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General and Economic Geology of the Baum Limestone, Ravia-Mannsville Area, Oklahoma

By

John Rex Wayland and William E. Ham

Norman

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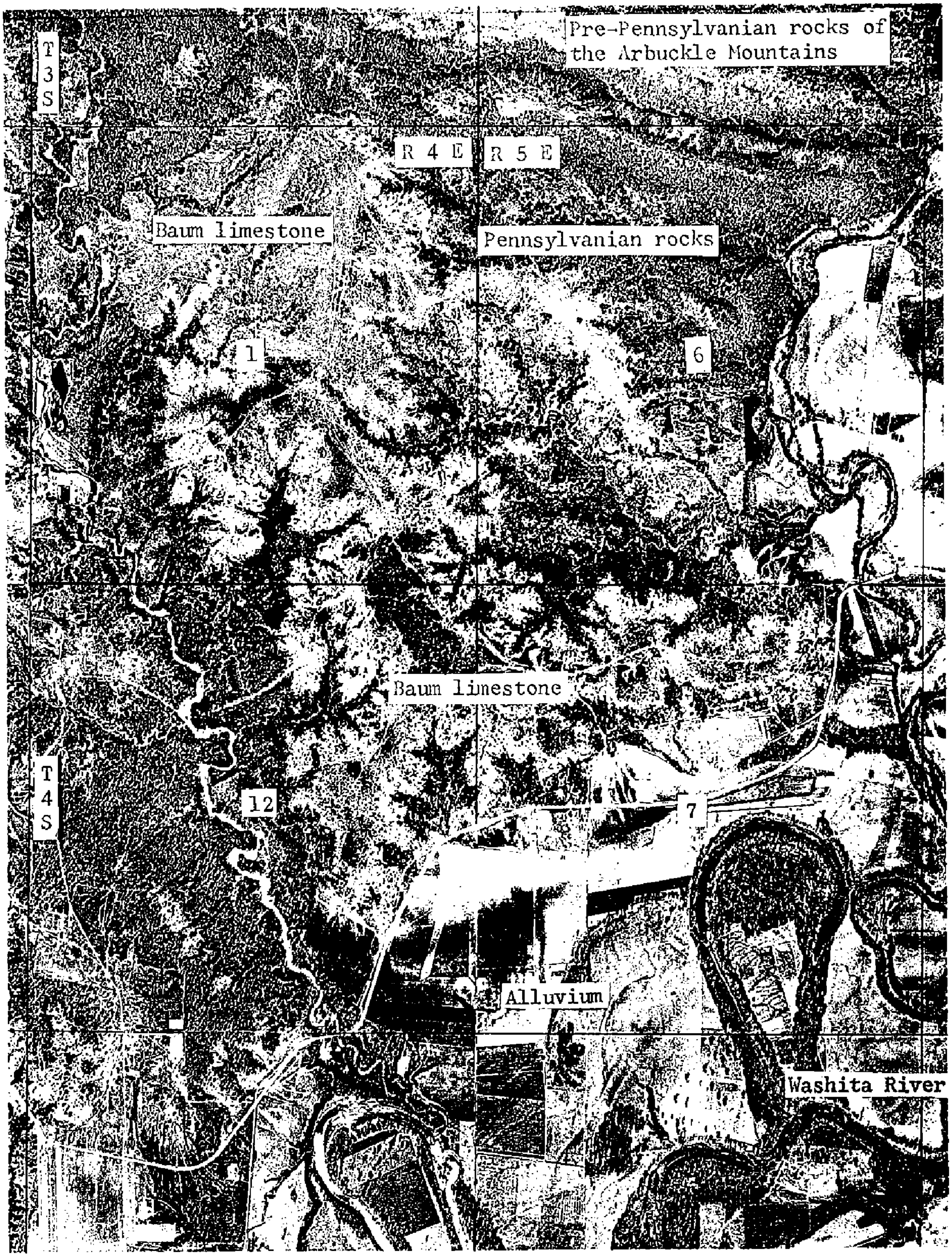

Aerial photograph showing the largest mesa of Baum limestone in the Ravia-Mannsville area. It is about 30 feet high and is characterized by irregular margins and flat upper surface. Photograph by the U. S. Department of Agriculture, 1940.

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GENERAL AND ECONOMIC GEOLOGY OF THE BAUM LIMESTONE, RAVIA-MANNSVILLE AREA, OKLAHOMA

By John Rex Wayland and William E. Ham

ABSTRACT

The Baum limestone member of the Paluxy formation, in the Trinity group of Lower Cretaceous age, has its maximum development in an area about 15 miles long and 10 miles wide that borders the southern part of the Arbuckle Mountain region in south-central Oklahoma. This limestone is a brackish-water facies deposited in a protected bay, to which an abundant supply of calcium carbonate was supplied by erosion of older Paleozoic carbonate rocks in the Arbuckle Mountains.

From a maximum exposed thickness of 73 feet and an inferred total thickness of about 90 feet in the central part of the area, the Baum thins and disappears both eastward and westward by interfingering with sands of the Paluxy formation.

Where it is present, the Baum is the basal member of the Paluxy and rests with marked angular unconformity on steeply dipping Pennsylvanian and older rocks of the Ardmore basin and Arbuckle Mountains. Near Ravia, in the eastern part of the area, it rests on pre-Cambrian granite.

The Baum limestone is composed of four intergrading lithofacies: (1) basal red clay, which is 28 feet thick at northwestern localities but disappears southeastward; (2) limestone conglomerate, which is 42 feet thick at north-central localities but disappears southward and eastward away from the ancient shoreline; (3) massive fine-grained limestone, principally of algal origin, which is the thickest and most widely distributed of all the Baum units; and (4) arkosic limestone and calcareous arkose, present only in the granite outcrop area near Ravia. Owing to irregular distribution resulting from local supply of material and irregularities of pre-Baum topographic relief, each of these lithofacies locally is at the base of the Baum limestone.

Except for abundant remains of low-order blue-green algae, the only fossils found in the Baum are charophyte oogonia and ostracodes, both of which indicate a brackish-water or fresh-water environment.

The massive fine-grained limestone has a maximum thickness of 73 feet and an exposed thickness normally ranging between 20 and 30 feet. It crops out in conspicuous mesas and bluffs, chalky and dazzling white, to which the name "White Hills" has been applied by local residents. Limestone was produced commercially for agri-

cultural fertilizer and crushed stone from two principal quarries in the period 1944-1952, when 110,000 tons of stone was produced.

It is concluded from the present investigations that the mapped area contains approximately 158,000,000 tons of limestone ranging in composition from 92.99 to 97.59 percent calcium carbonate. The greatest potentialities of the Baum limestone are in the production of high-calcium limestone for chemical use. The purest limestone, averaging 97.53 percent calcium carbonate and having a reserve of 52,000,000 tons, has never been quarried. It is suitable for making quicklime and hydrated lime, and may be used in water treatment, building plasters, as flux in metallurgical processes, and in the manufacture of paper, certain grades of glass, and calcium carbide. The Baum also is an ideal material for mixing with shale to make portland cement.

Numerous open-face quarry sites with little or no overburden are available in the area. Railroad transportation is accessible at Ravia and at the nearby urban centers of Ardmore and Madill; and water supplies are obtainable from Washita River, which flows eastward through the central part of the Ravia-Mannsville area.

INTRODUCTION

The limestone here mapped and described as the Baum member of the Paluxy formation has been known as a division of the Trinity group, early Cretaceous in age, since the investigations of Taff published in 1903. Brief reference to this limestone has been made in later years in publications by C. W. Tomlinson of Ardmore, Oklahoma; and, although it was never formally described and named, geologists working in the Ardmore region were sufficiently familiar with the term "Baum limestone" to understand its general meaning.

During the course of detailed mapping of rocks in the Arbuckle Mountains region beginning in 1943, William E. Ham as geologist of the Geological Survey examined the Baum limestone outcrops north of Washita River and mapped them in reconnaissance. Attention was drawn to the potential economic value of the limestone deposits when, in 1943, a quarry was opened in the central part of the outcrop area for the production of agricultural limestone. At that time, samples of limestone outcrops at the quarry and of plant-run agstone were collected by Ham and analyzed in the laboratory of the Geological Survey. Neither of these samples was of exceptionally high purity, and no further investigation was made until post-war demand for high-calcium limestone, prompted partly by the erection in Oklahoma of a calcium carbide plant, led to a new search for limestone of chemical grade.

The present investigations were started in 1953. John Rex Wayland spent three months in the Ravia-Mannsville area during the spring and summer, mapping the outcrops of Baum limestone and sampling critical localities for chemical analysis. This geological phase of the work, undertaken by Wayland as a Master's thesis in Southern Methodist University, was supported by the Geological Survey and Dr. C. W. Tomlinson, who also supplied the aerial photographs for Wayland's field work. The completed thesis was used as a basis for the geological discussions in the first part of the present report; and the geologic map (Plate I) is reproduced with slight modifications by Ham. Subdivision of Mississippian and older rocks shown in the northern part of Plate I is adapted from "Geologic Map and Sections of the Arbuckle Mountains, Oklahoma" (Ham and McKinley, 1954).

Final drafting of the geologic map, all chemical analyses, the preparation of illustrations, and the chapter on economic geology are by the Oklahoma Geological Survey. The drafting of Plate I is by Clifford O. Walden, under the supervision of Dwight H. Ford; and all photographs not otherwise acknowledged are by Myron E. McKinley.

GENERAL GEOLOGY

By John Rex Wayland

The Baum limestone is a nonmarine algal-rich deposit that occurs as a local facies in the basal part of the Paluxy formation. In the area here studied the Paluxy is the lowest formation of the Trinity group, which is of Lower Cretaceous (Comanchean) age. The Baum is best known in south-central Oklahoma, in the area of outcrop south of the Arbuckle Mountains that extends from Ravia westward to Baum and southward to the vicinity of Mannsville. Its distribution is genetically related to the Arbuckle Mountains, from which the calcium carbonate was chiefly derived. Nearly all the outcrops are in the Ravia-Mannsville area, which was mapped for this report (Plate I) and which covers 114 square miles in southwestern Johnston County, eastern Carter County, and northwestern Marshall County.

Within this area the limestone has a maximum exposed thickness of 73 feet and crops out over approximately 10 square miles; and probably over an area of about 25 square miles it is covered by alluvium and terrace deposits. Beyond the limits of the mapped area in southern Oklahoma, similar limestone in the Paluxy formation is thin and lenticular, and occurs in widely scattered exposures.

Previous and present investigations. The first published reference to the Baum limestone was by Taff (1903, p. 6), who wrote as follows:

> The lower part of the [Trinity] formation from the vicinity of Ravia eastward to the border of the [Tishomingo] quadrangle, where it rests upon the granite, is composed of sand which has been produced chiefly from the granite. From the vicinity of Ravia westward to the border of the quadrangle, where the lower part approaches the limestone formation of the Arbuckle Mountains, it is composed of a very coarse limestone conglomerate cemented in a matrix of chalky white lime and grit. The materials composing the conglomerate vary from bowlders a foot in diameter to small pebbles, and have originated chiefly from the Cambrian and Ordovician limestones of the Arbuckle Mountain region. This limestone conglomerate grades upward from calcareous sediments into the finer and purer sands of the middle portion of the Trinity formation.

In Taff's work the limestone was not mapped separately but was included with the sands of the Trinity group, and since that time no detailed mapping of Cretaceous rocks in this area has been published.

Tomlinson (1926) referred to the basal limestone of the Trinity resting on folded older rocks of the Mannsville anticline in northwestern Marshall County; and later Tomlinson (1952, pp. 3-4, Plates II, III, and V) used the term Baum limestone in text and on maps for an Ardmore Geological Society Guidebook. Thus the term "Baum limestone" came into use informally and was well known locally, but no detailed descriptions of the rock had been published.

The present work is an investigation specifically of the Baum limestone. Under auspices of Dr. Tomlinson and the Oklahoma Geological Survey, the writer spent parts of 3 months in the field during the spring and summer of 1952, mapping the limestone and its associated rocks with aerial photographs on a scale of 1:20,000, or approximately 3 inches to 1 mile. The investigation included measurements of thickness, search for fossils, studies of lithofacies and stratigraphic relations, and detailed sampling of outcrops for chemical analysis. The writer is deeply indebted to Dr. Tomlinson and to Dr. Ham of the Oklahoma Geological Survey for encouragement, stimulation, and guidance in the field, and for the financial assistance that made this work possible.

The results of the field work, together with subsequent investigations in the laboratory, were used as a thesis entitled "Geology of the Baum limestone of Southern Oklahoma", presented to the faculty of the Graduate School of Southern Methodist University in partial fulfillment of the requirements for the Master of Science degree, which was granted in June, 1954. Dr. A. Richards, Dr. C. C. Albritton, Jr., and Mr. Bob F. Perkins of the faculty of Southern Methodist University freely gave assistance and encouragement in this work, for which the writer is sincerely grateful. An account of this investigation has been published (Wayland, 1954) and is used extensively in the present report.

Type locality. In present nomenclature the Trinity is a group of several formations, early Cretaceous in age, of which the Paluxy sand is the only representative in central southern Oklahoma. In the Ravia-Mannsville area the limestone here discussed is at the base of the Paluxy sand and is clearly a stratigraphic division of it, grading from a limestone and limestone conglomerate laterally and upward into the sands of the Paluxy. Formal proposal to name this unit the Baum limestone member of the Paluxy formation was made in the publication previously cited (Wayland, 1954, p. 2402). The name appears on the Geologic Map of Oklahoma, published December 31, 1954, as a member of the Paluxy formation. The name is taken from the small village of Baum, SW¼ NE¼ sec. 35, T. 3 S., R. 3 E., which formerly was a thriving community but now consists of two dwellings. The type locality is here designated as the hill in the NE¼ SE¼ sec. 36, T. 3 S., R. 3 E., 1.2 miles east of Baum, where three of the four lithofacies of the Baum limestone are well exposed. The best exposures are in the south side of the cut on an east-west county road, approximately 1,000 feet west of the E¼ corner of sec. 36, T. 3 S., R. 3 E., Carter County, Oklahoma, where the following section was measured:

	Thickness in feet
Baum limestone (top eroded)	
3b. Limestone, pinkish gray, compact, extremely fine-grained, clastic. Contains veinlets and irregular patches of calcite. Weathers to rubbly surface of rounded masses, some showing brown banding (algal?)	4
3a. Limestone, pinkish gray to white, compact, fine-grained, argillaceous; contains pebbles of chert and limestone, and well-rounded, frosted, quartz sand grains. Weathers to sloping surface	18
2. Limestone conglomerate, consisting of limestone pebbles and cobbles as much as 4 inches in diameter, loosely cemented by crystalline white calcite and pink clay	2
1. Clay, pink and red, containing well-rounded, frosted, quartz sand grains and nodules of pinkish shaly limestone which weather brilliant white. Limestone nodules have Baum lithology, and increase in number toward the top of the unit. Abundant charophyte oogonia	17.5
Total thickness	41.5
Angular unconformity	
Deese formation	
Maroon shale, not measured.	

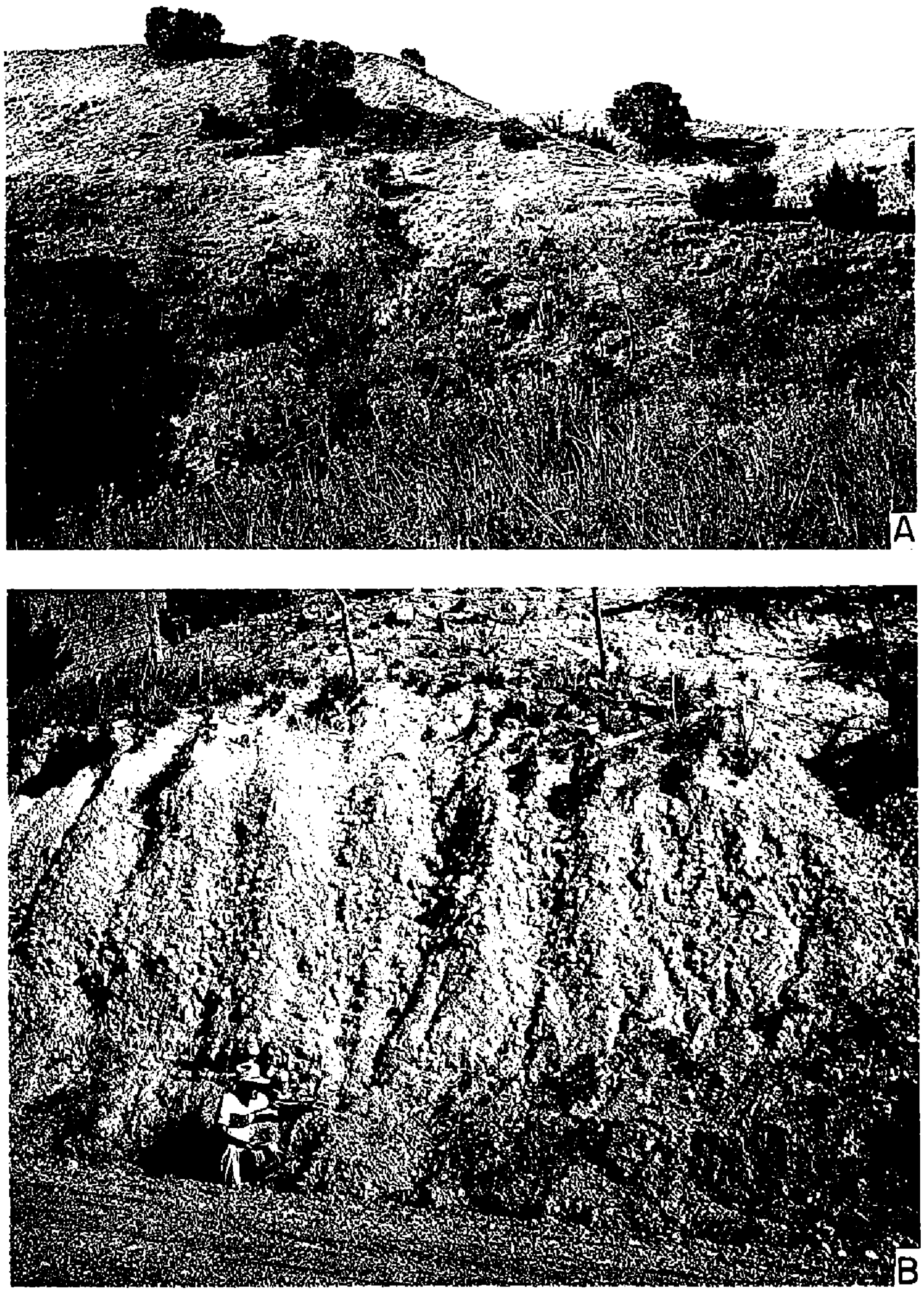
Distribution and thickness. The outcrops of Baum limestone are principally at three localities north of Washita River between Ravia and Baum, and at two localities south of Washita River near Mannsville and westward nearly to Oklahoma Highway 18. The Baum dips about 40 feet per mile southward, but at any given locality it appears to be horizontal.

Near Ravia, in its easternmost outcrop, the Baum rests with marked unconformity on pre-Cambrian granite and on pre-Pennsylvanian highly folded rocks of the Arbuckle Mountains. About 0.5 mile east of Ravia, in the east-central part of sec. 2, T. 4 S., R. 5 E., the Baum interfingers with and grades eastward into sands of the Paluxy formation.

At the north-central locality, between Mill Creek and Oil Creek, the Baum lies on steeply dipping Pennsylvanian shales and sandstones of the Ardmore basin. At one excellently exposed contact described by Tomlinson (1952, p. 4), in the cen. SE¼ SW¼ sec. 34, T. 3 S., R. 4 E., fine-grained limestone of the Baum extends downward as much as 5 feet between beds of nearly vertical Pennsylvanian (Lake Ardmore) sandstone. The sandstone forms a pre-Baum topographic ridge that stood well above the top of the basal clay member of the Baum. The northern limit of the Baum generally is marked in the north-central locality by the steep escarpment at the top of the Sycamore limestone (Mississippian), which here formed the shore of the sea at the time the Baum was deposited.

East of Baum in the vicinity of the type locality, the Baum limestone rests on steeply dipping Pennsylvanian rocks. It disappears westward, apparently by interfingering with sand of the Paluxy formation. At all these northern localities the upper part of the Baum limestone is eroded or is covered by alluvium and terrace depostis.

South of Washita River the upper part of the Baum limestone is locally well exposed, so that gradation into overlying sands of the Paluxy may be observed. The base, however, is covered by alluvium and terrace deposits everywhere except near Wolf Creek and at the Mannsville anticline on Turkey Creek. On Turkey Creek steeply dipping pre-Pennsylvanian rocks are unconformably over-



Outcrops of Baum limestone at type locality.

A. Escarpment edge of low mesa capped by compact, light-weathering limestone, looking north from CNL SE¼ sec. 36, T. 3 S., R. 3 E.

B. Contact of Baum limestone (at man's hand) on maroon shale of Deese formation. Basal division of Baum is calcareous pink clay containing nodules of limestone. South cut of road, 1,000 feet west of E¼ cor. sec. 36, T. 3 S., R. 3 E.

lain by Baum limestone. The unconformable contact of Baum on Sycamore limestone is particularly well exposed in the SW¼ NE¼ SE¼ sec. 34, T. 4 S., R. 4 E. Here the fine-grained phase of the Baum irregularly covers and extends downward as much as 4 feet into eroded beds of Sycamore limestone. It is wedged into bedding planes, joints, and spaces from which thin-bedded layers of Sycamore had been removed.

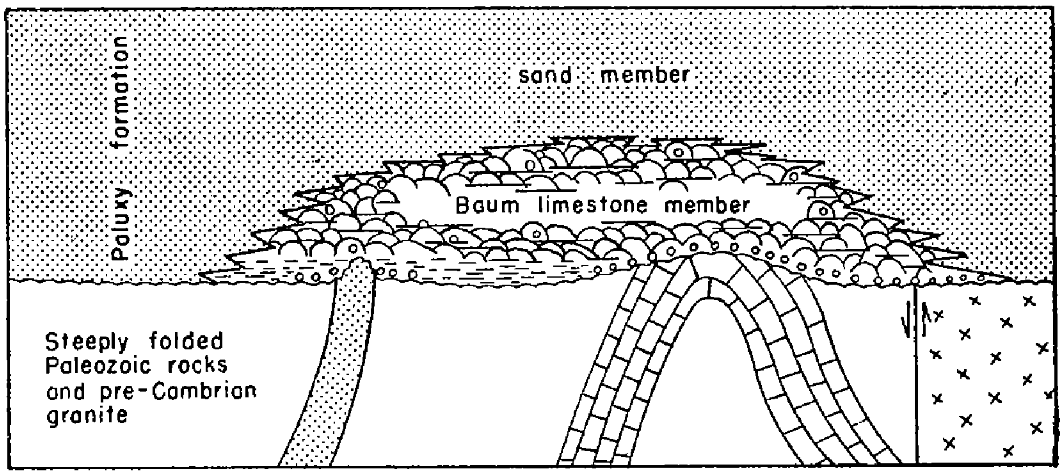


FIG. 1. Generalized diagram showing east-west stratigraphic relations of the Baum limestone in the Ravia-Mannsville area.

The thickness of the Baum limestone ranges from 13 feet on Turkey Creek, SW¼ SW¼ NW¼ sec. 35, T. 4 S., R. 4 E., where the base and top are well exposed, to a maximum measured thickness of 73 feet on Washita River, NE¼ NW¼ sec. 14, T. 4 S., R. 4 E., where the base is not exposed and the top is eroded. In other areas the thickness is as follows: Wolf Creek, 13-23 feet; type locality, 41.5 feet; between Mill Creek and Courtney Creek, 28-40 feet; and near Ravia, 2-24 feet. At these last four localities the base of the Baum is exposed but the top is eroded, so that the full thickness is not measurable.

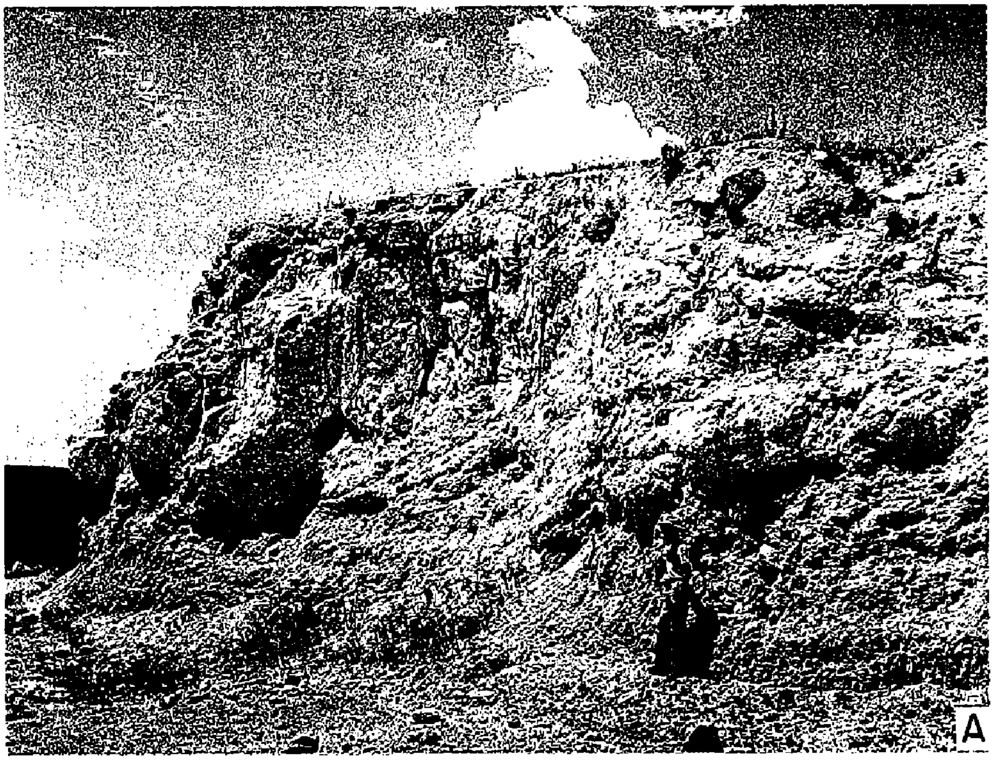
The maximum thickness of the Baum limestone before erosion probably did not exceed 80 or 90 feet in the Ravia-Mannsville area, the site of its thickest deposition. It disappears both eastward and westward by gradation into sand, although a few thin lentils of limestone or conglomerate in the lower part of the Paluxy sand are known in Love County to the south, and in Atoka County to the east. In Love County, sec. 17, T. 6 S., R. 2 E., lenses of limestone pebbles 1-1½ feet thick and 3-4 feet long occur 3 feet above the base of the Paluxy formation. The pebbles are rounded, have a maximum diameter of 2 inches, and are similar to those in the Baum near Mannsville. In Atoka County, CNL sec. 33, T. 3 S., R. 9 E., massive Baum-type limestone in the Paluxy crops out in poor exposures near a large inlier of Arbuckle limestone and dolomite. Dr. Tomlinson conducted the writer to these localities.

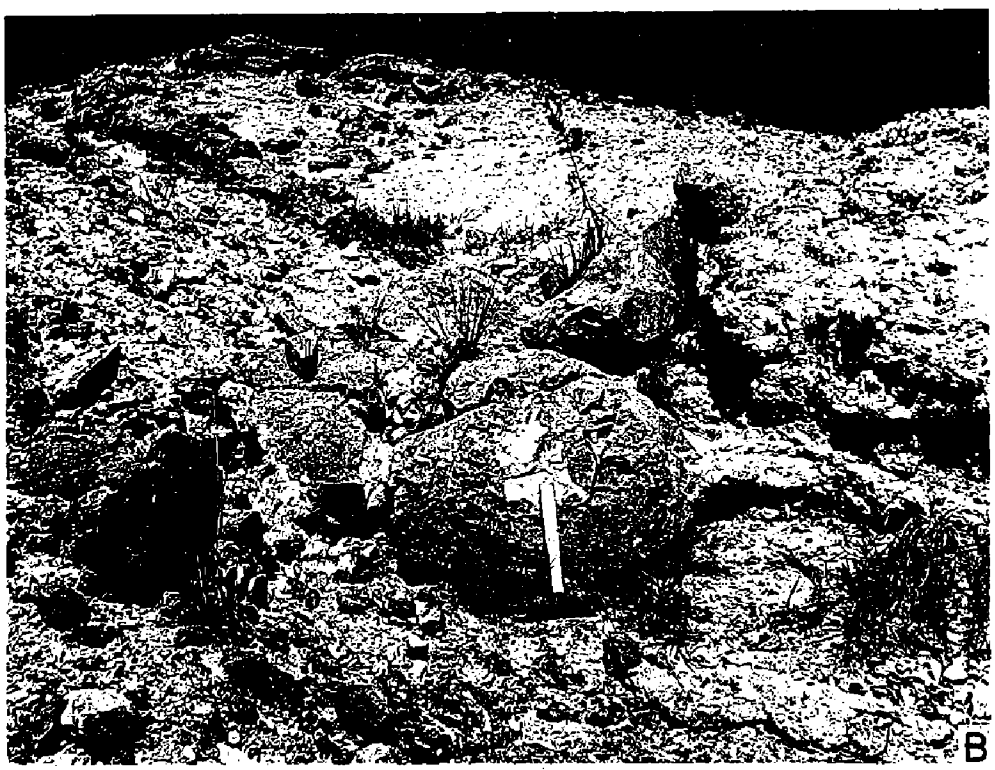
Lithofacies. The Baum limestone in the mapped area consists of four intergrading lithofacies: (1) basal red clay, which disappears southeastward, (2) limestone conglomerate, which is best developed at the northern margin of outcrop near the Arbuckle Mountains, (3) massive fine-grained limestone, which is the thickest and most widely distributed of all the Baum units, and (4) arkosic limestone and calcareous arkose, present only in the eastern outcrop area near Ravia. Owing to irregular distribution, each of these units locally is at the base of the Baum limestone.

The basal clay is a pink to red, structureless clay containing well-rounded, frosted, and clear quartz grains, and limestone nodules as much as 6 inches in diameter. The clay has a maximum observed thickness of 28 feet in sec. 3, T. 4 S., R. 4 E. It thins northwestward to 17 feet at the type locality, and thins to extinction southward and eastward.

The conglomerate lithofacies of the Baum contains pebbles, cobbles, and boulders of sandstone, limestone, dolomite, and shale which were derived from Paleozoic rocks of the Arbuckle Mountains (Plate IV, B). The matrix is limestone which ranges from an earthy to coarsely crystalline calcite and clastic limestone to a compact, extremely fine-grained limestone. The conglomerate attains its maximum thickness of 42 feet in the SE¼ SW¼ sec. 27, T. 3 S., R. 4 E., where it consists of conglomerate beds interstratified with red shale. At the 3 outliers centering around the SW cor. sec. 31, T. 3 S., R. 5 E., it occurs as massive boulder-cobble conglomerate 20 feet thick, but one-half mile southward even pebbles are inconspicuous.

The conglomerate occurs predominantly along the northern edge of the outcrop of the Baum, nearest the closely folded rocks





Outcrops of Baum limestone.

A. Agstone quarry 20 feet high in fine-grained, compact limestone lithofacies, C NE¼ SE¼ sec. 12, T. 4 S., R. 4 E.

B. Typical outcrop of Baum limestone on sloping mesa escarpment, showing rounded masses of algal limestone and characteristic rubble-covered surface. NW¼ NE¼ NE¼ sec. 1, T. 4 S., R. 4 E.

of the Arbuckle Mountains. It occurs only in the lower part of the limestone sequence, and disappears southward away from the source of supply. South of Washita River the conglomerate was not observed in the Baum limestone except at the Mannsville anticline on Turkey Creek.

The principal rock of which the Baum limestone is composed is a gray or pinkish-gray, fine-grained, compact, massive limestone (Plate III, A). The percentage of calcium carbonate in this limestone ranges from 92.99 to 97.59 and averages 95.57, as shown by the 10 analyses given in Table 1. It has been quarried for use as agricultural limestone and as crushed stone for highway construction. This type of limestone has a maximum observed thickness of 73 feet in the NE¼ NW¼ sec. 14, T. 4 S., R. 4 E., where the base is covered and the top is eroded. There is no discernible bedding that may be traced more than 8 feet laterally. Boulders as much as 2 feet in diameter weather out of the matrix of fine-grained clastic limestone (Plate III, B). These boulders are extremely fine-grained and compact limestone, and contain veinlets and irregular patches of crystalline calcite. Some boulders exhibit light and dark-colored wavy bands which are believed to be the result of algal deposition, and much of the massive limestone shows under the microscope certain structures that are believed to be of algal origin.

The arkosic limestone is confined to the eastern edge of the outcrop area where it overlies pre-Cambrian granite. It consists of quartz and feldspar cemented by yellowish, soft, fine-grained, marly limestone. A water well drilled in the town of Ravia penetrated 24 feet of this rock. Northward from Ravia the Baum thins to a feather edge, and southward it grades into sands of the Paluxy formation.

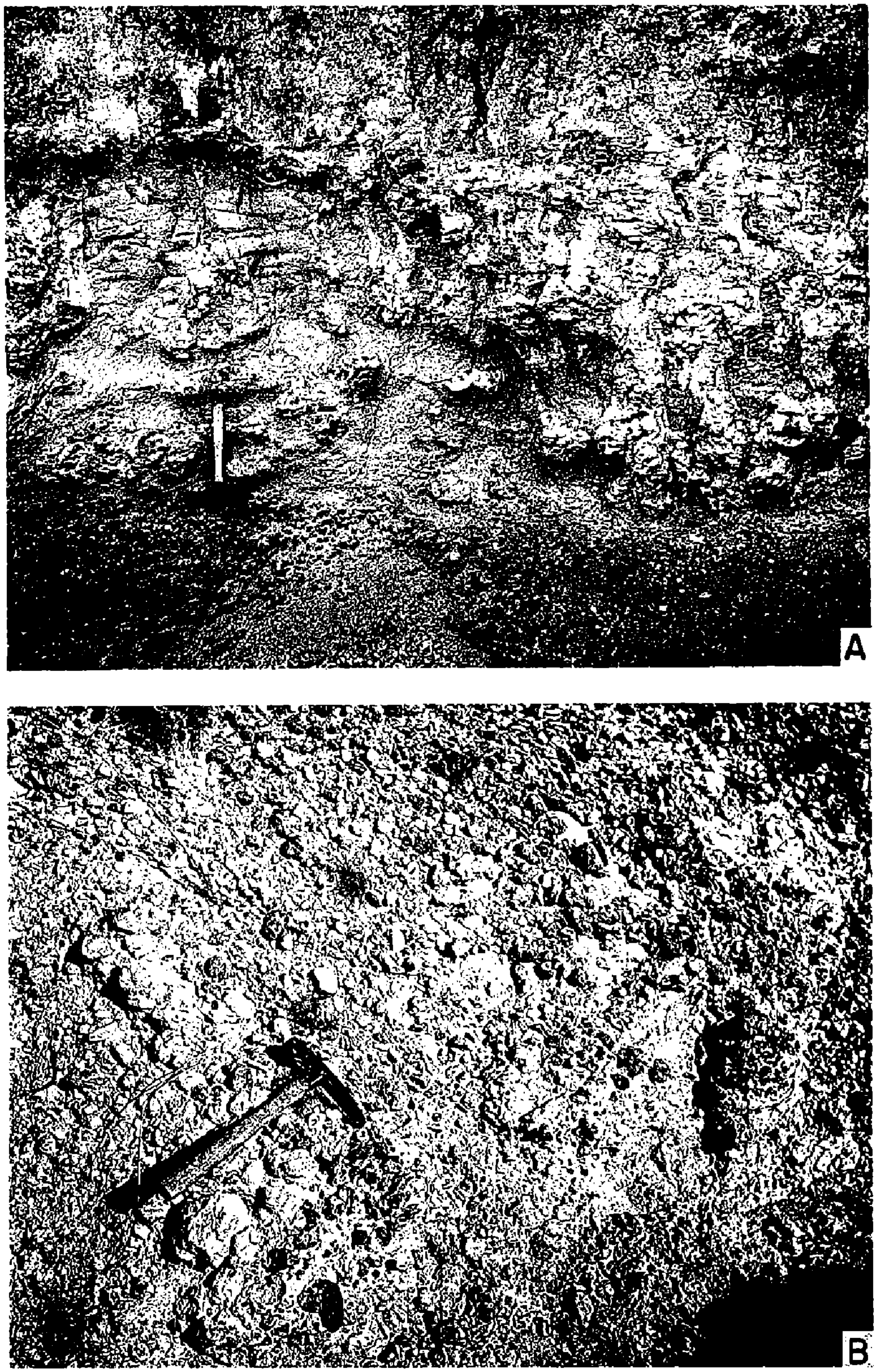
An abnormal phase of the Baum crops out in the inlier south of Ravia, NW¼ NE¼ SE¼ sec. 10, T. 4 S., R. 5 E., and along the banks of Camp Creek southwest of Mannsville, cen. N½ NW¼ sec. 33, T. 4 S., R. 4 E. At both localities, masses of fine-grained limestone in the form of irregular vertical columns are embedded in calcareous silt (Plate IV, A). From the occurrence of bedding that passes through the silt into the limestone columns, and from the lateral gradation of this lithofacies into massive limestone, it may be inferred that the limestone columns were deposited contemporaneously with the enclosing silts. The best explanation appears to be that the limestone columns are cylindrical algal colonies that grew upward about as fast as silty calcareous sediments accumulated around them.

Fossils. The only fossils found in abundance in the Baum limestone are charophyte oogonia, which occur in the basal clay and in silts intercalated with limestone. The charophyte oogonia were identified by Mr. Bob F. Perkins, Instructor in Geology at Southern Methodist University, as *Atopochara trivolvis* Peck and *Clavator harrisi* Peck, the most abundant being *A. trivolvis.* Peck (1941) has identified these forms from Lower Cretaceous rocks of the Rocky Mountain region and from the Trinity group in Texas and Oklahoma. A few ostracodes found in the basal division of the Baum were identified by Mr. Perkins as specimens of the fresh-water genus *Metacypris.* Charophyte oogonia and ostracodes occur also in the compact limestone (Plate IX, E), and are indicators of the nonmarine environment in which the Baum was deposited.

Part of the fine-grained limestone of the Baum shows distinctive wavy bands that probably were formed by algal activity, and much of the calcite-flecked, extremely fine-grained limestone is similar to that deposited by blue-green algae (Plates VII, VIII, and IX A, B, C).

Geologic history. Taff (1903, p. 1) states that at the beginning of Cretaceous time the Arbuckle Mountains had been reduced to a peneplain. The Arbuckle Mountain region was reduced still further by the transgressing Cretaceous sea, which formed a flat, though gently sloping, wave-cut surface of marine planation. On this surface the Trinity sediments were deposited, extending an unknown distance northward from the present limit of outcrop.

During the transgression of the Cretaceous sea from the southeast, the less resistant shales of Pennsylvanian age lying south of the Arbuckle Mountains were deeply scoured by wave action, in contrast to the more resistant limestones and sandstones which stood temporarily as rocky headlands. In sec. 27, T. 3 S., R. 4 E.,



Outcrops of marl and conglomerate in Baum limestone member.

A. Arkosic conglomerate overlain (at head of hammer) by calcareous sandy shale that contains irregular columns of fine-grained limestone (algal?). Lower part of Baum member in Ravia district, NW¼ NE¼ SE¼ sec. 10, T. 4 S., R. 5 E.

B. Limestone pebble-cobble conglomerate near base of Baum, SE¼ SE¼ NE¼ sec. 31, T. 3 S., R. 4 E.

the Sycamore limestone stands in a hogback that rises 51 feet above the base of the Baum, and large boulders of Sycamore limestone are enclosed within the Baum. It is believed that the erosional surface between the Sycamore and Baum limestones is a wave-cut cliff made by the Cretaceous sea.

The outcrop of the Baum limestone follows a nearly straight line in the 3-mile distance from the southern part of sec. 36 to the southwestern part of sec. 27, T. 3 S., R. 4 E. (Plate I). This line corresponds with the outcrop of the Sycamore hogback, the southernmost resistant ridge of the Arbuckle Mountains. Westward from this area the Baum has been stripped away by erosion, but eastward the Baum has overlapped the Sycamore onto the sedimentary rocks and granites of the Arbuckle Mountain region. From these field relations it appears probable that the Baum was never deposited north of the Sycamore outcrop in the area that lies westward from sec. 36, T. 3 S., R. 4 E., and that the Sycamore hogback in this area formed the northern shoreline of the sea during Baum time.

It is in this area also that red clay is a conspicuous basal member of the Baum. This clay was derived from underlying shales of Pennsylvanian age, which had been deeply weathered to bright red, lavender, and yellow in pre-Baum time (Tomlinson, 1952, and personal communication).

From the non-marine character of the rocks, as deduced from the general lack of bedding, the abundance of algae, and the presence of fresh-water fossils, it is inferred that a lagoon or bay was developed in Baum time in the southern part of the Ravia-Mannsville area, probably by sand bars and by local uplifts of bedrock such as the Mannsville anticline. Fresh water from streams flowing into the bay from the exposed outcrops of Paleozoic limestones in the Arbuckle Mountain region were mixed with salty sea water to form brackish water highly charged with calcium carbonate. In this environment calcium carbonate was precipitated, both chemically and by algae, at the same time the basal red clays of the Baum were being deposited. This dual deposition continued until the source of the red clays below was covered. Then algae flourished in their maximum development and the massive limestones were formed, only to be partly reworked by wave action in water which probably was never deeper than 10 fathoms or 60 feet.

The conglomerates are deposits of gravel carried by longshore currents and derived from the resistant Paleozoic beds. This gravel was obtained both at the shore line by the mechanically destructive action of waves, and from fresh-water streams discharging their load brought from higher parts of the Arbuckle Mountains. Well-rounded pebbles and cobbles such as those in the outcrop area near Baum (Plate IV, B) obviously have been abraded more and have travelled farther than angular fragments derived from subjacent bedrock. The conglomerate beds disappear southward and eastward, away from the shoreline and away from the points of stream discharge into the bay.

ECONOMIC GEOLOGY

By William E. Ham

From the geological discussion in the first section of this report, it is clear that the Baum limestone of the Ravia-Mannsville area is locally thick, relatively pure, and has substantial areal extent. In this chapter the economic aspects are considered, and the conclusion is reached that the mapped area contains approximately 158,000,000 tons of limestone ranging in composition from 92.99 to 97.59 percent calcium carbonate.

In the past, small quarries have been operated intermittently for the production of agricultural fertilizer and crushed stone, but as a result of the present investigation it is now known that the highest purity limestone has not been quarried, and that the greatest potentialities of the Baum limestone are in the production of high-purity stone for chemical use. The purest limestone, averaging 97.53 percent $CaCO_3$ and having a reserve of 52,000,000 tons, is suitable for making quicklime and hydrated lime, and may be used in water treatment, in making building plaster, as flux in metallurgical processes, and in the manufacture of paper, certain grades of glass, and calcium carbide. As a basic raw material for chemcial manufacture, the Baum limestone is a potentially valuable mineral resource for the southern Oklahoma region.

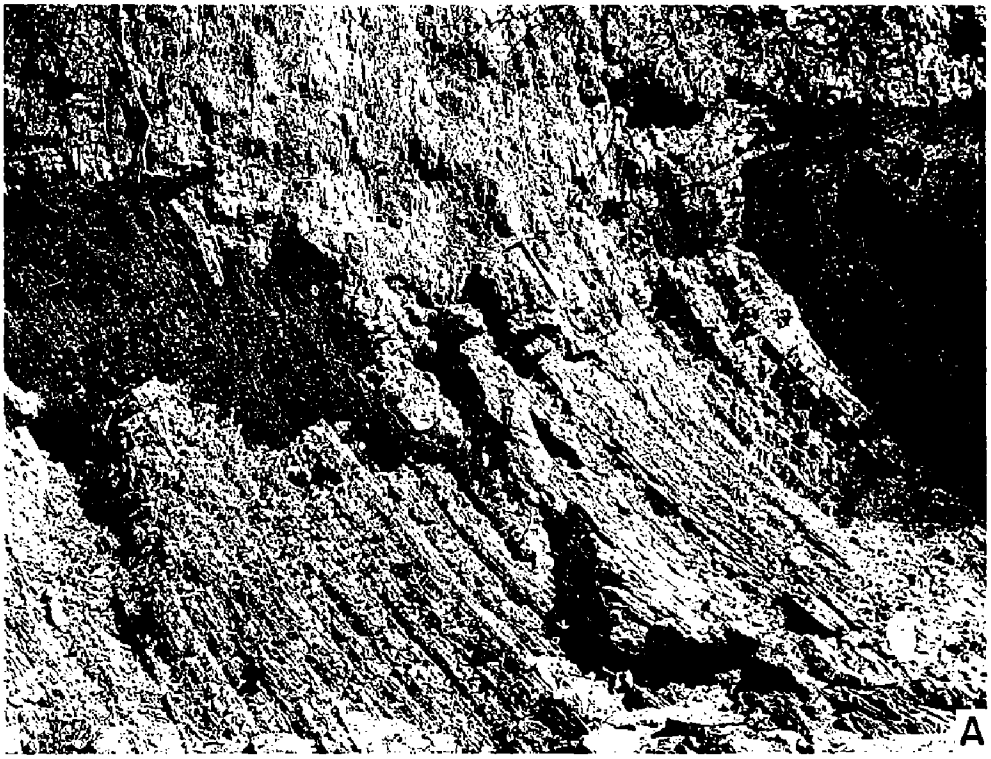
PHYSICAL PROPERTIES

The Baum limestone member of the Paluxy formation, as mapped in Plate I, consists dominantly of compact limestone, but contains also some conglomerate and loosely consolidated marl, calcareous clay, and calcareous sandstone. These marls, clays, and sandy calcareous rocks are impure lithofacies occurring generally at the base of the limestone sequence or at the outer margins of the regional outcrop. Clays and marls normally are at the base, where the first calcareous deposits of the Baum were mixed with clay derived from underlying shale bedrock. They are best developed in outcrops north of Washita River and west of Mill Creek. Conglomerate phases are restricted mostly to the northern border of outcrop, particularly in secs. 34 and 35, T. 3 S., R. 4 E., and to a lesser extent near the southern boundary, on Turkey Creek southeast of Mannsville. The sandy calcareous phases have their greatest area of outcrop in the Ravia district, in the northeastern part of the area, where the underlying granite bedrock contributed abundant quartz-feldspar sand, and where also the Baum rocks begin to interfinger with sands of the Paluxy formation.

The normal rock type of the Baum, which is the type referred to in all the reserves estimated for this report, is fine-grained pinkish gray or light gray limestone. It crops out in 3 districts over an area of about 2,450 acres and ranges in exposed thickness from 10 to 73 feet. In bluff faces the stone appears chalky and dazzling white, it shows little or no bedding, and weathers to a sloping surface partly covered by rubble of compact algal limestone (see Frontispiece, Plate III, and Plate V, B).

The fine-grained rock is speckled with coarsely crystallized calcite that occurs as small irregular bodies and veinlets. Locally a faint asphaltic odor is emitted when the rock is struck by a hammer, and at a few localities in the area small patches of black asphaltite were observed. The limestone consists mostly of calcium carbonate, but contains small amounts of finely disseminated quartz silt and clay. The pink color of the rock is due to the inclusion of this clay, which was derived from deeply weathered underlying shales.

Although superficially resembling a conglomerate, the rock actually consists of beds, isolated colonies, and fragments of algal limestone that are complexly mixed with fine-grained inorganically precipitated calcium carbonate and lime muds washed from the Arbuckle Mountains. The algae are aquatic plants which were growing on the sea floor at the time the Baum limestone was being deposited, and they contributed significantly to the total volume of the rock. Portions of the algal colonies were broken loose by wave action and transported a short distance to other parts of the depositional basin, where they were incorportated in the lime muds as subrounded pebbles, cobbles, and boulders. These rounded masses of extremely fine-grained and compact algal limestone weather out of the rock on exposed slopes, and form the characteristic rubble.



Outcrops of Baum limestone.

A. Unconformable contact of Baum limestone on steeply dipping beds of the Woodford formation, on branch of Turkey Creek, SE¼ NE¼ SE¼ sec. 34, T. 4 S., R. 4 E.

B. View toward southwest from top of mesa supported by Baum limestone, SW¼ NE¼ sec. 2, T. 4 S., R. 4 E.

All the algae appear to be of the low-order, blue-green type, of which at least 3 different kinds are present in the Baum limestone. One has hemispherical form and is made up of concentric upward-arching layers (Plate VIII, A, B). The colonies are 6 inches or less in diameter and generally occur in beds 3-6 inches thick. A second type of algal limestone in the Baum is made up of ovoid to spherical pellets mostly 0.1-1.5 mm. in diameter, each consisting of irregular or concentrically banded algal crusts (Plate VIII, C). Original openings in the pellets, as well as spaces between individual pellets in the framework of the rock, are filled with clear calcite. The third type is closely similar to the "birdseye" algal limestones of the Ordovician McLish formation, which crops out extensively in the northern and eastern parts of the Arbuckle Mountains (Ham, 1954).

The best developed "birdseye" limestone in the Baum was observed at the quarry in the SE¼ NE¼ SE¼ sec. 13, T. 4 S., R. 3 E., Carter County, where it consists of extremely fine-grained, pale lilac, subparallel algal crusts that are partly separated by coarsely crystallized clear calcite (Plate VII). No well-defined external form is apparent in this type of algal growth, either in the McLish or in the Baum deposits. From the close similarity in appearance of the two rocks it might be suspected that the "birdseye" algal limestone at the quarry in the Baum possibly is in the form of large blocks transported from the McLish formation in the Arbuckle Mountain region, but the absence of true conglomerate at this locality makes such a conclusion highly improbable.

Studies of thin sections cut from representative specimens of the Baum limestone show that the normal rock consists of fine-grained calcite together with finely divided quartz. Photomicrographs of the most common rock type are Plate VI, B and Plate IX, A, both of which show rock consisting of algal fragments embedded in fine-grained limestone matrix. Stringers and irregular patches of clear calcite are present in the matrix and in the broken fragments of algal limestone.

There is a wide range in the percentage of quartz, the principal impurity, which was deposited from suspension at the time the limestone deposits were accumulating. The quartz occurs almost

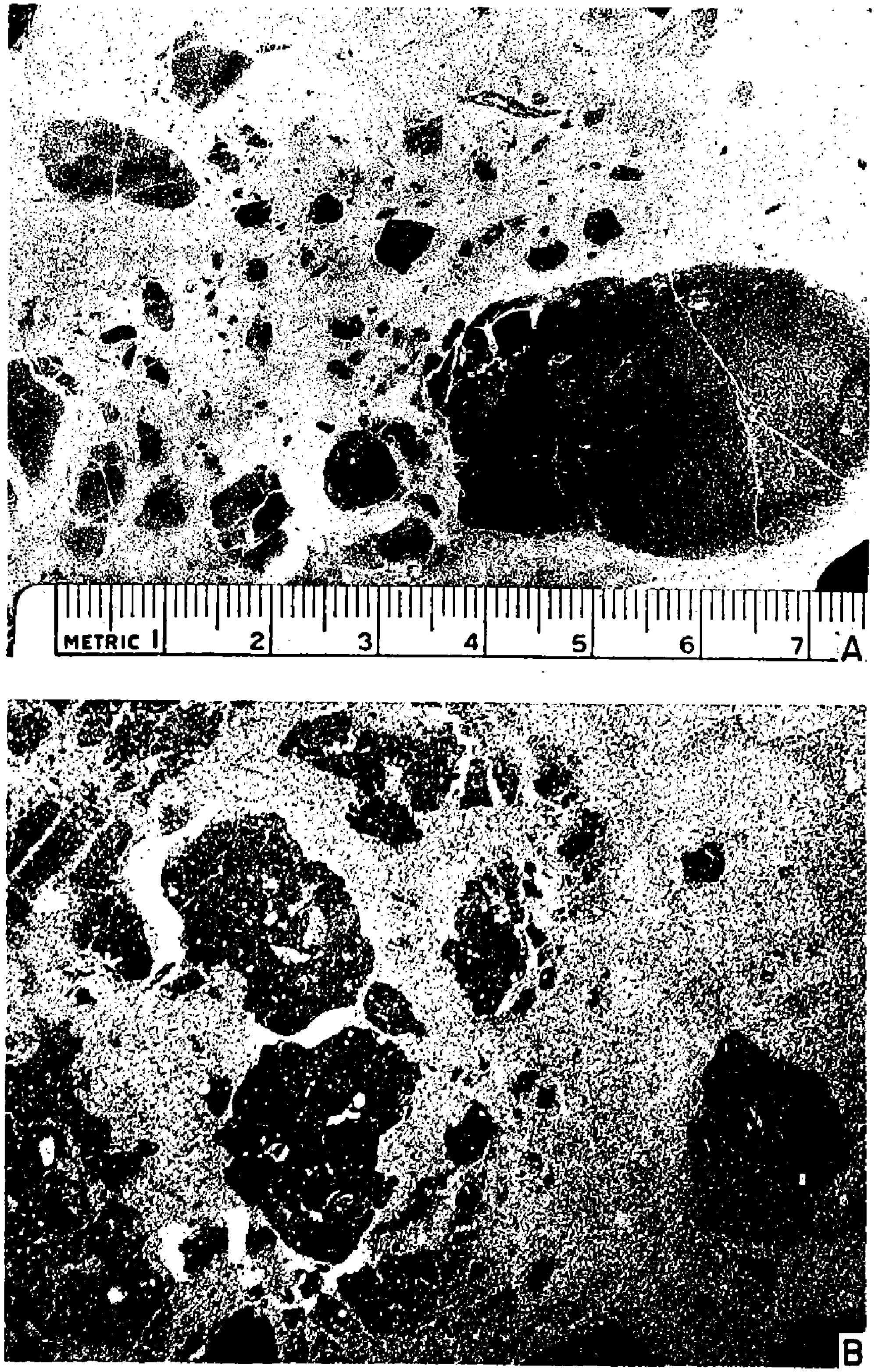
TABLE 1

CHEMICAL ANALYSES OF BAUM LIMESTONE IN RAVIA-MANNSVILLE AREA

District	Mill Creek-Sycamore Creek						Wolf Creek			Baum
Laboratory Number	9383	10094	10101	10091	10095	10096	10098	10099	10103	10102
SiO_2	1.57	1.16	2.83	1.51	1.26	0.98	3.84	3.78	2.43	4.32
Al_2O_3	0.40	0.36	0.42	0.28	0.24	0.42	0.94	0.81	0.59	0.94
Fe_2O_3	0.24	0.28	0.17	0.18	0.064	0.075	0.200	0.252	0.13	0.223
CaO	53.54	54.20	53.59	54.63	54.63	54.62	52.10	52.60	53.34	52.16
MgO	1.02	0.50	0.46	0.48	0.38	0.37	0.69	0.49	0.76	0.48
S	0.007	0.101	0.004	0.006	0.005	0.008	Trace	0.008	0.015	0.019
P_2O_5	0.007	0.003	0.003	0.003	<0.001	0.009	0.05	0.009	0.006	0.014
H_2O at 105° C.	0.06	*	*	*	*	0.04	0.19	0.10	*	0.17
Loss on ignition (105-950° C.)	43.27	43.17	42.49	43.15	43.28	43.46 (3)	41.90 (4)	41.84 (5)	42.47	41.60 (6)
Total oxides	100.114 (1)	99.774	99.967	100.239	99.859 (2)	99.882	99.91	99.889	99.741	99.926
RECALCULATION										
$CaCO_3$	95.56	96.74	95.65	97.59	97.50	97.49	92.99	93.88	95.20	93.10
$MgCO_3$	2.13	1.05	0.96	1.00	0.79	0.77	1.44	1.02	1.59	1.00
Total	97.69	97.79	96.61	98.59	98.29	98.26	94.43	94.90	96.79	94.10

*Asterisked samples analyzed after drying at 105° C.

(1) Also contains 0.02 MnO_2
(2) Also contains 0.04 MnO_2
(3) Includes 43.29 CO_2
(4) Includes 41.82 CO_2
(5) Includes 41.54 CO_2
(6) Includes 41.34 CO_2



Textural features of Baum limestone.

A. Polished surface of specimen representing typical rock of the compact limestone facies, showing intraformational pebbles and grains of algal limestone in fine-grained calcite matrix. From quarry, C NE¼ SE¼ sec. 12, T. 4 S., R. 4 E.

B. Photomicrograph of same, ordinary light, X8, showing crudely developed algal structure within larger grains. Light areas are clear calcite.

9383. C NE¼ SE¼ sec. 12, T. 4 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 28 feet thick at quarry; no overburden. Sampled in October, 1944, by W. E. Ham; analysis by A. L. Burwell.

10094. NW¼ NE¼ NE¼ sec. 1, T. 4 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 23 feet thick cropping out on hill slope; overlain by 2 feet of weathered limestone and 1 foot of soil. Sampled in July, 1953, by J. R. Wayland; analysis by A. L. Burwell.

10101. C S½ NW¼ sec. 7, T. 4 S.. R. 5 E., Johnston County. Fine-grained, pink-gray compact limestone 27 feet thick cropping out in bluff face; overlain by 10 feet of limestone partly covered by soil. Sampled in July, 1953, by J. R. Wayland; analysis by T. E. Hamm.

10091. SE¼ SE¼ SE¼ sec. 13, T. 4S., R. 4 E., Johnston County. Fine-grained pink-gray compact limestone 45 feet thick in bluff face; overlain by 9 feet of weathered limestone and 6 feet of terrace sands; upper beds of limestone are weathered beneath unconformity. Sampled in June, 1953, by J. R. Wayland; analysis by T. E. Hamm.

10095. C W½ NE¼ sec. 2, T. 4 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 13 feet thick cropping out on hill slope; no overburden. Sampled in July, 1953, by J. R. Wayland; analysis by T. E. Hamm.

10096. C NW¼ SE¼ sec. 3. T. 4 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 13 feet thick cropping out on hill slope; overlain by 3 feet of impure limestone and soil. Sampled in July. 1953, by J. R. Wayland; analysis by Sharp-Schurtz.

10098. C S½ SW¼ SW¼ sec. 8, T. 4 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 13 feet thick cropping out in bluff face; overlain by poorly exposed limestone 8 feet thick and 10-14 feet of terrace sands. Sampled in July, 1953, by J. R. Wayland; analysis by Sharp-Schurtz.

10099. SW¼ NE¼ SW¼ sec. 19, T. 4 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 18 feet thick cropping out on hill slope; overlain by 8 feet of poorly exposed limestone and 5 feet of Paluxy sand. Sampled in July, 1953, by J. R. Wayland; analysis by Sharp-Schurtz.

10103. SE¼ NE¼ SE¼ sec. 13, T. 4 S., R. 3 E., Carter County. Fine-grained pink-gray compact limestone 17 feet thick at quarry; overlain by 1-5 feet of terrace clay, sand, and gravel. Sampled in July, 1953, by J. R. Wayland; analysis by A. L. Burwell.

10102. NW¼ SE¼ NE¼ sec. 31, T. 3 S., R. 4 E., Johnston County. Fine-grained, pink-gray compact limestone 10 feet thick cropping out in bluff face; overlain by 2 feet of limestone and soil. Sampled in July, 1953, by J. R. Wayland; analysis by Sharp-Schurtz.

exclusively in the form of silt-sized, subrounded grains that were derived from older rocks cropping out in the Arbuckle Mountains. These grains are particularly abundant in the "birdseye" limestone of the Wolf Creek district (Plate IX, A, B, C and Plate VII), and account for the relatively high silica content of the Baum limestone of that district. Elsewhere the detrital quartz grains are randomly scattered throughout the rock. In the Ravia district, where granite contributed much detrital material to the limestone, the normal impurities are sand-sized grains of granite and quartz (Plate IX, D).

Crushing strength. Samples of the normal fine-grained compact phase of the Baum limestone tested by A. L. Burwell in the laboratory of the Oklahoma Geological Survey showed a range in crushing strength from approximately 6,000 to 9,000 psi. Quarried stone from sec. 13, T. 4 S., R. 3 E., which has been used as coarse aggregate for highway base construction, averaged 7,000 psi; and stone from the quarry in sec. 12, T. 4 S., R. 4 E., averaged 7,500 psi. This crushing strength is relatively high for common limestone and is due to the compactness of the rock and the interlocking character of its constituent calcite grains.

Chemical Composition

To determine the chemical character of the Baum limestone, and thus to evaluate its possibilities for chemical use, outcrops were sampled at strategic localities where the stone is well exposed. The sampled localities include quarry faces and natural bluffs where all the workable stone could be seen and sampled for chemical analysis. Samples were obtained by the channel method, whereby a fragment of rock is chipped by a hammer out of the face for each inch of vertical thickness. The method used yielded a composite sample weighing about 40-50 pounds for a face 30 feet high. As the outcrops generally are excellent, it is believed that the samples collected are fully representative of the Baum limestone in the mapped area.

Each composite sample was crushed and carefully mixed in the laboratory, then ground and quartered for chemical analysis. Analyses were made in the laboratory of the Oklahoma Geological Survey by Albert L. Burwell and by Thomas E. Hamm, under

TABLE 2
CHEMICAL ANALYSES OF MARL AND CLAY FROM BASAL PART OF BAUM LIMESTONE

Laboratory number	9382	10092	10097
Sample description	Unconsolidated marl at base of Baum	Dolomitic marl at base of Baum	Structureless red clay at base of Baum
Collector	W. E. Ham	J. R. Wayland	J. R. Wayland
Thickness sampled (feet)		12.0	13.0
Overburden	Plant-run agstone sampled at shipping point in Ravia	Overlain by 1-10 feet of limestone	Overlain by Baum limestone 10 or more feet thick
Location	Quarry in C NW¼ SE¼ sec. 12, T. 4 S., R. 4 E.	Roadcut and hillside, SE¼ SW¼ SW¼ sec. 2, T. 4 S., R. 4 E.	Side of gully, SW¼ SW¼ NE¼ sec. 3 T. 4 S., R. 4 E.
Analyst	Sharp-Schurtz	T. E. Hamm (O.G.S)	T. E. Hamm (O.G.S)
SiO_2	10.42	10.37	50.12
Al_2O_3	2.14	0.72	7.84
Fe_2O_3	0.435	0.75	3.76
CaO	47.74	27.80	18.46
MgO	0.37	18.24	1.77
S	0.010	n. d.	n. d.
P_2O_5	0.010	<0.001	<0.001
H_2O at 105° C.*	0.40	*	*
Loss on ignition (105-950° C.)	38.28 (1)	41.68 (2)	17.29 (4)
Total oxides	99.805	99.56 (3)	99.268 (5)
Calculated $CaCO_3$	85.21	49.62	32.00
Calculated $MgCO_3$	0.77	35.51	
Total	85.98	85.13	32.00
*Asterisked samples analyzed after drying at 105° C.	(1) Includes 37.78 CO_2	(2) Includes 40.35 CO_2 (3) Also contains 0.05 TiO_2, 0.10 K_2O, and 0.40 Na_2O	(4) Includes 14.07 CO_2 (5) Also contains 0.42 TiO_2

the direction of Mr. Burwell, and in the laboratory of the Sharp-Schurtz Co. of Lancaster, Ohio.

Ten samples of limestone, two of marl, and one of clay were analyzed and the analyses are cited in Tables 1 and 2. The marls and clays occur at the base of the Baum and are calcareous materials containing 10.37 to 50.12 percent silica. Other samples collected in the area were judged on the outcrop to be too impure for chemical use and were not analyzed.

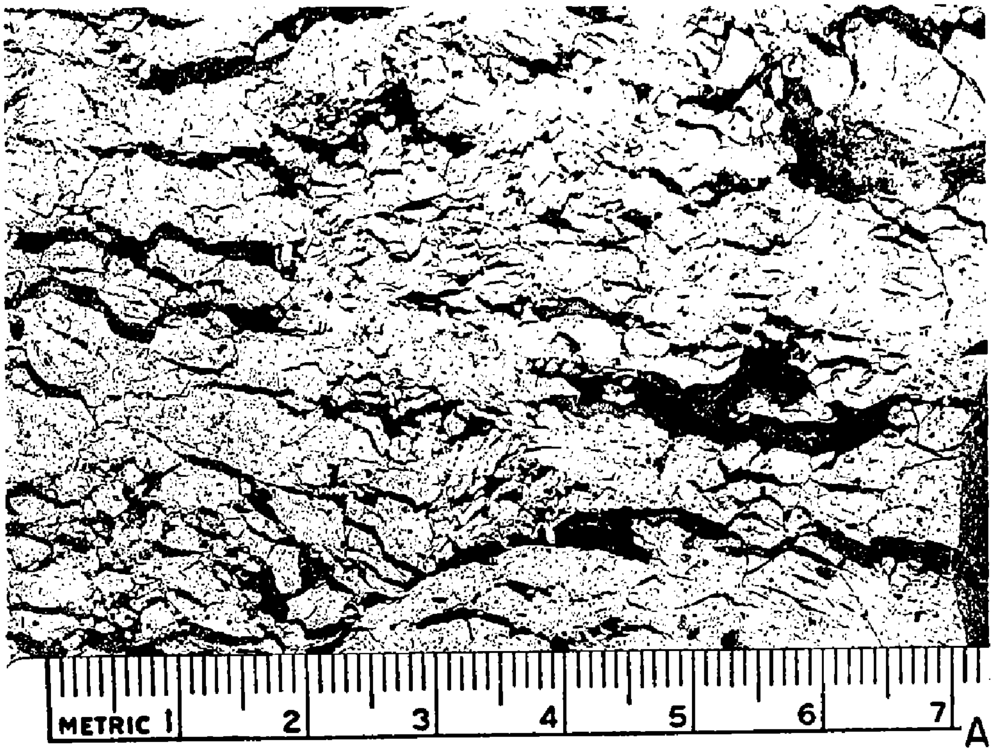
As shown in Table 1, the most valuable limestone in the Ravia-Mannsville area is in the Mill Creek-Sycamore Creek district, where the average of 6 analyzed samples is 96.755 percent calcium carbonate, 1.117 percent magnesium carbonate, 1.55 percent silica, 0.37 percent alumina, 0.168 percent iron oxide, 0.022 percent sulphur, and 0.004 percent phosphorus pentoxide. It is high-calcium limestone and therefore is generally acceptable for chemical use.

Silica, the principal impurity, is present as finely divided grains of quartz intimately distributed throughout the rock. Disseminated clay particles likewise are present in small amounts and account for part of the silica, much of the iron oxide, and all the alumina shown by analysis. Sulphur is present chiefly in the form of pyrite, an iron disulfide; and phosphorus probably is contained in microscopic fossils. Owing to the small size and disseminated character of the mineral impurities, the stone could not be upgraded economically by beneficiation.

Production

Agricultural limestone. Agstone, or agricultural limestone, has been produced intermittently from the Baum in the Ravia-Mannsville area since 1944. Two small quarries have been worked in the district about 5 miles west of Ravia, one in the C NE¼ SE¼ sec. 12, T. 4 S., R. 4 E., and the other in the C S½ NW¼ sec. 7, T. 4 S., R. 5 E. Total estimated production from these quarries is 88,000 short tons.

The quarry in sec. 12 was opened in September, 1944, by Ward-Stinnett, a partnership formed to meet the demand for agricultural limestone induced through AAA subsidy payments. At the time



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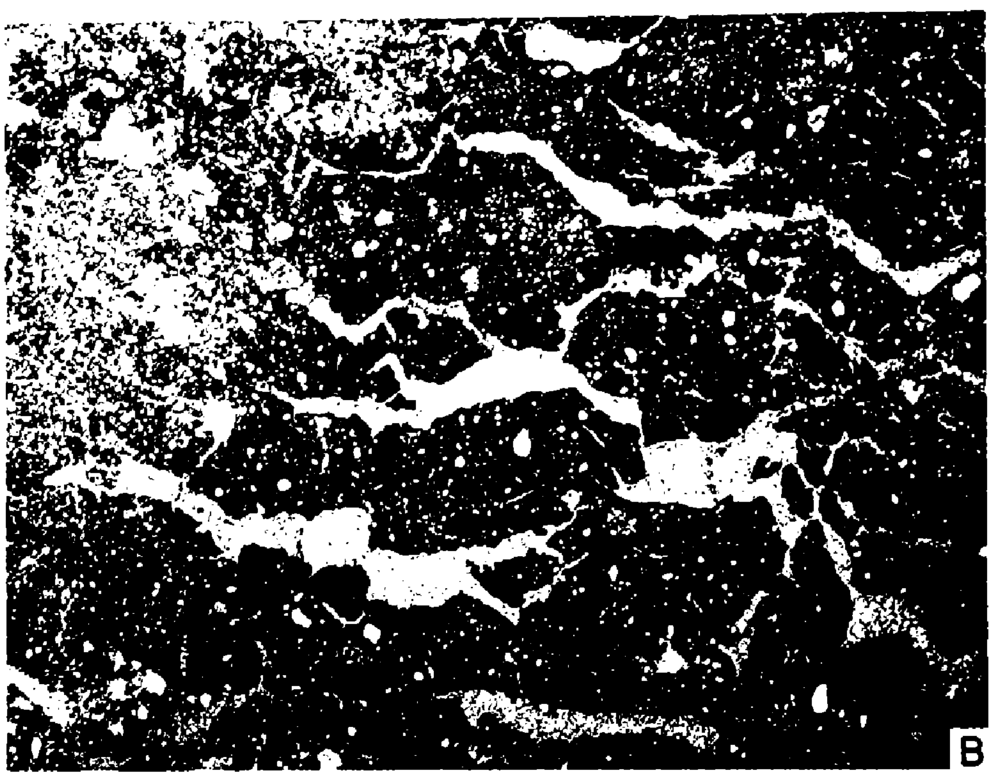


B

"Birdseye" limestone from the Baum member.

A. Polished surface of "birdseye" limestone from quarry in the SE ¼ NE ¼ SE ¼ sec. 13, T. 4 S., R. 3 E., showing subparallel algal crusts separated by coarsely crystallized calcite.

B. Photomicrograph of same, ordinary light, X8, showing extremely fine-grained calcite of algal origin that contains disseminated silt-sized grains of quartz. Light gray veinlike areas are calcite.

of the writer's first visit in October, 1944, the unconsolidated marl in the lower 15 feet of the Baum was worked on the low slopes at the base of the mesa escarpment by a gasoline-powered 3/4-yard shovel. On these low slopes there is no overburden, and the workings had not extended far enough back into the escarpment to reach the compact normal type of Baum limestone.

The marl is unconsolidated and so loose that it was cut by the shovel without previous blasting. Loaded into 5 3/4-ton dump trucks, it was hauled to the open-air plant on a siding of the Frisco railroad at Ravia, where it was classified through a 4-compartment trommel having successive openings as follows: 1½-inch square, ½-inch square, 3/4-inch round, and 1-inch round. Oversize was recycled through an 8 x 36-inch jaw crusher set to crush minus 1 inch. Finished product, consisting mostly of impalpable marl but containing a small amount of -1 inch compact limestone, was loaded by belt conveyor to rail gondolas and shipped to points in south-central Oklahoma. A 60-pound sample of plant-run agstone taken by the writer from a loaded car contained 85.21 percent $CaCO_3$ and 0.77 percent $MgCO_3$ (lab. no. 9382, Table 2), showing that the marl was well above the minimum AAA specification of 80 percent calcium carbonate equivalent.

Maximum production was in the last four months of 1944, when 673 cars or approximately 37,000 short tons were shipped by rail from Ravia. The next production was in May, June, and July, 1945, during which time 154 cars or about 8,500 tons were shipped. Production then dwindled and was intermittent through the remainder of 1945 and through all of 1946, only 49 cars or 2,700 tons being shipped. Thus from the time of its opening in September, 1944, to the end of 1946, the quarry in sec. 12 produced 48,200 tons of agstone.

The next sustained operation of this quarry was from the spring of 1948 to the spring of 1951, when Paul Thurman of Tishomingo produced about 30,000 tons of agstone. Most of the agstone was loaded at the quarry into truck spreaders for direct shipment to farms and ranches in Johnston, Marshall, and Carter Counties. Approximately 50 cars or 2,750 tons also were shipped over the Frisco railroad from Ravia. A part of the quarry face is shown in Plate III, A.

Quarrying by Mr. Thurman was almost entirely in the compact phase of the Baum limestone, which was shot from the bluff face by wagon-drilled blast holes 15 feet deep. The quarried area is approximately 500 feet long and 40-50 feet wide. All stone was pulverized in a hammermill before loading through a storage hopper into trucks.

The quarry in sec. 12 has been idle since 1951, but from it has been produced a total of about 78,000 tons of agstone.

A much smaller quarry, shown on the map (Plate I) in sec. 7, T. 4 S., R. 5 E., together with several even smaller openings nearby, were worked at the edge of the Baum escarpment apparently in the period 1947-1948. The material is unconsolidated marl, which was taken from the faces by direct excavation. Approximately 10,000 tons of agstone was produced from these small openings.

At the present time all demand for agstone in the region is filled from the quarry of the Rock Products Manufacturing Corp. at Troy, which produces high-purity dolomite from the Royer formation, and from the quarry of the Dolese Bros. Co. at Bromide, which produces limestone from the Viola formation.

Crushed stone. Compact limestone from the Baum has been quarried for coarse aggregate in highway construction in sec. 13, T. 4 S., R. 3 E. (Plate I), on the property of H. T. Smith. The quarry was opened by the Park Ward Construction Company in the fall of 1951 and was worked until fall, 1952. Using a portable crusher, the company produced an estimated 22,500 tons of stone for base construction of Oklahoma Highway 18 from Dickson north to the Washita River bridge. The quarry, abandoned since 1952, is approximately 300 feet long and 100 feet wide, and has an average height of 10 feet. Chemical analysis of a composite sample of the quarry face showed the calcium carbonate content to be 95.20 percent (Table 1, laboratory number 10103).

Uses

For chemical use, limestone must be sufficiently pure to make quicklime and hydrated lime. Limestones containing 99 percent calcium carbonate normally make the best lime and are most eagerly sought, but such purity is rarely found in limestone deposits, and stone of lesser purity is extensively used. No exact specifications are available, but it is generally agreed that high-calcium limestone (containing 95 percent or more calcium carbonate) is chemical stone and may be used for the manufacture of lime.

To satisfy existing markets, a conveniently located limestone containing less than 95 percent calcium carbonate may be used successfully if it does not compete with purer stone available at the same cost.

Silica and alumina are particularly objectionable in limestone because at the high temperatures of the lime kiln they combine with quicklime to make chemically inert compounds, which detract from the value of the lime.

In the Ravia-Mannsville area the Baum limestone has its highest purity in the west half of the Mill Creek-Sycamore Creek district, three samples from which (10091, 10095, and 10096) contain an average of 97.53 percent $CaCO_3$, 0.85 percent $MgCO_3$, and 1.22 percent SiO_2. These samples were burned and slaked by Mr. A. L. Burwell in the chemical laboratory of the Oklahoma Geological Survey. All burned to quicklime of light gray to nearly white color, which on slaking to calcium hydroxide or slaked lime turned to pale yellowish gray. Although not having the best colors and not being of the highest purity obtainable, these Baum limestone samples doubtless would make an acceptable grade of lime for most chemical uses. Baum limestone from other parts of the mapped area also will make lime, but it will be of inferior grade.

Some of the chemical uses to which the Baum limestone may be put, together with notes on the most objectionable impurities for each use, are listed below.

Alkalies. Sodium carbonate or soda ash is an alkali generally made from salt and high-calcium limestone. Soda ash is an essential ingredient in glass making. The best grades of Baum limestone would be satisfactory, but they are close to the upper limit of silica (about 1.00 percent).

Calcium carbide. One of the principal sources of acetylene is calcium carbide, which is made by fusing lime with coke in an electric-arc furnace. High-calcium limestone used for the lime should contain impurities not to exceed the following: magnesium carbonate 1 percent, alumina and ferric oxide 0.5 percent, phosphorus 0.004 percent, silica 1.2 percent, and sulphur in traces (Lamar and Willman, 1938, p. 15). The best grades of Baum limestone meet these specifications.

Flux. Where used as a flux in making pig iron from blast furnaces and steel from open-hearth furnaces, limestone should contain as little silica, alumina, sulfur, and phosphorus as possible, because it is these materials that are being removed from the metal. Alumina, sulfur, and phosphorus are particularly low in the Baum, and the silica content probably is not excessive.

Glass. Lime or limestone used in glass making as a source of calcium should be uniform in quality and contain little iron, the chief objectionable impurity because of its strong coloring effect in the glass. For the manufacture of flint glass a maximum of 0.12 percent iron oxide generally is imposed. Most samples of Baum limestone contain more than 0.13 iron oxide, but samples 10095 and 10096 respectively contained 0.064 and 0.075 percent.

Paper. Limestone used in the manufacture of paper from sulphite pulp should be especially low in iron oxide and should contain " . . . more than 95 percent calcium carbonate, less than 2½ percent magnesium carbonate, and less than 2½ percent of other impurities. . ." (Lamar and Willman, 1938, p. 31). The best of the Baum limestone outcrops, particularly those in the Mill Creek-Sycamore Creek district, would be suitable for use in the manufacture of paper.

Another outstanding potential use of the Baum limestone is in the manufacture of Portland cement, which may be prepared by burning together high-calcium limestone and shale. The market for portland cement in the region at the present time, however, is served by plants at Ada, Oklahoma, and in the Dallas-Fort Worth area of northern Texas.

Accessibility

The reserves of Baum limestone in the Ravia-Mannsville area are accessible by existing roads to rail shipping points at Ravia, Ardmore, Simpson, and Madill, all located within a 15-mile radius of the center of the district. All are on the St. Louis and San Francisco Railway, and Ardmore is served also by the Gulf, Colorado, and Santa Fe Railway. Ardmore and Madill are the largest towns, having in 1950 respective populations of 17,890 and 2,791. Tishomingo, 5 miles east of Ravia, and having a 1950 population of 2,325, is not served by a railroad but is accessible by trucking.

Abundant supplies of electric power, natural gas, and water are available in the region. Electric power is obtainable from private utilities and from Texoma dam. Washita River, the chief source of supply of water for Lake Texoma, flows through the mapped area and would be available for industrial use. According to records made at the station where Oklahoma Highway 18 crosses Washita River near the western edge of the map area (Plate I), the dissolved solids in the river water range from a maximum of 936 ppm to a minimum of 140 ppm, and the total hardness ranges from a maximum of 574 ppm to a minimum of 114 ppm (Chemical Character of Surface Waters of Oklahoma, 1949-1950, p. 59).

Natural gas and casinghead gas are produced in Carter and Marshall Counties, the combined production in 1953 being 15.7 trillion cubic feet in Carter County and 3.2 trillion cubic feet in Marshall County.

With the availability of fuel, power, water, transportation, and urban centers, it appears probable that the Baum limestone will be utilized for chemical markets at some future date. The reserves of high-calcium limestone may well be a principal factor in attracting chemical industry to the region.

Reserves of Limestone

The outcrops of Baum limestone in the Ravia-Mannsville area may be divided for purposes of evaluation into 5 districts, in each of which the stone is characterized by reasonable uniformity in chemical composition, thickness, and mode of outcrop. In three of the five districts total workable reserves of limestone are estimated to be 158,000,000 tons. High-calcium limestone occurs principally in the Mill Creek-Sycamore Creek district, where 127,000,000 tons are contained in outcrops averaging 26 feet thick and covering 1,780 acres.

Ravia district. The outcrops of Baum limestone in the Ravia district are north of Washita River and east of Mill Creek (Plate I). The village of Ravia (1950 population: 327) lies near the southeastern edge of the principal outcrop area, which covers about 5 square miles in an irregular, northwest- trending strip 5 miles long and 0.5 to 4 miles wide. The St. Louis and San Francisco Railway and Oklahoma Highways 12 and 22 follow parallel southeasterly courses across this area of outcrop to Ravia, where Highway 22 turns eastward to Tishomingo and Highway 12 turns southwestward toward Mannsville. Nine smaller outcrop areas, lying southward and westward from Ravia and having a combined areal extent of about 300 acres, are included in this district.

The Baum limestone in the Ravia district generally is too thin and too impure to be quarried economcially. Its average thickness probably is less than 10 feet, and most of the outcrops lie directly on granite which locally has contributed 15-50 percent feldspar and quartz to the rock, rendering it unfit for use as agricultural or chemical limestone.

Mill Creek-Sycamore Creek district. This district includes outcrops of the Baum limestone north of Mannsville and west of Mill Creek, in secs. 1, 2, 3, 10, 11, 12, 13, and 14, T. 4 S., R. 4 E.; secs. 27, 34, 35, and 36, T. 3 S., R. 4 E.; and secs. 6 and 7, T. 4 S., R. 5 E., all in southeastern Johnston County (Plate I). Sycamore Creek flows southward near the western border of the district.

The first quarrying and all the production of agricultural limestone from the Baum has been in this district. Moreover, it contains the thickest deposits, the largest outcrop area, and the greatest reserve of high-calcium limestone in the entire mapped area; and thus the district deserves first consideration as a source of commercial stone. Many sites are available that have naturally developed quarry faces and little or no overburden. The stone ranges in workable thickness from 13 to 45 feet and the average calcium carbonate content, as determined from 6 analyses, is 96.755 percent.

The outcrops of Baum limestone stand above the surrounding area as low mesas having irregular, highly dissected outlines (see Frontispiece). The distribution and general form of these mesas is determined by the present streams, which in the northern part of the district have cut through the once-continuous limestone sheet and left remnants of it capping long and narrow interstream divides. In about the southern half of the district alluvium deposited by Washita River and some of the smaller streams laps up against the edges of the higher mesas and irregularly covers some of the outcrops at lower elevations.

The largest mesa in the district, and the largest single outcrop of high-calcium Baum limestone in the Ravia-Mannsville area, extends east of Courtney Creek nearly to Mill Creek (see Frontispiece). It covers approximately 1.5 square miles. Two quarries have been opened for the production of agricultural limestone at the southern edge of the mesa at localities adjoining a graveled road that leads 5 miles eastward to Ravia, the only rail shipping point within the mapped area. These quarry sites are the nearest and most accessible to Ravia.

Virtually the entire mesa could be quarried for limestone. The top is characteristically flat and is covered by a moderate growth of cedar (*Juniperus*) trees. Over most of the top there is no overburden, although 1-2 feet of soil is present locally. The sides of the mesa slope moderately or steeply down to the surrounding plain. Three carefully channeled samples taken at localities where the rocks are fully exposed show the average thickness of workable limestone to be 26 feet. Limestone weighs about 150 pounds per cubic foot or approximately 3,000 tons per acre-foot, and the volume of stone in the 1,000 acres of the mesa is estimated to be 75,000,000 short tons.

Average composition of the stone, as shown by chemical analyses of the three samples (laboratory numbers 9383, 10094, and 10101, Table 1), is 95.98 percent calcium carbonate, 1.38 percent magnesium carbonate, 1.85 percent silica, and 0.23 percent iron oxide.

That part of the Baum limestone in the Mill Creek-Sycamore Creek district lying west of the large mesa is irregularly covered and is dissected into 16 isolated outcrop areas. The northernmost outcrops are small and contain much conglomerate, and therefore are of no value as high-calcium limestone. The southernmost outcrops, however, particularly those in secs. 2, 3, the S½ sec. 11, the NW¼ NW¼ sec. 13, and the N½ sec. 14, T. 4 S., R. 4 E., contain limestone of the highest purity found during this investigation. Three channel samples taken to represent the stone in the above sections were shown by analysis to contain an average of 97.53 percent calcium carbonate, 0.85 percent magnesium carbonate, 1.22 percent silica, and 0.106 percent iron oxide.

The reserves of stone in the western part of the Mill Creek-Sycamore Creek district may be divided as follows.

1. The largest outcrop covers about 325 acres in the central part of sec. 2, T. 4 S., R. 4 E. It has the form of a southward-sloping mesa, the southern boundary of which is covered by high-terrace sands and clays. The thickness of stone is 22 feet, and the reserve is calculated to be 22,000,000 tons. The laboratory number of the analyzed sample is 10095 (Table 1).

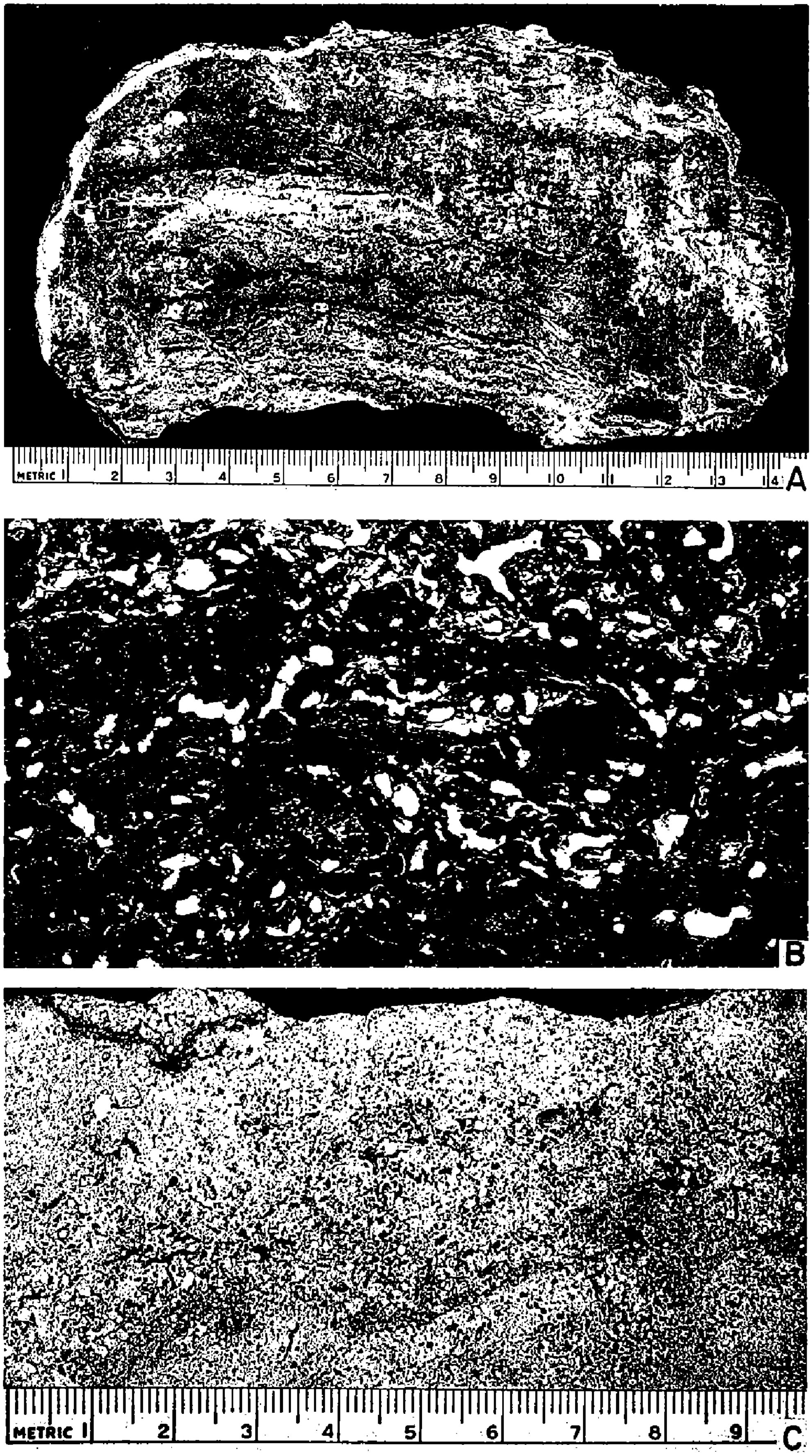
2. The next largest outcrop covers about 45 acres in bluffs along the eroded edge of a mesa near Washita River, centering around the common corner of secs. 11, 12, 13, and 14, T. 4 S., R. 4 E. The 45 feet of stone sampled is the thickest, and the 97.59 percent $CaCO_3$ is the highest, of all the samples of Baum limestone collected in the Ravia-Mannsville area. The volume of stone in this outcrop

PLATE VIII.

A. Polished surface of hemispherical algal colony, showing parallel banding of algal layers; NW¼ NE¼ NE¼ sec. 1, T. 4 S., R. 4 E.

B. Photomicrograph of same, ordinary light, X8. Light areas are clear calcite deposited in original openings of the algal colony.

C. Polished surface of limestone consisting of algal pellets; SE¼ NW¼ SE¼ sec. 12, T. 4 S., R. 4 E.



Algal limestone from the Baum member.

is estimated to be 6,000,000 tons. The laboratory number of the analyzed sample is 10091 (Table 1).

3. A substantial reserve is indicated in the area between localities 1 and 2, including about 400 acres in the NE¼ sec. 11, the S½ SE¼ sec. 2, the W½ NW¼ and the W½ SW¼ sec. 12, T. 4 S., R. 4 E. The limestone is covered by 5-10 feet of terrace sands, clay, and gravel, and is inferred from geologic evidence to be at least 20 feet thick. The top surface of the limestone doubtless will be irregular, owing to scour and fill at the time Washita River was flowing at a higher elevation on the limestone surface. The indicated reserve of limestone is 24,000,000 tons, and analysis of the stone probably will be chemically similar to the analyses of samples 10091 and 10095.

4. An isolated mesa in the central part of sec. 3, T. 4 S., R. 4 E. is composed of high-purity Baum limsetone but is small in areal extent and has low reserves. It is crossed by the main-travelled road between Ravia and Baum. The area of outcrop is about 10 acres and the average thickness of limestone is 18 feet, from which a reserve of 500,000 tons is indicated. The stone contains 97.49 percent $CaCO_3$ and has 0.98 percent SiO_2, the lowest of all samples analyzed in the mapped area (sample 10096, Table 1).

Baum district. This district includes outcrops of limestone north of Washita River and between Oil Creek and Baum, mostly in secs. 19, 30, and 31, T. 3 S., R. 4 E., Johnston County, and secs. 25 and 36, T. 3 S., R. 3 E., Carter County. Beds of conglomerate occur locally at the base and interbedded within the lower part of the limestone sequence, so that only the upper part, about 10 feet thick, can be considered a potential source of commercial stone. This upper 10 feet, represented by the analysis of sample 10102, Table 1, contains 93.10 percent $CaCO_3$ and 4.32 percent SiO_2. It therefore is not a high-calcium limestone, but is still sufficiently pure for non-chemical use.

Reserves of limestone containing as much as 93 percent $CaCO_3$ are difficult to estimate in this district because the uppermost, purer beds have been removed by erosion at many places. The limestone here does not have the form of a flat-topped mesa that is typical of most Baum outcrops north of Washita River, but has instead an undulating upper surface and margins that generally are low and gently sloping (Plate II, A). The total outcrop of limestone is about 1.5 square miles, within which the upper beds of highest relative purity are present over approximately 70 acres; and the total indicated reserve is of the order of 2,000,000 tons. The most promising localities are along low ridges, principally in the SE¼ SE¼ SE¼ sec. 25, T. 3 S., R. 3 E.; the SW¼ SW¼ SW¼ sec. 30, T. 3 S., R. 4 E.; the E½ SE¼ and the SE¼ NE¼ sec. 31, T. 3 S., R. 4 E.; and the SW¼ sec. 32, T. 3 S., R. 4 E. On these ridges the limestone crops out at the surface or is concealed under 1-2 feet of grass-covered soil.

Wolf Creek district. Outcrops of Baum limestone in the southwestern part of the map area (Plate I) are assigned to the Wolf Creek district. The valley of Wolf Creek approximately bisects the district into an eastern half, chiefly in secs. 8, 18, and 19, T. 4 S., R. 4 E., Johnston County, and into a western half, chiefly in secs. 13, 14, and 24, T. 4 S., and R. 3 E., Carter County.

The outcrops are in sinuous bluffs that rise above and face the alluvial plains of Wolf Creek and Washita River. Limestone averaging about 20 feet thick crops out in these bluffs, the tops of which typically extend back from the face in a narrow, flat, and barren bench. The mapped outcrop of the Baum comprises all the economically workable stone in this district, as the limestone has been mostly eroded away along the alluvial valleys, and elsewhere it is covered by 5-25 feet of sandy overburden. The overburden occurs in the form of terrace deposits and loosely consolidated sands of the Paluxy formation.

PLATE IX.

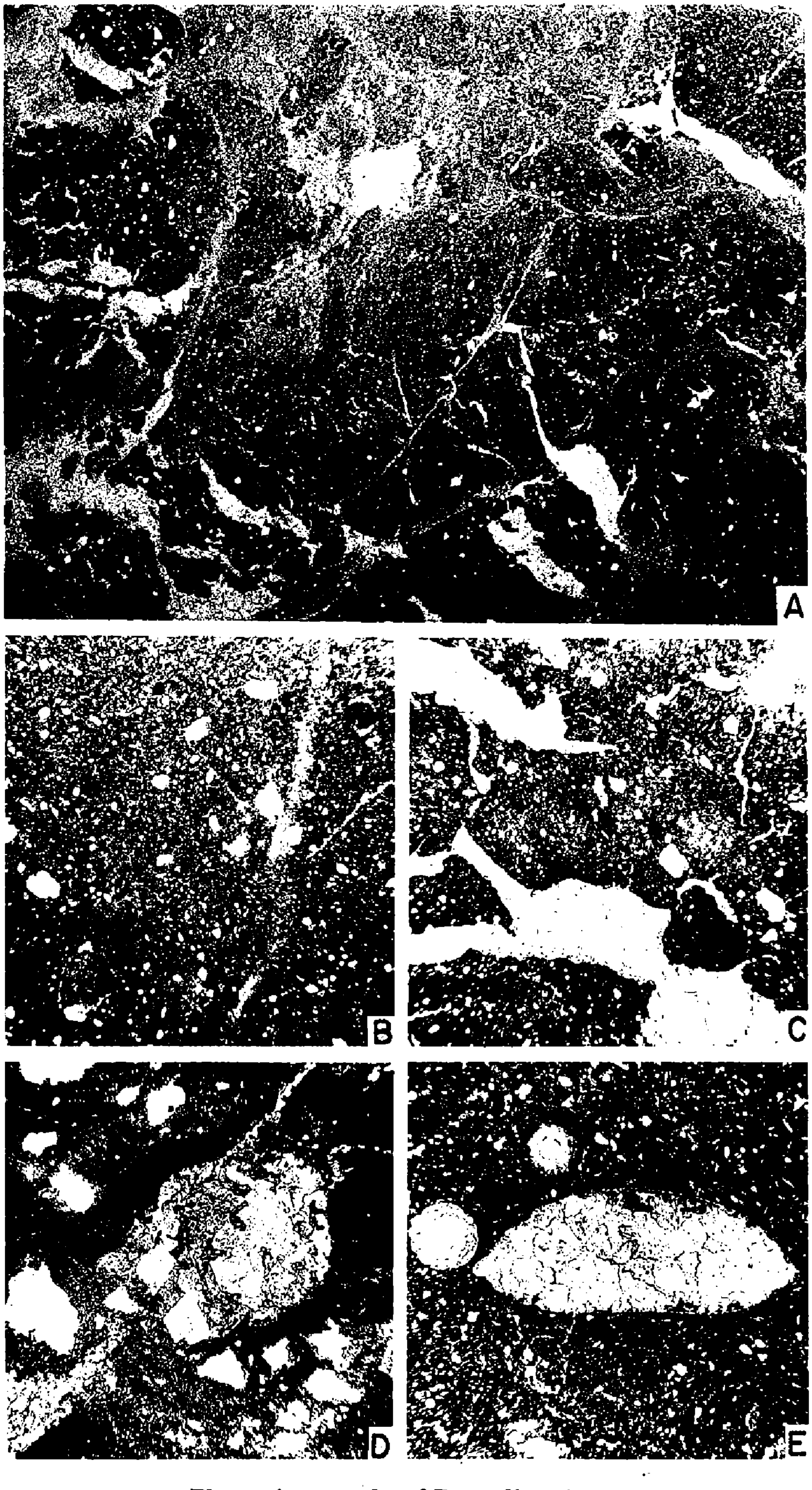
A. White limestone from quarry in the SE¼ NE¼ SE¼ sec. 13, T. 4 S., R. 3 E., ordinary light, X6, showing fragments of quartz-bearing "birdseye" limestone in fine-grained calcite matrix. Light areas are calcite.

B. Enlarged view, X28, of grain in upper right corner of A, showing abundant light-colored quartz grains. Ordinary light.

C. Enlarged view of "birdseye" limestone in Plate VII, B, showing details of calcite filling and the included small quartz grains. Ordinary light, X16.

D. Limestone from the Ravia district containing fragments of granite, center, and smaller, clear grains of quartz. Ordinary light, X16.

E. Ostracode and charophyte oogonia from cobble in Baum limestone, CNL SE¼ sec. 36, T. 3 S., R. 3 E. Ordinary light, X22.



Photomicrographs of Baum limestone.

Where the limestone could be quarried, as shown by the outcrop on the geologic map, the surface is either bare rock or is covered by less than 5 feet of soil overburden. The outcrop covers about 600 acres and the average thickness of sampled stone is 16 feet, from which a reserve of 29,000,000 short tons is calculated. Chemical analyses of three channel samples, taken at well distributed localities along the outcrop, show the average composition of the limestone to be 94.02 percent $CaCO_3$, 3.35 percent SiO_2, and 0.19 percent Fe_2O_3 (laboratory numbers 10098, 10099, and 10103 of Table 1). The best stone sampled in the Wolf Creek district is at the now abandoned quarry in the SE¼ NE¼ SE¼ sec. 14, T. 4 S., R. 3 E.. the stone there containing 95.20 percent $CaCO_3$, 2.43 percent SiO_2, and 0.13 percent Fe_2O_3. Although not of the highest grade, the limestone is excellent for agricultural fertilizer.

The nearest rail shipping points are Ardmore and Simpson. At Ardmore, which is 10.5 miles west from Wolf Creek on U. S. Highway 70, the facilities of the Gulf, Colorado, and Santa Fe Railway, and of the St. Louis and San Francisco Railway, are available. The small settlement of Simpson is served by the St. Louis and San Francisco Railway. It is 4 miles south of Mannsville, which is 2.5 miles east of the limestone outcrops in the Wolf Creek district. Shipping facilities of the Frisco railroad also are available at Madill, 11 miles southeast of Mannsville on U. S. Highway 70.

Mannsville district. The two small areas of exposure of Baum limestone south of Mannsville along Turkey Creek, in secs. 34 and 35, T. 4 S., R. 4 E., and along Camp Creek, chiefly in secs. 28, 29, and 33, T. 4 S., R. 4 E., are included in the Mannsville district. On Turkey Creek the Baum rests with marked angular unconformity on steeply dipping rocks of the Arbuckle Mountain facies, including strata from the Viola limestone through Sycamore limestone. Approximately 20 feet of Baum limestone crops out in the steep walls of the valley and as a narrow bench above that extends back to a thick overburden of Paluxy sand. In addition to the lack of quarry sites, the limestone is conglomeratic and contains much silica in the form of quartz sand and pebbles of chert, and therefore is of little value except possibly as a low-grade agricultural limestone.

TABLE 3

SUMMARY OF BAUM LIMESTONE RESERVES IN RAVIA-MANNSVILLE AREA, BY DISTRICTS

District		Average composition* $CaCO_3$	SiO_2	Fe_2O_3	Best stone sampled $CaCO_3$	SiO_2	Fe_2O_3	Outcrop area	Average workable thickness (feet)	Reserves (short tons)
Mill Creek-Sycamore Creek	East half	95.98	1.85	0.23	96.74	1.16	0.28	1,000 acres	26	75,000,000
Mill Creek-Sycamore Creek	West half	97.53	1.22	0.106	97.49	0.98	0.075	780 acres	26	52,000,000
Wolf Creek		94.02	3.35	0.19	95.20	2.43	0.13	600 acres	16	29,000,000
Baum		93.10	4.32	0.223	one analysis			70 acres	10	2,000,000
Ravia		Stone generally impure and thin, and outcrops lacking in good quarry sites						5 square miles	—	—
Mannsville								small	—	—

*For complete analyses see Table 1.

Outcrops of Baum limestone in the stream bed and in adjoining gentle valley slopes of Camp Creek are not conglomeratic, but consist largely of clay-rich marl containing vertical columns of limestone. There are no outstanding quarry sites and the stone is unsuitable for high-purity uses.

Summary of reserves. Of the five districts into which the Baum limestone outcrops of the Ravia-Mannsville area may be divided, one district contains practically all the reserves of high-calcium limestone. It is the Mill Creek-Sycamore Creek district in the central part of the map area, north of Washita River and south of the Arbuckle Mountain region, where the thickest and purest limestones have their most extensive outcrop. These deposits are accessible by existing roads to Ravia, the nearest shipping point, and they also are within reach of rail facilities at Ardmore, Simpson, and Madill. Tishomingo, five miles east of Ravia, likewise is within reach by truck haulage, but at the present time it is not served by a railroad.

In the Mill Creek-Sycamore Creek district, limestone averaging 26 feet thick and containing 96.755 percent $CaCO_3$ could be worked in virtually ideal natural quarry sites over approximately 1,780 acres, in which the estimated reserve is 127,000,000 tons. Judging from chemical analyses of 6 outcrop samples, the best stone expectable has the following approximate composition: 97.50 $CaCO_3$, 0.90 $MgCO_3$, 1.15 SiO_2, 0.35 Al_2O_3, 0.07 Fe_2O_3, 0.006 sulphur, and 0.004 phosphorus. Ranges of the various impurities are given in Table 1.

Stone of this purity generally is suitable for many chemical uses, including the manufacture of quicklime and hydrated lime for numerous industrial markets, metallurgical fluxing stone, paper manufacture, certain grades of glass, and calcium carbide manufacture. It also is excellent for agricultural fertilizer.

Outcrops of Baum limestone in the Wolf Creek district, south of Washita River between Mannsville and Ardmore, contain substantial reserves but the stone is thinner, less pure, and covers a smaller area. Limestone averaging 94.02 percent $CaCO_3$ and having a workable thickness of 16 feet could be quarried in excellent sites over approximately 600 acres, in which the estimated reserve is 29,000,000 tons. In composition it approaches and locally reaches the lower limit of high-calcium limestone, but the high average silica content of 3.35 percent normally is considered excessive for most chemical markets. Limestone in the Baum district, in the northwestern part of the mapped area, is similar in containing 93.10 percent $CaCO_3$ and 4.32 percent SiO_2. Its reserves of 2,000,000 tons are scattered over about 70 acres distributed in 1.5 square miles of outcrop. Stone from these two districts containing 93-95 percent $CaCO_3$ makes a good grade of agricultural fertilizer, and it has been used as crushed stone for road construction.

Limestone in the Ravia and Mannsville districts is mostly thin and so impure that it contains less than 80 percent calcium carbonate and therefore would not meet the specifications for agricultural limestone.

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