medium-crystalline; beds 2 to 6 inches thick; weathers light tan to gray slightly pitted blocks.	1	Coarse-grained silt with glassy, euhedral feldspar and quartz (D). Silt aggregates, milky, finely granular, dolomoldic (C). Green waxy flakes, some dolomoldic (R).
77-79	42.0	Limestone: dark gray, fine grained, contains 5 to 15 percent dolomite in lacy, crystalline aggregates; beds 6 to 12 inches thick; weathers light blue-gray, thin-bedded.	2	Silt aggregates, milky to tan, finely granular, dolomoldic to porous.
73-76	55.0	Dolomite: gray to tan, medium-crystalline; beds 3 to 10 inches thick; weathers smooth to slightly pitted with sugary-textured surface.	1	Fine-grained sand, arkosic (D). Euhedral feldspar (C). Silt aggregates, milky, dolomoldic to porous (C). Fine-granular quartz druse (R).
65-72	88.0	Dolomite: light gray to pink, coarse-crystalline; massive beds 1 to 3 feet thick; weathers dark gray, honeycombed.	1	Euhedral, glassy feldspar (adularia) of coarse silt size (D). Silt aggregates, milky (C).
61-64	44.0	Dolomite: light chocolate-brown to gray, medium crystalline, sugary texture; beds to 2 feet thick; weathers dark gray, slightly to deeply pitted.	1	Euhedral, glassy feldspar (D). Silt aggregates, milky, smooth, dolomoldic (R).

At point 1,100 feet north and 1,800 feet east of the SW cor. sec. 36, T. 2 S., R. 4 E. Shifted line of sampling about 0.5 mile to south, across fault, to point 1,400 feet east and 1,100 south of the NW cor. sec. 1, T. 3 S., R. 4 E. Strike N. 10° E., dip 10° west.

FORT SILL LIMESTONE: 400.6 FEET THICK.

58-60	44.0	Dolomite: gray to tan, medium-crystalline; beds 1 to 2 feet thick; weathers to dark gray blocks, some smooth and some slightly pitted.	13	Very fine-grained, arkosic sand and coarse-grained silt.
57	11.0	Limestone, dolomitic: gray, ifnely crystalline; weathers to brownish-gray layers 1 to 2 inches thick.	9	Very fine-grained arkosic sand and coarse-grained silt.

47-56	119.0	Limestone: dark gray to brownish, mottled by patches of brown medium-crystalline dolomite; fine grained; dolomite commonly about 10 to 25 percent, although small lenses are completely dolomitized; massive beds 1 to 3 feet thick in ledges 5 to 7 feet thick, interbedded with marly, dolomitic limestone that is poorly exposed on grassy benches.	8	Very fine-grained arkosic sand, with some fine-grained sand and silt. Some euhedral feldspar (D). Silt aggregates, milky, finely granular, dolomoldic (C).
46	11.0	Dolomite: gray, medium-crystalline; beds 4 to 12 inches thick; weathers to yellowish, pitted blocks.	1	Same as above.
42-45	49.5	Limestone, dolomitic: dark gray to light brown, fine-crystalline calcite groundmass with reticulate masses of tan, medium-crystalline dolomite; about 25 percent dolomite; at base a conglomerate of limestone pebbles set in a sandy matrix; mostly thin-bedded.	2	Very fine-grained arkosic sand, with some euhedral, glassy feldspar (D). Silt aggregates, light brown, flaky, granular, dolomoldic (C).
41	5.0	Dolomite: gray, medium-crystalline, a little drusy quartz; beds 3 to 4 inches thick; weathers to yellow-brown blocks, some smooth and some deeply pitted.	1	Quartz druse, granular, milky.
37-40	56.5	Limestone, dolomitic: mottled dark gray and light brown; fine-grained limestone with reticulations and irregular patches of medium crystalline, tan dolomite; some beds have lenses of dolomite as much as 15 feet long; beds 2 to 6 inches thick; weathers to layers 1 inch thick.	2	Very fine-grained arkosic sand, with some euhedral, glassy feldspar (D). Silt aggregates, milky to light brown, finely granular, dolomoldic to lacy (C).
29-36	104.6	Limestone, slightly dolomitic: gray to greenish gray, fine crystalline and compact; contains lacework of brownish dolomite that weathers into positive relief; massive-bedded strata at top; beds 6 to 12 inches thick; at base a 3 foot bed of arkosic limestone that channels into underlying Honey Creek dolomite; weathers to dark gray boulders.	1	Very fine-grained arkosic sand, with some euhedral, glassy feldspar (A). Silt aggregates, milky to pale green, smooth to finely granular, some dolomoldic (C). Green, waxy flakes (R).

HONEY CREEK DOLOMITE: 233.8 FEET THICK.

28	22.1	Dolomite: pink, very coarse-crystalline, arkosic; thick beds 2 to 4 feet thick, cross-bedded; weathers to cavernous, dark gray pedestals 2 to 6 feet high.	40	Poorly sorted arkose (D). Green waxy flakes and granules (R).
24-27	60.5	Dolomite: gray to tan, medium-crystalline; beds 2 to 6 inches thick; weathers light brown to dark gray, smooth; a few ledges 18 inches thick weather slightly pitted.	6	Very fine-grained arkosic sand (D). Green waxy flakes, dolomoldic (R).
23	11.0	Dolomite: sandy; gray to tan, medium-crystalline, beds 1 foot thick; weathers light brown, laminated, smooth to slightly pitted.	48	Very fine-grained arkosic sand (D). Glauconite, dark green, granular (R).
22	22.1	Sandstone: gray to tan, fine-grained, glauconitic and dolomitic; beds 2 to 6 inches thick. Much of upper part covered.	76	Same as above.
19-21	49.5	Dolomite: gray, tan, and pink, medium-crystalline, sandy, and glauconitic; beds 6 to 15 inches thick; weathers to smooth, light brown, laminated, sandy blocks.	40	Very fine-grained arkosic sand (D). Glauconite, typical dark green granules (C).
18.8	5.0	Dolomite: like above, numerous well-preserved *Billingsella* cf. *coloradoensis* and *Eoorthis remnicha* (?).	16	Very fine-grained arkosic sand (D). Quartz druse, granular, replacement of fossils (C). Glauconite (C).
15-17	63.6	Dolomite: gray, fine-crystalline, sandy and glauconitic; beds 2 to 6 inches thick; weathers to smooth blocks, tan to nearly black. Trilobite fragments.	54	Very fine-grained arkosic sand (D). Glauconite, typical dark green granules (C).

REAGAN SANDSTONE: 347.9 FEET THICK.

14	27.6	Sandstone, arkosic: brown to yellowish, coarse-grained to conglomeratic; glauconitic at top; Five feet below top a 3-foot bed cemented with pink dolomite.	98	Poorly sorted arkosic sand; quartz sub-angular, frosted, pitted, and showing secondary crystal faces. Feldspar pink to green (D). Glauconite, dark green pellets (C).

13-12	44.2	Sandstone: brown to yellowish, coarse-grained, arkosic; some thin conglomeratic layers.	100	Poorly sorted arkose like above.
4-11	171.2	Sandstone, conglomeratic: buff to brown, arkosic; beds 1 to 2 feet thick, cross-bedded.	100	Poorly sorted arkose; quartz subangular to subrounded, pitted, frosted, and with some secondary crystal faces.
3	22.1	Sandstone: gray to brown, calcareous, mostly medium-grained with some conglomeratic layers; quartz pebbles ¾ inch in diameter; cross-bedded layers.	90	Arkose like above.
2a	27.6	Covered by alluvium of Bee Creek.		
		Strike N. 15° E., dip 10° west.		
1-2	55.2	Arkose, sandy to conglomeratic: different shades of red, yellow, and brown; thick, poorly defined, friable beds, cross-bedded; quartz pebbles ¼ inch in diameter.	100	Very poorly sorted arkose.

Base Reagan. Rests unconformably on pre-Cambrian Tishomingo granite. At point 700 feet east and 1,000 south of the NW cor. sec. 6, T. 3 S., R. 5 E., 5 miles south of Mill Creek village.

*Letter symbols are used to designate relative abundance of insoluble materials as follows:
(D) Dominant: more than 50 percent (C) Common: 5-25 percent
(A) Abundant: 25-50 percent (R) Rare: 1-5 percent

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