INFORMATION CIRCULAR 13

TERTIARY LIMESTONES OF PULASKI AND SALINE
COUNTIES, ARKANSAS

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By
MILTON W. CORBIN
AND
GEORGE R. HEYL

LITTLE ROCK
1941

STATE OF ARKANSAS
ARKANSAS GEOLOGICAL SURVEY
Rooms 443-447 State Capitol
Little Rock, Ark.

George C. Branner
State Geologist   March 3, 1941

Hon. Homer M. Adkins,
Governor, State of Arkansas,
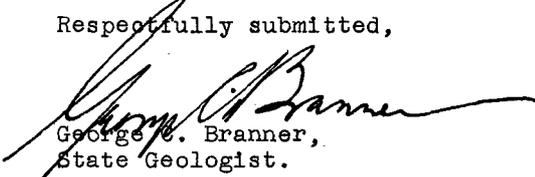Little Rock, Arkansas.

Sir:

   I have the honor to submit herewith Arkansas Geological Survey Information Circular 13, "Tertiary Limestones of Pulaski and Saline Counties, Arkansas," by M. W. Corbin and G. R. Heyl.

   The occurrence of limestones of Tertiary age near the edge of the Gulf Coastal Plain in Pulaski and Saline Counties has been known for at least 80 years, their presence being noted in 1860 by Dr. D. D. Owen of the first Arkansas Geological Survey. However, until the present study was begun in 1938, no systematic attempt had been made to determine the extent, thickness, and quality of these limestones.

   The field work for this report was undertaken by personnel furnished by the Works Progress Administration, the Arkansas Geological Survey acting as sponsor for the project. In carrying out the prospecting program, 130 test holes were drilled and logged. The thickness of the overburden and limestone was determined in each hole in which limestone was encountered and, from data secured, it has been possible to estimate the approximate tonnage of the limestone, in the areas prospected as well as the amount of overburden. Chemical analyses of the limestone indicate that the calcium carbonate content averages about 60 per cent. Two areas were found to be of especial promise, one near Alexander which is estimated to contain about 2,075,000 tons, and one southwest of Mabelvale estimated to contain about 2,250,000 tons.

   It is believed that the principal use to which this limestone can be put is for supplying lime for the lime-deficient soils of central Arkansas. Its economic importance depends in great measure on whether or not it can compete successfully with the higher-grade limestone from northern Arkansas. With efficient management of production operations and an ample local demand for the product, it is believed that at least a part of the limestone can be profitably quarried.

Respectfully submitted,

George C. Branner,
State Geologist.

C O N T E N T S

I L L U S T R A T I O N S

T A B L E

LIMESTONE IN PULASKI AND SALINE COUNTIES, ARKANSAS

ABSTRACT

An investigation of limestone suitable for agricultural purposes was made in southwestern Pulaski and eastern Saline Counties. Through the drilling of 130 test holes four areas containing an estimated 4,325,000 tons of limestone have been defined in Pulaski County. It is estimated that there is in these areas a ratio of about 1 cubic yard of overburden to 1 ton of limestone. Analyses of the limestone show that the calcium carbonate content averages close to 60 per cent. The economic importance of this limestone depends in great measure on competition of higher-grade limestone from other parts of the state.

INTRODUCTION

Purpose of the Investigation

The presence of surface outcrops of limestone in Pulaski County was known in 1860 and probably before that date. The remains of a kiln can still be seen along the Missouri Pacific Railroad between Alexander and Mabelvale, where limestone was burned by John Olsen in 1876-78. Information obtained in a drilling program for bauxite in 1934 indicated that limestone underlies parts of Saline and Pulaski Counties.

A WPA project to investigate the extent and accessibility of limestone in this area was begun on January 28, 1938, and continued until August 26, 1938, when work was stopped pending approval of funds to continue the project. Work recommenced on November 12, 1938, and continued until June 1, 1939.

The object of the investigation was to determine the extent and accessibility in southwestern Pulaski County of limestone that could be mined and furnished to farmers for agricultural purposes. Soils of this portion of Pulaski County and surrounding areas are deficient in lime, ranging from acid to strongly acid[1].

Location of Area Drilled

Areas in central and western Pulaski County and in eastern Saline County were tested by drilling. The belt drilled is more or less parallel to the Missouri Pacific Railroad and extends from Little Rock southwestward to the State Hospital for Nervous Diseases, 4 miles southwest of Benton, Arkansas.

Summary of Previous Work

Several state reports have mentioned limestone in Pulaski and Saline Counties. Owen[2], in the survey of the southern counties in 1860, mentions Tertiary limestone outcropping on the western outskirts of Little Rock and on Fourche Creek, near the mouth of Crooked Creek, in sec. 8, T. 1 S., R. 13 W.

In 1892 Harris[3], in a report on the Tertiary formations of southern Arkansas, stated that the limestone in this region was determined to be of Midway age.

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[1] Nelson, M., Sachs, W. H., and Austin, R. H., The soils of Arkansas: Arkansas Univ., Agri. Exper. Sta., Bull. 187, 1923. This bulletin contains a tabulation of the principal types of soils in the state, showing the composition of each type and indicating whether the soil is deficient in lime. A map showing the distribution of the different types of soils is also included.

[2] Owen, D. D., Second report of a geological reconnaissance of the middle and southern counties of Arkansas: p. 73, Philadelphia, Sherman & Son, Printers, 1860.

[3] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, Vol. 2, pp. 26-31, 36-49.

N

W — E

LEGEND
✳ LIMESTONE OUTCROP
● DRILL HOLE
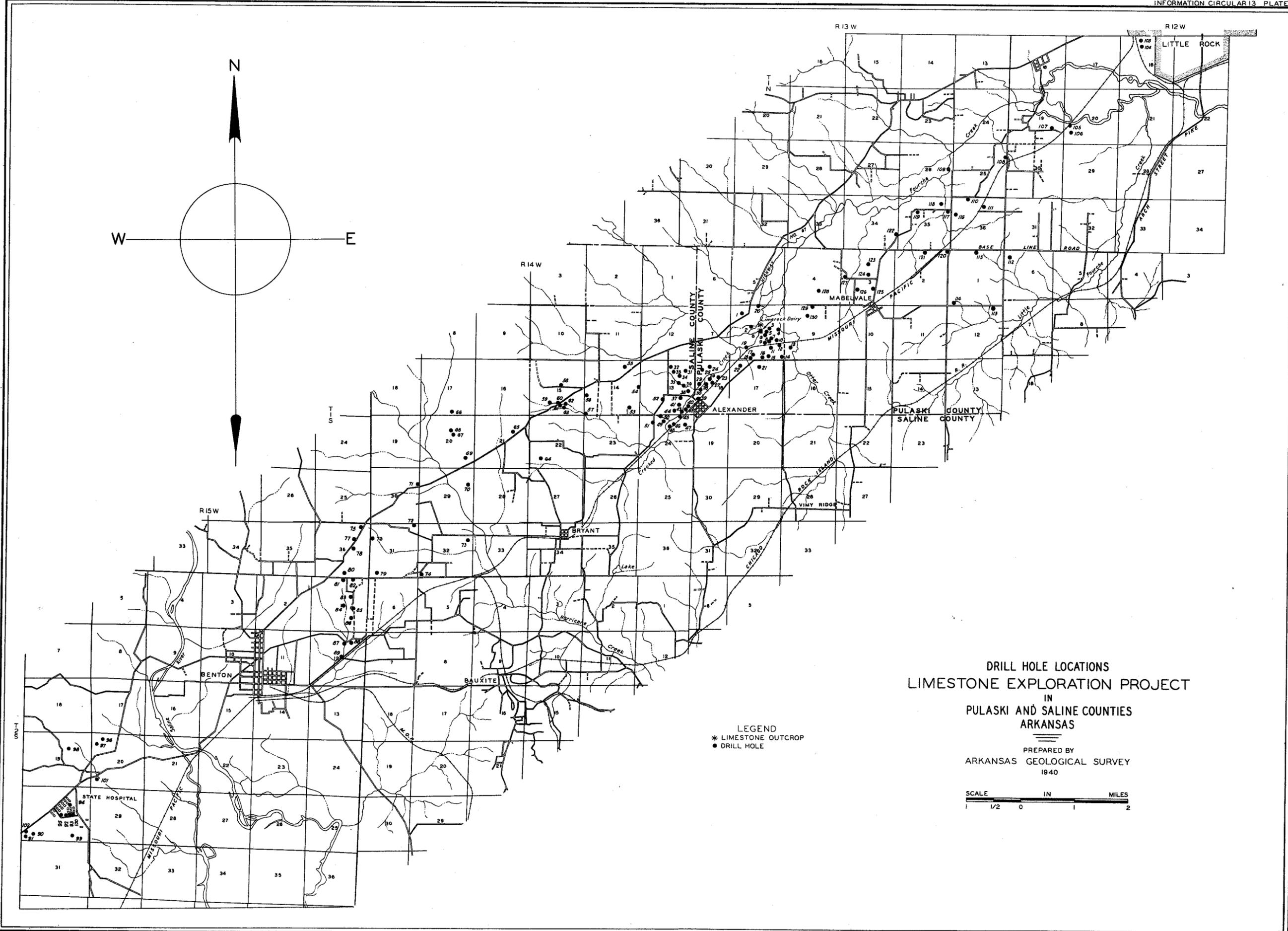
DRILL HOLE LOCATIONS
LIMESTONE EXPLORATION PROJECT
IN
PULASKI AND SALINE COUNTIES
ARKANSAS

PREPARED BY
ARKANSAS GEOLOGICAL SURVEY
1940

SCALE   IN   MILES
1   1/2   0   1   2

R 13 W

N

U.S. Highway No.67-70

300

Creek

20

1

2

300

320

Limestone
Outcrop

A

3

4

C'

5

Fourche

Limerock Dairy

6

7

8

10

9

R.R.

Pacific

12

11

19

Missouri

17

15

18

16

A'

14 B'

T I S

A.H.
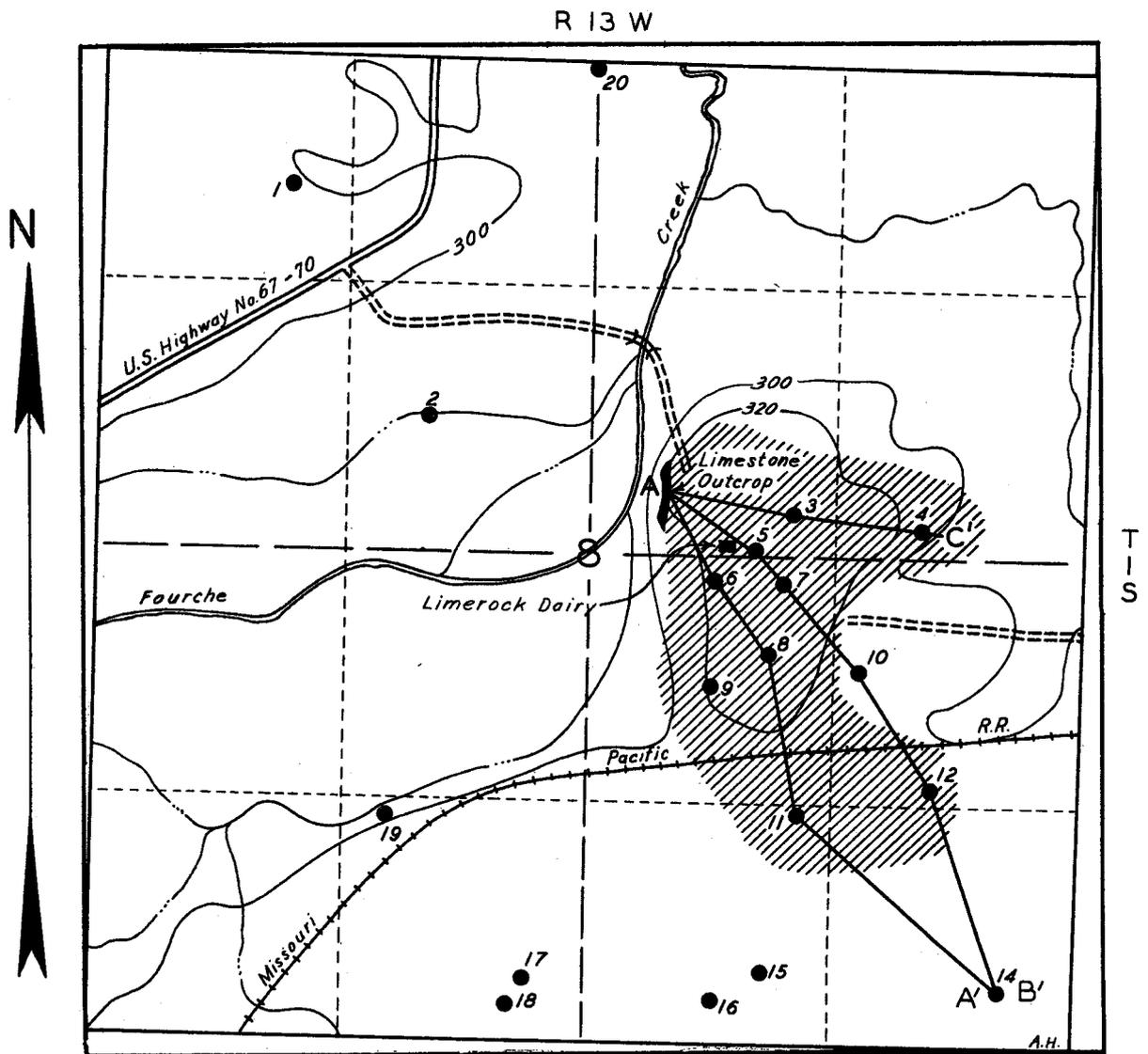
VICINITY OF LIMEROCK DAIRY

MINIMUM EXTENT OF AREA
UNDERLAIN BY RECOVERABLE
LIMESTONE

LIMESTONE OUTCROP

● 99   DRILL HOLE

SCALE   IN   FEET

500   0   500   1000   1500
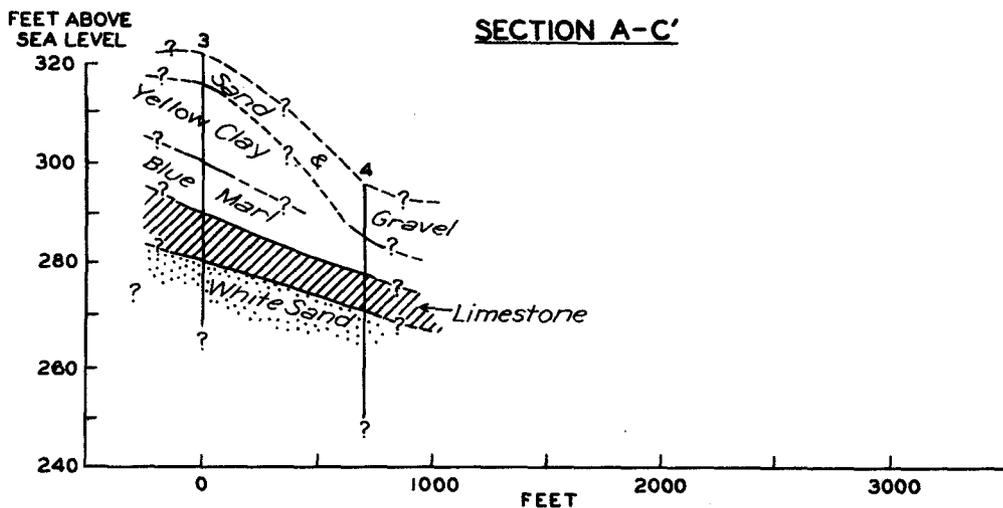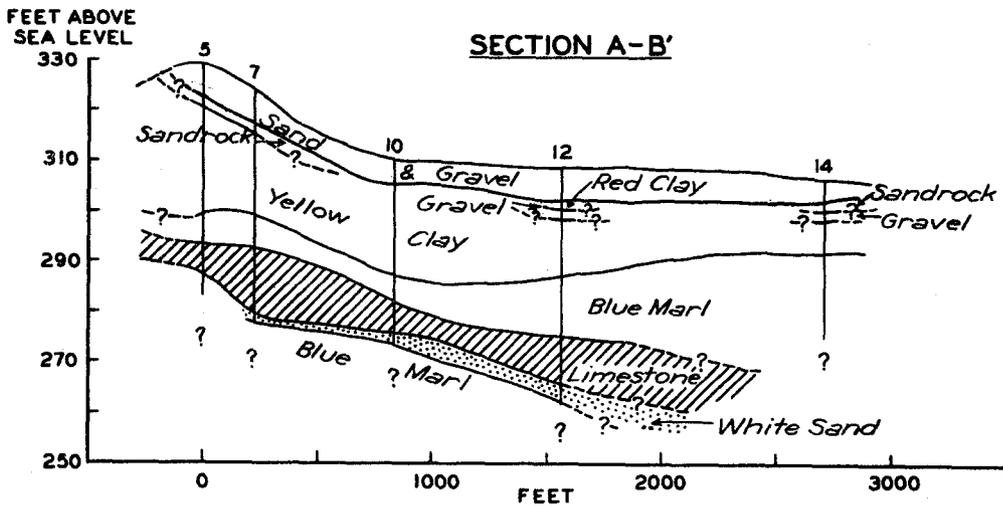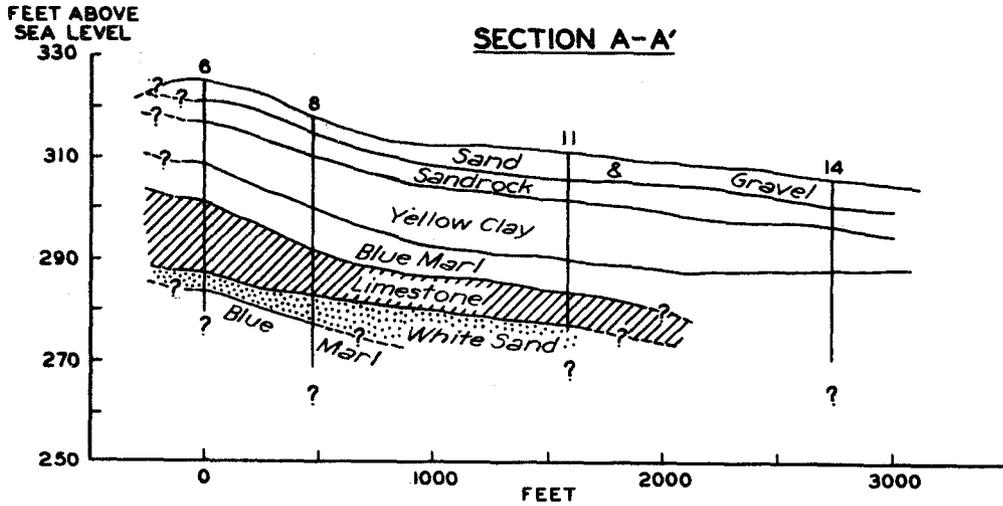
CROSS SECTIONS
DRAWN FROM
WELL LOGS IN THE LIMEROCK DAIRY AREA

In 1916 Stephenson and Crider[4], reporting on the groundwater conditions in the lowland north of the Arkansas River, traced the Midway formation along the western edge of the Gulf Coastal Plain from Little Rock southwestward through Pulaski and Saline Counties to Rockport, near Malvern, in Hot Spring County.

More recent information on the limestone in central Arkansas was made available in 1934 by Bramlette's study of the bauxite regions in Pulaski and Saline Counties[5]. A series of 55 test holes ranging from 27 to 463 feet in depth, averaging 166.7 feet to a hole, was drilled in connection with this study. In the holes west of Alexander in sec. 13, T. 1 S., R. 14 W., Saline County, limestone was encountered in beds with a maximum thickness of 16 feet, at about 23 feet beneath the surface. Limestone was found in 28 holes of the 55 drilled during the course of the bauxite investigation.

Methods of Work on the Investigation

Test holes were drilled with a drill of the churn type similar to those used in the shallow test drilling for bauxite. A crew of 11 men, including a supervisor, a timekeeper, a blacksmith, and 8 laborers, was used on the project.

Chemical analyses were made of the limestone that crops out along Fourche Creek near the mouth of Crooked Creek in sec. 8, T. 1 S., R. 13 W., Pulaski County, and of samples of limestone and marl collected near Alexander, Pulaski County.

Acknowledgments

Personnel for the project was supplied by the Works Progress Administration. The State Geological Survey, under the direction of George C. Branner, State Geologist, served as sponsor.

The report was compiled in the office of the State Geological Survey. The chemical analyses of the limestone were made by F. D. Roach and W. F. Manglesdorf.

Typing for reproduction was by Carolyn Goldman of the State Mineral Survey.

GEOLOGY

The limestone in this region is a member of the Midway formation, which is considered to be the lowest unit of the Tertiary deposits in Arkansas. The Midway formation crops out between the steeply folded Paleozoic rocks of the Ouachita Mountains and the later Tertiary beds of clay, sand, and gravel of the Gulf Coastal Plain.

In the area drilled the Midway formation contains at the base a blue marl from 1 foot to 24 feet or more thick. This basal marl is not everywhere present. Above the blue marl, in some places, is a white sand 18 feet or more in thickness. Locally resting on the blue marl or on the white sand is a white to buff fossiliferous limestone, 1 to 18 feet thick. A blue marl similar to the basal marl overlies the limestone in most places. The upper marl ranges from 1 foot to 19 feet or more in thickness, and this is overlain by brown and yellow clays, and sand and gravel, believed to be of later Tertiary age.

Not all the beds above mentioned were encountered in each hole drilled. A study of the logs and the cross sections (see Pls. III and V) shows that the various members of the Midway formation occur as thin lenticular bodies. The Midway was thus either deposited on an irregular erosion surface, or it was formed by intermittent deposition interrupted by intervals of erosion. It is evident, therefore, that a continuous body of limestone with a uniform thickness does not extend throughout the area.

4/ Stephenson, L. W., and Crider, A. F., Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, pp. 44-54, 1916.
5/ Bramlette, M. N., Geology of the Arkansas bauxite region: Arkansas Geol. Survey Information Circ. 8, 1936.

LIMESTONE DEPOSITS

Location of Holes

In all, 130 holes were drilled by the project. Their locations are shown on Plate I. The purpose of the drilling was to locate limestone adjacent to surface outcrops, and at shallow depths where the material could be mined by stripping. Consequently no systematic drilling program for the area as a whole was carried out. Drilling was carried on most intensely where the limestone outcropped or where a test hole indicated that the limestone occurred in sufficient quantities and at shallow enough depths to allow profitable quarrying. Holes 1 to 22, inclusive, were drilled in secs. 8, 9, and 17, T. 1 S., R. 13 W. The limestone crops out in sec. 8, and these holes were drilled to establish the extent of the limestone in that vicinity. Holes 23 to 52, inclusive, were drilled in the area north, west, and southwest of Alexander, in Pulaski and Saline Counties, and the logs of these holes indicate considerable quantities of limestone in this region.

In all other holes drilled, limestone was either not penetrated or it occurred in spots so isolated that its economic importance was believed to be negligible. These holes are numbered from 53 to 130. Holes 53 to 89, inclusive, were drilled over an area beginning in sec. 14, T. 1 S., R. 14 W., and extending westward and southwestward to a point east of Benton, in sec. 12, T. 2 S., R. 15 W. Holes 90 to 102, inclusive, were drilled on the property of the State Hospital for Nervous Diseases, southwest of Benton. Holes 103 to 130, inclusive, were drilled in an area extending southwestward from Little Rock, parallel to the Missouri Pacific Railroad, to a point west of Mabelvale. The locations of these holes are shown on Plate I, and the logs of the holes are included in the appendix.

Occurrences of Limestone

As this report is concerned only with the economic aspects of utilizing the limestone, only those areas are discussed in which it is believed that the limestone has possible economic importance. The results of the drilling program indicate that limestone occurs in two such areas: (1) in sec. 8, T. 1 S., R. 13 W., near the Limerock Dairy, Pulaski County, and (2) in sec. 18, T. 1 S., R. 13 W., Pulaski County, and secs. 13 and 24, T. 1 S., R. 14 W., Saline County, near Alexander.

Sec. 8, T. 1 S., R. 13 W., Pulaski County. A total thickness of 17.5 feet of limestone crops out along Fourche Creek near Limerock Dairy in sec. 8. A series of 20 holes (Nos. 1 to 20) was drilled in this general vicinity. Plate II shows the locations of these holes, and Plate III shows cross sections along three lines of holes southeast of the outcrop (lines A-C', A-B', and A-A'), where the land is underlain by limestone.

Holes 1, 2, and 20 were drilled west and northwest of the outcrop at Fourche Creek. The surface elevation of these holes is less than that of the outcrop on the right bank of the creek and only thin limestone was encountered in hole 2. Holes 3 to 9, inclusive, 11, and 12 all penetrated limestone and are included in the area shaded on Plate II. This area, underlain by limestone ranging from 6 to 18 feet in thickness and averaging 11.7 feet, is estimated to cover about 75 acres. Hole 10, in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 8, and holes 15 and 16, in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 8, were drilled to depths of 37, 50 and 40 feet respectively, but they showed no limestone. Holes 17 and 18 were drilled in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 8, and showed a considerable body of limestone at a depth of 18 feet. Hole 19 was drilled northwest of the Missouri Pacific Railroad in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 8, and penetrated 1 foot of limestone at a depth of 10 feet and 25 feet of blue clay beneath the limestone.

The logs of the holes drilled in sec. 8 indicate that the limestone thins toward the southeast. (See cross sections, Pl. III.) The logs of holes 17, 18, 19, and 22, in sec. 17 (see Pl. I), all show limestone and indicate that the material continues southwestward from the outcrop at Fourche Creek. Too few holes were drilled to deter-
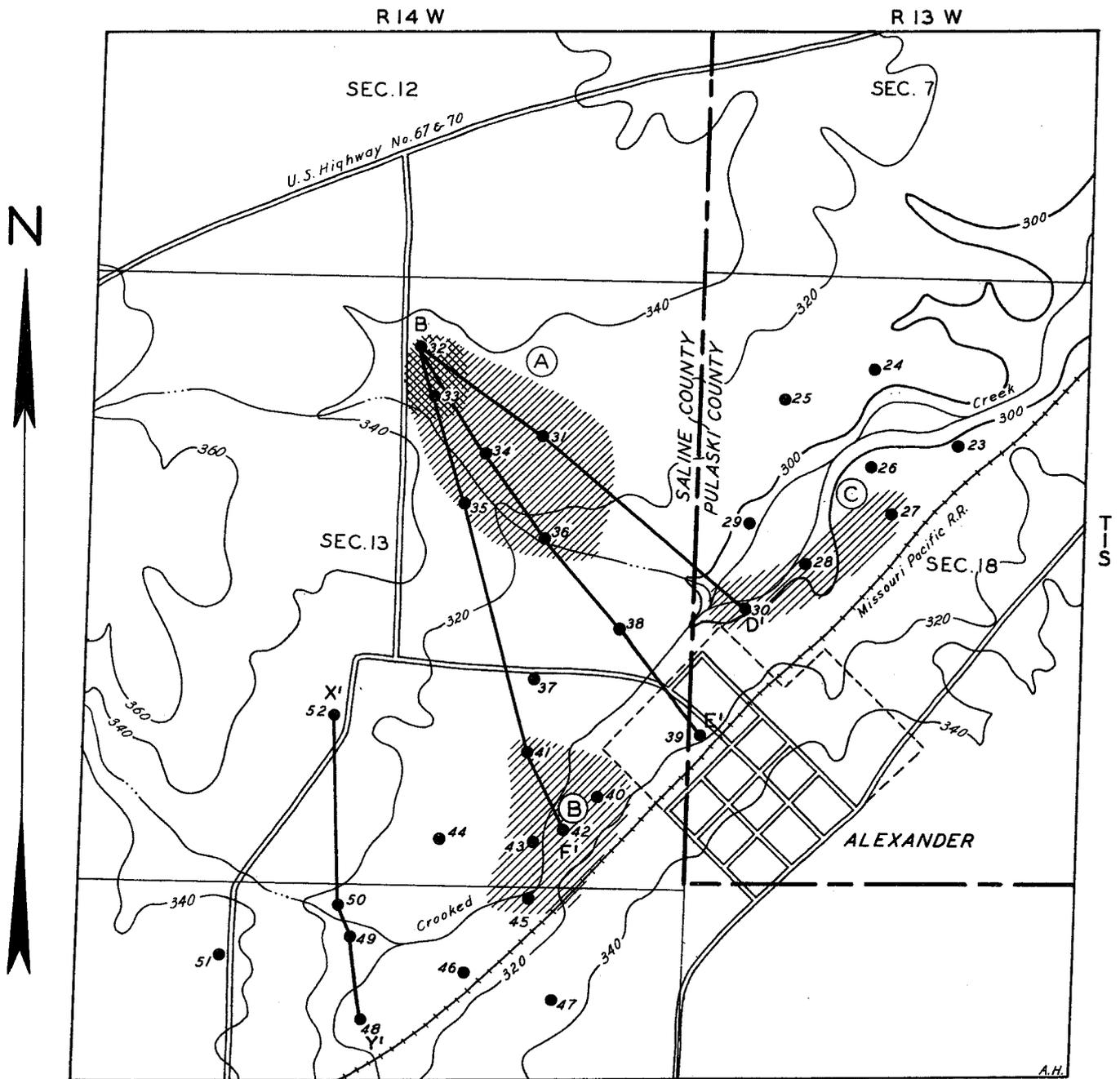
VICINITY OF ALEXANDER

LEGEND
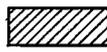
MINIMUM EXTENT OF AREAS
UNDERLAIN BY RECOVERABLE
LIMESTONE
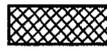
AREA MOST FAVORABLE FOR
STRIPPING

● 99   DRILL HOLE

SCALE   IN   FEET

500   0   500   1500   2500

FEET ABOVE
SEA LEVEL

SECTION B-D'

FEET ABOVE
SEA LEVEL

SECTION B-E'

FEET ABOVE
SEA LEVEL

SECTION B-F'

FEET ABOVE
SEA LEVEL
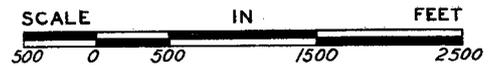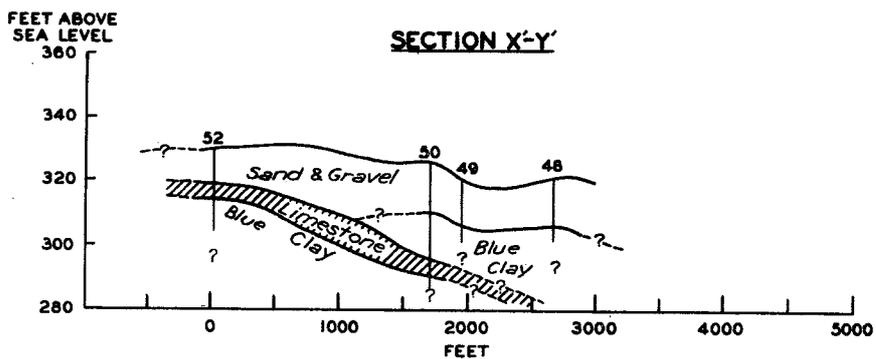
SECTION X'-Y'

CROSS SECTIONS
DRAWN FROM
WELL LOGS IN THE ALEXANDER AREA

mine whether this area is completely underlain by limestone.

Sec. 18, T. 1 S., R. 13 W., Pulaski County and secs. 13 and 24, T. 1 S., R. 14 W., Saline County. Holes 23 to 52, inclusive, were drilled near Alexander, and the logs indicate that this region is partly underlain by limestone. Plate IV shows the locations of the holes, and Plate V shows cross sections of four lines of holes (lines B-D', B-E', B-F', X'-Y'). Three areas are underlain by limestone in this region and are shown by shading on Plate IV; they are designated A, B, and C.

Area A is delimited on the basis of six holes (Nos. 31 to 36 inclusive) and covers about 80 acres. Limestone was penetrated in each hole and ranges from 5 to 7 feet in thickness, with an average of 6.3 feet. Limestone does not crop out within this area, but it is within 5 feet of the surface south of hole 33, along the left bank of the intermittent creek northwest of Alexander. (See cross section B-F', Pl. V.) The portion of area A indicated on Plate IV by cross hatching covers about 5 acres and offers the best possibility for stripping.

Area B, in secs. 13 and 24, T. 1 S., R. 14 W., is delimited by five holes (Nos. 40, 41, 42, 43, and 45) and covers about 35 acres. Limestone was penetrated in each hole, and its thickness ranges from 8 to 13 feet with an average of 10.8 feet. There are no outcrops in this area. The overburden ranges from 16 to 28 feet, with an average of 21.8 feet. The limestone is nearest the surface in hole 43, where the overburden is 16 feet thick.

Area C, in sec. 18, T. 1 S., R. 13 W., is delimited by three holes (Nos. 27, 28, and 30) and covers about 20 acres. Each hole penetrated limestone, with a thickness ranging from 6 to 10 feet and an average of 8.7 feet. No outcrop occurs within this area. The overburden ranges in thickness from 10 to 15 feet, with an average of 11.7 feet.

No other areas contained a sufficient amount of limestone to warrant description.

ECONOMIC CONSIDERATIONS

Quantity of Material and Amount of Overburden

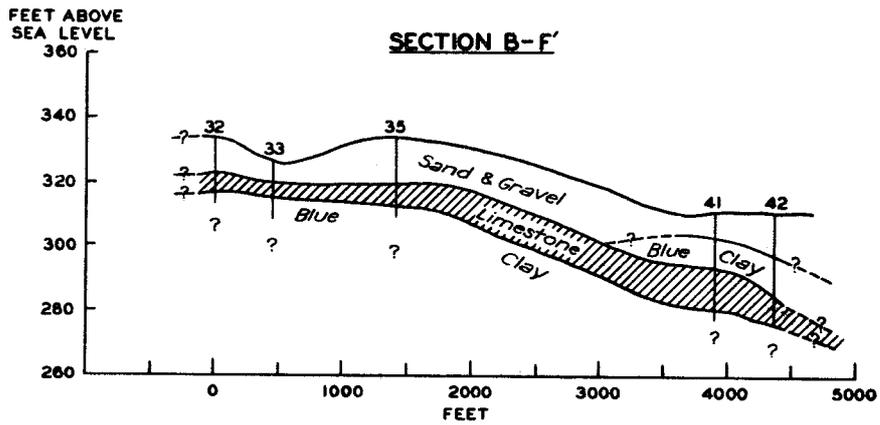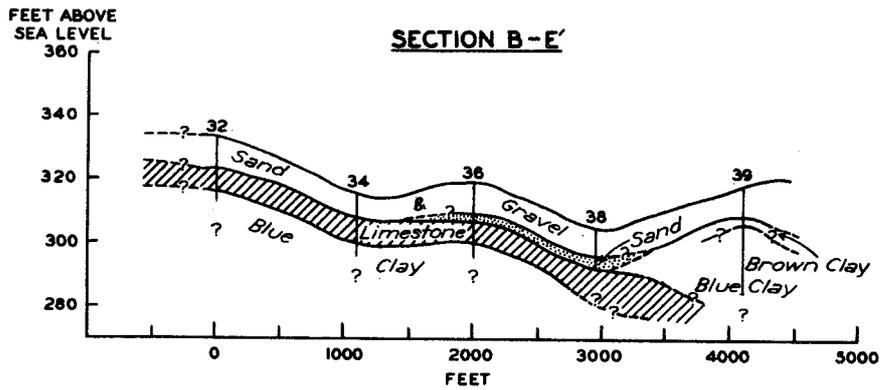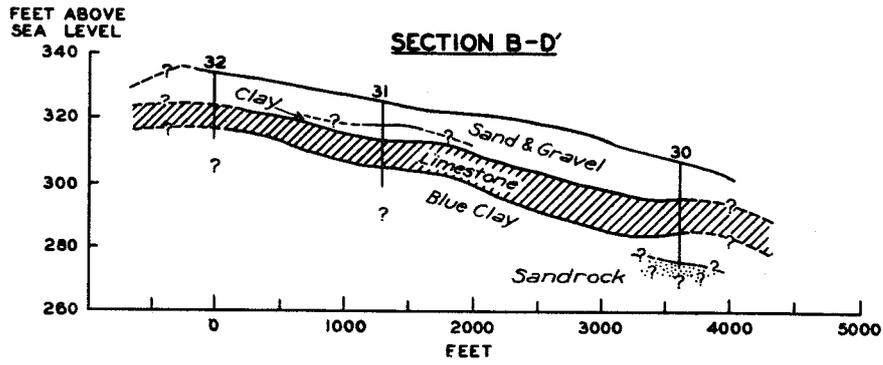Estimates of limestone and overburden in the areas indicated by shading on Plates II and IV were calculated by blocking out the areas according to thicknesses of limestone and overburden as shown in the drill logs. The weight of a cubic foot of limestone was assumed to be 150 pounds. Estimates of limestone were made in short tons; overburden in cubic yards.

As shown above, it has been found that the limestone bodies are lenticular. In defining their extent, therefore, the shaded areas follow closely the limits as indicated by the test holes. Some of the holes that penetrated limestone were not included within the shaded areas because insufficient tests were made between these holes and the shaded areas to establish the continuity of the deposit.

Sec. 8, T. 1 S., R. 13 W. The only outcrop of limestone within the entire area is found in sec. 8, T. 1 S., R. 13 W. (See Pl. II.) The limestone, having an average thickness of 11.7 feet, is exposed east of Fourche Creek and extends underground to the southeast.

It is estimated that this area contains about 2,250,000 short tons of limestone. The average thickness of overburden is about 29 feet, and it is estimated that about 2,750,000 cubic yards of earth would have to be removed to strip the overburden from the limestone. The best conditions for stripping are in the portion of the area immediately adjacent to the limestone outcrop.

Sec. 18, T. 1 S., R. 13 W., and secs. 13 and 24, T. 1 S., R. 14 W., near Alexander. No limestone crops out in the region near Alexander, but the test holes indicate that the three areas designated A, B, and C and shown by shading on Plate IV are underlain by limestone.

Area A covers about 80 acres and is estimated to contain about 760,000 short tons of limestone; the overburden in the area is estimated at 575,000 cubic yards. The portion of the area that offers the best possibility for stripping is the northwestern part, shown by cross hatching on Plate IV. This small area covers about 5 acres and as indicated in the cross section along the line B-F' (see Pl. V), the limestone occurs a few feet beneath the surface along the creek. This 5-acre area is estimated to contain about 125,000 short tons of limestone and about 90,000 cubic yards of overburden.

Area B, west of Alexander, covers about 35 acres. This area is estimated to contain about 950,000 short tons of limestone and about 775,000 cubic yards of overburden. The limestone averages 10.8 feet in thickness, and the overburden averages 21.8 feet.

Area C covers about 20 acres and is estimated to contain 365,000 short tons of limestone and 290,000 cubic yards of overburden.

As most of the drill holes outside areas A, B, and C penetrated no limestone, no attempt was made to connect these areas.

The total amount of limestone and overburden in the shaded areas shown on Plates II and IV is estimated to be as follows: Limestone 4,325,000 short tons; overburden 4,390,000 cubic yards.

Quality of Material

In Table I are listed chemical analyses of the limestone that crops out along the right bank of Fourche Creek near Limerock Dairy, and of limestone and marl specimens collected in the vicinity of Alexander.

In the Fourche Creek outcrops, the calcium carbonate content of the limestone averages close to 60 per cent. The beds which are exposed in the right bank of Fourche Creek, several hundred feet north of Limerock Dairy, show, as a unit, a calcium carbonate content of 56.70 per cent. In this same outcrop there are considerable variations in the composition of the several beds (see analyses No. 3 to No. 6), the uppermost zone being of the highest grade with 73.26 per cent calcium carbonate. The two blue marl samples collected near Alexander contain respectively 71.65 and 57.80 per cent calcium carbonate. All of the analyzed calcareous rocks in the Mabelvale-Alexander region show a relatively high silica content, and little or no magnesium.

Use of Limestone for Agricultural Purposes

Lime may be applied to the soil as quick lime (oxide), hydrated lime (hydroxide), or in the form of the natural rock (carbonate) as limestone, chalk, or marl. If it is applied as quick lime or hydrated lime it is soon converted to the carbonate form.

According to Drake[6], a single application of one-half to one ton of burnt lime, or twice that amount of ground limestone, per acre, is usually sufficient to last five or six years.

Regarding the desirability of liming the soils in Arkansas, Drake says: "Almost all our soils would be benefited by the application of lime; however, some of the limestone soils of the northwest and southwest parts of the State would need but lit-

[6] Drake, N. F., Mineral fertilizers in Arkansas: Arkansas Bur. of Mines, Manufactures, and Agriculture, p. 21, 1924.

A. View of the limestone outcrop east of Fourche Creek, near Limerock
    Dairy. A thickness of 8 feet, 8 inches of almost flat-lying lime-
    stone has been uncovered in the steep slope.

B. The north outcrop of limestone near Limerock Dairy, in the right
    bank of Fourche Creek. The total thickness exposed in the outcrop
    is 16 feet, 4 inches.

tle, if any, additional lime. The swamp regions of eastern and southern Arkansas stand in very great need of lime."

Table 1. Limestone and marl analyses

	1	2	3	4	5	6	7	8	9
$CaCO_3$	68.53	56.70	49.48	52.34	47.98	73.26	76.40	71.65	57.80
CaO	38.40	31.76	27.72	29.32	26.89	41.06	42.81	40.15	32.38
$MgCO_3$·	trace	neg.	neg.	neg.	neg.	neg.	0.75	0.75	0.75
MgO	trace	neg.	neg.	neg.	neg.	neg.	0.36	0.36	0.36
SiO_2	27.22	41.14	49.30	45.92	50.06	22.78	17.00	23.00	35.00
Al_2O_3	2.33	0.83	0.58	0.82	0.87	1.17 ⎱	5.00	4.00	5.25
Fe_2O_3	1.01	0.85	0.58	0.76	0.85	0.93 ⎰			
CO_2	30.13	24.94	21.76	23.02	20.09	32.20	33.98	31.89	25.80
P_2O_5	-	-	-	-	-	-	0.10	0.10	0.20
K_2O	-	-	-	-	-	-	trace	trace	trace
Moisture	-	-	-	-	-	-	0.75	0.50	1.00

1.   Channel sample taken across the limestone outcrop east of Fourche Creek near Limerock Dairy; thickness. sampled 8 feet, 8 inches.

2.   Channel sample taken across the limestone outcrop in the right bank of Fourche Creek, lying 250 feet to north of outcrop from which Sample No. 1 was taken; thickness sampled, 16 feet, 4 inches.

3.   Channel sample taken across the lowest bed exposed in the Fourche Creek outcrop described under No. 2. The rock is a pale buff-gray, are-naceous limestone, weathering to a medium gray; thickness, 1 foot, 9 in-ches.

4.   Channel sample taken across the next to lowest bed exposed in the Fourche Creek outcrop described under No. 2. The rock is a yellowish brown, arenaceous limestone, weathering to pale bluish gray, thickness, 1 foot, 7 inches.

5.   Channel sample taken across the median zone exposed in the Fourche Creek outcrop described under No. 2. The rock is a fossiliferous, pale buff-gray, finely arenaceous limestone, weathering coarsely pitted and gashed; thickness, 5 feet, 8 inches.

6.   Channel sample taken across the top zone exposed in the Fourche Creek outcrop described under No. 2. The rock is a highly fossiliferous buff limestone, weathering pale gray to white and irregularly pitted; thick-ness, 7 feet, 4 inches.

7.   Selected sample of white limestone collected near Alexander.

8.   Selected sample of light blue marl collected near Alexander.

9.   Selected sample of dark blue marl collected near Alexander.

Economic Exploitation of the Limestone

The possibility of recovering the limestone by stripping depends to a large ex-tent on the ratio of recoverable limestone to the amount of overburden that must be removed. The tonnage of limestone in the areas shown on Plates II and IV is consider-able, but the amount of overburden is also large. In the shaded area shown on Plate II the ratio of overburden to limestone is greater than 1 cubic yard to the ton. A

very small and narrow zone parallel to Fourche Creek, north and south of the outcrop, has a somewhat more favorable ratio.

About 5 acres of area A (Pl. IV) has a ratio of overburden to limestone of about 0.7 cubic yard to the ton. The remainder of area A and all of areas B and C have a ratio of overburden to limestone of about 0.8 cubic yard to the ton.

The usefulness of an agricultural lime is based on its neutralizing value, which is proportional to the calcium carbonate content. High-grade limestone, such as those of northern Arkansas, contain 95 to 99 per cent of calcium carbonate.

The limestone in this area was not comprehensively sampled, but the few samples that were analyzed indicate that the calcium carbonate equivalent averages close to 60 per cent. This is lower than is generally recommended for crushed limestone for agricultural purposes, because for every ton of limestone recovered more than one-third of a ton would have practically no value to the soil.

If the limestone in this area could be produced cheaply enough to offset the lower neutralizing value as compared to that of a high-grade limestone, its value in Pulaski County or vicinity should then be based on the delivered price of the purer limestone. High-grade agricultural limestone (98% calcium carbonate) is produced in Independence County and sells at $1.00 per ton, f.o.b., Batesville. The freight charge on this to Mabelvale is $1.21 per ton, and to Woodson, $1.27 per ton. Therefore the competitive price of 98 per cent calcium carbonate limestone at Mabelvale is $2.21 per ton, and at Woodson, $2.27 per ton.

If 60 per cent is taken as a representative figure for the calcium carbonate content of the rock that crops out along Fourche Creek near Limerock Dairy, then the competitive price of limestone of that grade laid down at Mabelvale would be $1.82 per ton, and at Woodson, $1.88 per ton. Assuming that modern loading and dumping equipment is used, it is estimated that the limestone can be hauled by truck within a radius of ten miles from the quarry site for 60 cents per ton, and within a radius of twenty miles for $1.00 per ton. Therefore, limestone meant for Mabelvale must be quarried at a cost plus profit basis of $1.22 or less per ton, and that meant for Woodson at $0.88 or less per ton.

Since in different localities quarrying conditions are variable, cost estimates are difficult to make until some experience is accumulated at a particular site. Average cost figures, however, may have some value. Thoenen[7] obtained a cost of 67 cents a ton as an average for 30 open-pit limestone quarries in various parts of the country. This would indicate that, with efficient management of production operations and an ample local demand for the product, the limestone outcropping along Fourche Creek near Limerock Dairy could be quarried on a commercial basis.

7/ Thoenen, J. R., Underground limestone mining: U. S. Bur. of Mines Bulletin 262, p. 94, 1926.

APPENDIX

APPENDIX

LOGS OF TEST HOLES DRILLED FOR LIMESTONE IN
PULASKI AND SALINE COUNTIES

Hole   1.   Thomas G. Douglas property, NW¼ NW¼ sec. 8, T. 1 S., R. 13 W.;
              500 feet northwest of Hwy. 67.

                    Feet
                    0- 5   Sand and gravel.
                    5- 8   Slate.
                    8-25   Soft slate.

Hole   2.   R. E. Morris property, SE¼ NW¼ sec. 8, T. 1 S., R. 13 W.; on
              creek bank   400 feet south of road leading to Limerock Dairy;
              surface altitude: 300 feet.

                    Feet
                    0- 4   Sand and gravel.
                    4- 7   Sandrock.
                    7-11   Blue marl.
                    11-13   Gray limestone.
                    13-28   Blue marl.
                       28   Hard rock.

Hole   3.   R. E. Morris property, SW¼ NE¼ sec. 8, T. 1 S.,R. 13 W.; 1,000
              feet east of outcrop on Fourche Creek;   surface altitude: 321
              feet.

                    Feet
                    0- 5   Sand and gravel.
                    5- 7   Gravel.
                    7-22   Yellow clay.
                    22-33   Blue marl.
                    33-44   Limestone.
                    44-55   White sand.

Hole   4.   R. E. Morris property, SE¼ NE¼ sec. 8, T. 1 S., R. 13 W.; 150
              feet west of Otter Creek; surface altitude: 294 feet.

                    Feet
                    0- 8   Sand and gravel.
                    8-11   Gravel.
                    11-18   Blue marl.
                    18-26   Limestone
                    26-44   White sand

Hole   5.   R. E. Morris property, SW¼ NE¼ sec. 8, T. 1 S.,   R. 13 W.; 300
              feet northwest of dirt road; surface altitude: 328 feet.

                    Feet
                    0- 5   Sand and gravel.
                    5- 7   Sandrock.
                    7-30   Gray and yellow clays.
                    30-35   Blue marl.
                    35-41   Limestone.
                    41-47   Void space; water would not stay in hole.

Hole   6.   R. E. Morris property,   NW¼ SE¼ sec. 8, T. 1 S., R. 13 W.; 300
             feet east of creek; surface altitude: 325 feet.

                        Feet
                        0- 4   Sand and gravel.
                        4- 7   Gravel.
                        7-15   Yellow clay.
                        15-24 Blue clay.
                        25-40 Limestone.
                        40-42 White sand.
                        42-46 Blue marl.

Hole   7.   R. E. Morris property,   NW¼ SE¼ sec. 8, T. 1 S.,   R. 13 W., 75
             feet north of dirt road; surface altitude: 323 feet.

                        Feet
                        0- 7   Sand and gravel.
                        7-10   Gravel.
                        10-25 Yellow clay.
                        25-31 Blue marl.
                        31-45 Limestone.
                        45-47 White sand.
                        47-53 Blue marl.

Hole   8.   R. E. Morris property, NW¼ SE¼ sec. 8,   T. 1 S., R. 13 W.; 350
             feet north of Missouri Pacific Railroad; surface altitude: 318
             feet.

                        Feet
                        0- 4   Sand and gravel.
                        4- 6   Sandrock.
                        6- 9   Gravel.
                        9-18   Yellow clay.
                        18-28 Blue marl.
                        28-36 Limestone.
                        36-41 White sand.
                        41-51 Blue marl.

Hole   9.   R. E. Morris property,   NW¼ SE¼ sec. 8, T. 1 S., R. 13 W.; 200
             feet north of Missouri Pacific Railroad; surface altitude: 315
             feet.

                        Feet
                        0- 5   Sand and gravel.
                        5- 7   Sandrock.
                        7-21   Yellow clay.
                        21-28 Blue marl.
                        28-46 Limestone.
                        46-50 White sand.

Hole   10.   R. E. Morris property, NE¼ SE¼ sec. 8, T. 1 S., R. 13 W.;   250
             feet south of road; surface altitude: 309 feet.

                        Feet
                        0- 5   Sand and gravel.
                        5-24   Yellow clay.
                        24-29 Blue marl.
                        29-34 Thin layers of limestone with clay seams between.
                        34-37 Coarse sand and sandrock.

Hole 11.   C. E. Olsen property, SW¼ SE¼ sec. 8, T. 1 S.,   R. 13 W.; 300
feet south of Missouri Pacific Railroad; surface altitude: 312
feet.

        Feet
         0- 6 Sand and gravel.
         6- 9 Sandrock.
         9-28 Yellow clay.
        28-35 Blue marl.
        35-45 Limestone
           45 White sand.

Hole 12.   R. E. Morris property, NE¼ SE¼ sec. 8, T. 1 S., R. 13 W.; 200
feet south of Missouri Pacific Railroad; surface altitude: 308
feet.

        Feet
         0- 8 Sand and gravel.
         8-10 Red clay.
        10-13 Gravel.
        13-22 Yellow clay.
        22-24 Blue marl.
        24-26 Hard gray marl.
        26-35 Blue marl.
        35-43 Limestone.
        43-48 White sand.

Hole 13.   NW¼ SW¼ sec. 9, T. 1 S., R. 13 W.; 310 feet south of Missouri
Pacific Railroad; surface altitude: 306 feet.

        Feet
         0- 8 Sand and gravel.
         8-10 Sandrock.
        10-13 Gravel.
        13-24 Yellow clay.
        24-38 Blue marl.
        38-40 Gray limestone.

Hole 14.   C. E. Olsen property, SE¼ SE¼ sec. 8, T. 1 S., R. 13 W.; 300
feet north of Alexander road; surface altitude: 307 feet.

        Feet
         0- 5 Sand and gravel.
         5- 8 Sandrock.
         8-10 Gravel.
        10-19 Yellow clay.
        19-40 Blue marl.

Hole 15.   C. E. Olsen property, SW¼ SE¼ sec. 8, T. 1 S.,   R. 13 W.; 375
feet north of Alexander road; surface altitude: 323 feet.

        Feet
         0-10 Sand and gravel.
        10-20 Brown clay.
        20-50 Blue clay.

Hole 16.   C. E. Olsen property, SW¼ SE¼ sec. 8, T. 1 S.,   R. 13 W.; 200
feet north of Alexander road; surface altitude: 313 feet.

```
            Feet
            0-10   Sand and gravel.
            10-40  Clay with hard rock at intervals.
```

Hole 17. C. E. Olsen property, SE¼ SW¼ sec. 8, T. 1 S., R. 13 W.; 350
           feet northwest of Alexander road; surface altitude: 308 feet.

```
            Feet
            0- 2   Sand and gravel.
            2- 4   Sandrock.
            4- 7   White clay.
            7-18   Blue clay.
            18-24  Limestone; stopped in limestone.
```

Hole 18. C. E. Olsen property, SE¼ SW¼ sec. 8, T. 1 S., R. 13 W.; 325
           feet northwest of Alexander road; surface altitude: 308 feet.

```
            Feet
            0- 2   Sand and gravel.
            2- 4   Sandrock.
            4- 7   White clay.
            7-18   Blue clay.
            18-33  Limestone.
            33-40  Blue clay.
```

Hole 19. C. E. Olsen property, SE¼ SW¼ sec. 8, T. 1 S., R. 13 W.; 150
           feet northwest of Missouri Pacific Railroad; surface altitude:
           293 feet.

```
            Feet
            0-10   Sand and gravel.
            10-11  Limestone.
            11-35  Blue clay.
```

Hole 20. N. F. Lawing property, NE¼ NW¼ sec. 8, T. 1 S., R. 13 W.; 650
           feet east of United States Hwy. 67; surface altitude: 300 feet.

```
            Feet
            0- 8   Sand and gravel.
            8-12   Gravel.
            12-20  Blue clay.
```

Hole 21. NW¼ NE¼ sec. 17, T. 1 S., R. 13 W.; 500 feet south of Alexan-
           der Road and 50 feet west of dirt road; surface altitude: 320
           feet.

```
            Feet
            0-10   Sand and gravel.
            10-20  Brown clay.
            20-30  Blue clay.
```

Hole 22. NW¼ NW¼ sec. 17, T. 1 S., R. 13 W.; 300 feet west of Alexander
           Road; surface altitude: 319 feet.

```
            Feet
            0-10   Sand and gravel.
            10-27  Clay.
            27-32  Limestone; drilling stopped in limestone.
```

Hole 23.   SE¼ NE¼ sec. 18,   T. 1 S., R. 13 W.; 300 feet west of Missouri
Pacific Railroad; surface altitude: 295 feet.

> Feet
> 0-10   Sand and gravel.
> 10-12 Gravel.
> 12-21 Blue sticky clay.

Hole 24.   NW¼ NE¼ sec. 18, T. 1 S., R. 13 W.;   600 feet north of Crooked
Creek; surface altitude: 293 feet.

> Feet
> 0-10   Sand and gravel.
> 10-12 Gravel.
> 12-30 Blue clay.

Hole 25.   NE¼ NW¼ sec. 18, T. 1 S.,   R. 13 W.; 700 feet north of Crooked
Creek; surface altitude: 311 feet.

> Feet
> 0- 8   Sand and gravel.
> 8-14   Brown limestone.
> 14-21 Blue clay.

Hole 26.   SW¼ NE¼ sec. 18, T. 1 S., R. 13 W.; 300 feet   south of Crooked
Creek; surface altitude: 302 feet.

> Feet
> 0-10   Sand and gravel.
> 10-12 Sand.
> 12-15 White sand with traces of limestone.

Hole 27.   SW¼ NE¼ sec. 18, T. 1 S., R. 13 W.;   300 feet east of Missouri
Pacific Railroad; surface altitude: 307 feet.

> Feet
> 0- 8   Sand and gravel.
> 8-15   Clay.
> 15-21 Limestone.
> 21-24 Blue clay.

Hole 28.   SW¼ NE¼ sec. 18, T. 1 S., R. 13 W.; 600 feet west of Missouri
Pacific Railroad; surface altitude: 298 feet.

> Feet
> 0-10   Sand and gravel.
> 10-20 Limestone.
> 20-30 Blue clay.
> 30-31 Sandrock.

Hole 29.   SE¼ NW¼ sec. 18, T. 1 S., R. 13 W.;   on bank of Crooked Creek:
surface altitude: 304 feet.

> Feet
> 0-12   Sand and gravel.
> 12-15 Gravel.
> 15-17 Blue sticky clay.

13

Hole 30. NE¼ SW¼ sec. 18, T. 1 S., R. 13 W.; 800 feet northwest of junction of railroad crossing and northernmost street of Alexander; surface altitude: 306 feet.

Feet
0-10 Sand and gravel.
10-20 Limestone.
20-30 Blue clay.
30-31 Sandrock.

Hole 31. SW¼ NE¼ sec. 13, T. 1 S., R. 14 W.; 700 feet north of creek, Saline County; surface altitude: 326 feet.

Feet
0- 8 Sand and gravel.
8-12 Clay.
12-19 Limestone.
19-25 Blue clay.

Hole 32. NW¼ NE¼ sec. 13, T. 1 S., R. 14 W.; 120 feet east of road; surface altitude: 333.7 feet.

Feet
0-11 Sand and gravel.
11-13 Brown limestone.
13-15 Hard white limestone.
15-17 Brown limestone.
17-20 Blue clay.

Hole 33. NW¼ NE¼ sec. 13, T. 1 S., R. 14 W.; 175 feet east of county road; surface altitude: 326 feet.

Feet
0- 6 Sand and gravel.
6-11 Limestone.
11-12 Yellow sand and gravel.
12-20 Blue clay.

Hole 34. SW¼ NE¼ sec. 13, T. 1 S., R. 14 W.; 250 feet east of creek; surface altitude: 315 feet.

Feet
0- 7 Sand and gravel.
7-14 Limestone.
14-20 Blue clay.

Hole 35. SW¼ NE¼ sec. 13, T. 1 S., R. 14 W.; 125 feet west of creek; surface altitude: 335 feet.

Feet
0-13 Sand and gravel.
13-14 Sandrock.
14-21 Limestone.
21-25 Blue clay.

Hole 36. SE¼ NE¼ sec. 13, T. 1 S., R. 14 W.; on bank of creek; surface altitude: 320 feet.

```
Feet
0-10    Sand and gravel.
10-12   Sand.
12-18   Limestone.
18-22   Blue clay.
```

Hole 37.   NW¼ SE¼ sec. 13,   T. 1 S., R. 14 W.;   175 feet south of county
road; surface altitude: 315 feet.

```
Feet
0- 7    Sand and gravel.
7- 8    Gravel.
8-21    Blue sticky clay.
```

Hole 38.   NE¼ SE¼ sec. 13,   T. 1 S., R. 14 W.;   300 feet north of county
road; surface altitude: 305 feet.

```
Feet
0- 8    Sand and gravel.
8-12    Sand.
  12    Limestone.
```

Hole 39.   NE¼ SE¼ sec. 18, T. 1 S.,   R. 13 W.; 75 feet   east of Missouri
Pacific Railroad; surface altitude: 320 feet.

```
Feet
0- 8    Sand and gravel.
8-10    Gravel.
10-12   Brown clay.
12-33   Blue clay.
```

Hole 40.   SE¼ SE¼ sec. 13,   T. 1 S., R. 14 W.; 500 feet west of Missouri
Pacific Railroad; surface altitude: 310 feet.

```
Feet
0- 8    Sand and gravel.
8-15    Gravel.
15-20   Blue clay.
20-30   Limestone.
30-35   Blue clay, hard layers.
```

Hole 41.   SW¼ SE¼ sec. 13,   T. 1 S., R. 14 W.;   500 feet west of Crooked
Creek; surface altitude: 312 feet.

```
Feet
0- 8    Sand and gravel.
8-17    Soft blue clay.
17-30   Limestone.
30-34   Blue clay.
```

Hole 42.   SE¼ SE¼ sec. 13,   T. 1 S., R. 14 W.;   300 feet east of Crooked
Creek; surface altitude: 312 feet.

```
Feet
0- 8    Sand and gravel.
8-15    Gravel.
15-28   Blue clay.
28-36   Limestone; bit lost in hole.
```

Hole 43. SE¼ SE¼ sec. 13, T. 1 S., R. 14 W.;   on bank of Crooked Creek;
           surface altitude: 312.5 feet.

                     Feet
                      0- 8 Gray clay.
                      8-16 Blue sticky clay.
                     16-27 Limestone.
                     27-30 Blue sticky clay.

Hole 44. SW¼ SE¼ sec. 13, T. 1 S., R. 13 W.; 800 feet east of Crooked
           Creek;·surface altitude: 317.5 feet.

                     Feet
                      0- 8 Sand and gravel.
                      8-13 Gravel.
                        13 Limestone.

Hole 45. NW¼ NE¼ sec. 24, T. 1 S., R. 14 W.; on bank of Crooked Creek;
           surface altitude: 314 feet.

                     Feet
                      0- 8 Sand and gravel.
                      8-15 Gravel.
                     15-28 Blue clay.
                     28-40 Limestone.
                     40-46 Blue clay.

Hole 46. NW¼ NE¼ sec. 24, T. 1 S., R. 13 W.; 50 feet west of Missouri
           Pacific Railroad; surface altitude: 316 feet.

                     Feet
                      0- 6 Sand and gravel.
                      6- 7 Sandrock.
                      7-40 Blue clay.

Hole 47. NE¼ NE¼ sec. 24, T. 1 S., R. 14 W.;· 800 feet east of Missouri
           Pacific Railroad; surface altitude: 330 feet.

                     Feet
                      0- 6 Sand and gravel.
                      6- 7 Sandrock.
                      7-40 Blue clay.

Hole 48. NE¼ NW¼ sec. 24, T. 1 S., R. 14 W.; 500 feet west of Missouri
           Pacific Railroad; surface altitude: 322 feet.

                     Feet
                      0- 8 Sand and gravel.
                      8-15 Gravel.
                     15-20 Blue clay.

Hole 49. NE¼ NW¼ sec. 24, T. 1 S., R. 14 W.; 350 feet west of Crooked
           Creek; surface altitude: 321 feet.

                     Feet
                      0- 5 Sand and gravel.
                      5-15 Sand.
                     15-20 Blue clay.

Hole 50. NE¼ NW¼ sec. 24, T. 1 S., R. 14 W.; 50 feet north of creek: surface altitude: 326 feet.

> Feet
> 0- 8 Sand and gravel.
> 8-16 Gravel.
> 16-30 Blue clay.
> 30-35 Limestone.
> 35-38 Blue clay.

Hole 51. NW¼ NW¼ sec. 24, T. 1 S., R. 14 W.; 25 feet west of county road; surface altitude: 345 feet.

> Feet
> 0- 8 Sand and gravel.
> 8-14 Gravel.
> 14-25 Blue clay.

Hole 52. NE¼ SW¼ sec. 13, T. 1 S., R. 14 W.; 25 feet west of county road; surface altitude: 330 feet

> Feet
> 0-10 Sand and gravel.
> 10-15 White soft limestone.
> 15-25 Blue clay.

Hole 53. SE¼ SE¼ sec. 14, T. 1 S., R. 14 W.; 600 feet north of county road, along dirt road leading to cemetery; surface altitude: 360 feet.

> Feet
> 0- 5 Sand and gravel.
> 5-40 Yellow clay.
> 40-52 Blue clay.

Hole 54. SE¼ NE¼ sec. 14, T. 1 S., R. 14 W.; 1,300 feet southeast of Hwy. 67; surface altitude: 365 feet.

> Feet
> 0- 5 Sand and gravel.
> 5-34 Blue marl.
> 34-39 Limestone.
> 39-48 Blue marl.

Hole 55. NW¼ NE¼ sec. 14, T. 1 S., R. 14 W.; 700 feet west of Hwy. 67; surface altitude: 360 feet.

> Feet
> 0- 6 Sand and gravel.
> 6-17 Yellow clay.
> 17-28 Blue marl.
> 28-32 Sand.

Hole 56. NW¼ SW¼ sec. 14, T. 1 S., R. 14 W.; 650 feet south of Hwy. 67; surface altitude: 410 feet.

```
Feet
0- 7   Sand and gravel.
7- 8   Gravel.
8-50   Blue marl.
```

Hole 57.   SW¼ SW¼ sec. 14, T. 1 S., R. 14 W.; on creek bank in southwest corner of section; surface altitude: 370 feet.

```
Feet
0- 7   Sand and gravel.
7-20   Sand.
20-52  Blue marl.
```

Hole 58.   SW¼ NE¼ sec. 15, T. 1 S., R. 14 W.; 25 feet north of road; surface altitude: 420 feet.

```
Feet
0- 9   Sand and gravel.
9-23   Yellow clay.
23-28  Blue marl.
28     Slate.
```

Hole 59.   SE¼ SW¼ sec. 15, T. 1 S., R. 14 W.; 800 feet north of Hwy. 67.

```
Feet
0-13   Sand and gravel.
13-19  Sand.
19-27  Yellow clay.
27-34  Blue clay.
34-43  Slate.
```

Hole 60.   SE¼ SW¼ sec. 15, T. 1 S., R. 14 W.; 100 feet north of Hwy. 67; surface altitude: 380 feet.

```
Feet
0- 8   Sand and gravel.
8-23   Blue clay.
```

Hole 61.   SW¼ SE¼ sec. 15, T. 1 S., R. 14 W.; south side of Hwy. 67; surface altitude: 380 feet.

```
Feet
0- 7   Sand and gravel.
7-16   Yellow clay.
16-19  Blue clay.
19-21  Gray limestone.
21-40  Blue marl.
```

Hole 62.   SW¼ SE¼ sec. 15, T. 1 S., R. 14 W.; on creek bank 300 feet east of Hwy. 67.

```
Feet
0- 6   Sand and gravel.
6- 8   Soft limestone.
8-21   Blue clay.
```

Hole 63. SW¼ SE¼ sec. 15, T. 1 S., R. 14 W.; 500 feet south of Hwy. 67.

Feet
0-10   Sand and gravel.
10-12 Hard limestone.
12-27 Blue clay.

Hole 64. SW¼ SW¼ sec. 22, T. 1 S., R. 14 W.; 900 feet east of road.

Feet
0- 5   Sand and gravel.
5- 7   Sandrock.
7-30   Blue marl.
30-31 Limestone.
31-40 Blue marl.

Hole 65. SW¼ NE¼ sec. 21. T. 1 S., R. 14 W.

Feet
0-15   Sand.
15-31 Yellow clay.
31-36 Gravel.
36-42 Yellow clay.

Hole 66. SW¼ SE¼ Sec. 17, T. 1 S., R. 14 W.

Feet
0-12   Gravel and clay.
12-49 Slate.

Hole 67. SW¼ NE¼ sec. 20, T. 1 S., R. 14 W.

Feet
0-10   Gravel.
10-12 Yellow clay.
12-14 Hard flint rock.

Hole 68. SW¼ NE¼ sec. 20, T. 1 S., R. 14 W.

Feet
0- 8   Gravel.
8-12   Yellow clay.
12-16 Slate.
16-17 Hard flint rock.

Hole 69. SE¼ SE¼ sec. 20, T. 1 S., R. 14 W.

Feet
0-12   Clay and gravel.
12-22 Yellow slate.
22-30 Blue slate.

Hole 70. SE¼ NE¼ sec. 29, T. 1 S., R. 14 W.

Feet
0- 6   Gravel.
6-10   Yellow clay.
10-14 Rotten slate.
14-22 Blue slate.

Hole 71. SE¼ NE¼ sec. 30, T. 1 S., R. 14 W.

Feet
0-15 Gravel.
15-34 Red sand.
34-36 Gravel.

Hole 72. NE¼ NE¼ sec. 31, T. 1 S., R. 14 W.

Feet
0-20 Gravel.
20-42 Red sand.
42-57 Yellow clay.

Hole 73. SE¼ NE¼ sec. 32, T. 1 S., R. 14 W.

Feet
0-10 Gravel.
10-24 Blue clay.
24-34 Limestone.

Hole 74. SW¼ SW¼ sec. 32, T. 1 S., R. 14 W.

Feet
0-44 Red sand.
44-62 Blue clay.

Hole 75. NE¼ NE¼ sec. 36, T. 1 S., R. 15 W.

Feet
0- 5 Sand.
5-12 Gravel.
12-20 Sand.
20-22 Limestone
22-32 Sand.
32-32½ Rock.

Hole 76. SW¼ NW¼ sec. 31, T. 1 S., R. 14 W.

Feet
0-10 Sand and gravel.
10-28 Yellow sand.
28-29 Limestone.
29-31 Sand.
31-32 Limestone.
32-42 Sand.
42-44 Rock.
44-46 Sand.

Hole 77. SE¼ NE¼ sec. 36, T. 1 S., R. 14 W.

Feet
0- 8 Gravel.
8-10 Limestone.
10-12 Sand.
12-13 Limestone.
13-18 Sand.
18-19 Limestone.

Feet
19-23   Sand.
23-24   Limestone.
24-26   Sand.
26-27   Limestone.
27-32   Sand.
32-33   Limestone.
33-35   Sand.

Hole 78.   SE¼ NE¼ sec. 36, T. 1 S., R. 15 W.

Feet
0-12   Sand.
12-14   Rock.
14-15   Limestone.
15-18   Sand.
18-19   Limestone.
19-24   Sand.
24-25   Limestone.
25-29   Sand.
29-30   Limestone.
30-36   Sand.
36-37   Limestone.
37-43   Sand.
43-45   Limestone.
45-48   Sand.

Hole 79.   E¼ SW¼ SW¼ sec. 31, T. 1 S., R. 14 W.

Feet
0-17   Sand and gravel.
17-21   Yellow clay.
21-42   White sand.
42-52   Red sand.

Hole 80.   SW¼ SE¼ sec. 36, T. 1 S., R. 15 W.

Feet
0- 3   Sand.
3- 4   Iron rock.
4-12   Blue clay.
12-14   Limestone.
14-18   Sand.
18-19   Limestone.
19-24   Sand.
24-26   Limestone.
26-33   Sand.

Hole 81.   NW¼ NE¼ sec. 1, T. 1 S., R. 15 W.

Feet
0- 5   Clay and sand.
5- 7   Black rock.
7- 9   Sand.
9-11   Limestone.
11-14   Sand.
14-16   Limestone.
16-22   Sand.

Feet
23-32 Sand.
32-33 Limestone.
33-38 Sand.

Hole 82. NW¼ NE¼ sec. 1, T. 2 S., R. 15 W.

Feet
0- 4 Sand.
4-38 Green clay.
38-40 Hard rock.

Hole 83. SW¼ NE¼ sec. 1, T. 2 S., R. 15 W.

Feet
0- 6 Sand.
6- 7 Sandrock.
7- 8 Sand.
8-10 Limestone.
10-12 Sand.
12-14 Limestone.
14-17 Sand.
17-18 Limestone.
18-24 Sand.
24-26 Limestone.
26-30 Sand.

Hole 84. SW¼ NE¼ sec. 1, T. 2 S., R. 15 W.

Feet
0- 8 Sand.
8-12 Gravel.
12-14 Iron rock.
14-15 Sand.
15-17 Soft limestone.
17-24 Sand.
24-25 Soft limestone.
25-31 Sand.

Hole 85. NW¼ SE¼ sec. 1, T. 2 S., R. 15 W.

Feet
0- 8 Sand.
8-16 Gravel.
16-24 Yellow clay.
24-38 Blue clay.

Hole 86. NW¼ SE¼ sec. 1, T. 2 S., R. 15 W.

Feet
0- 6 Sand and gravel.
6- 6½ Very hard rock.

Hole 87. NW¼ NE¼ sec. 12, T. 2 S., R. 15 W.

Feet
0- 8 Sand.
8-12 Gravel.

Feet
12-20 Blue clay.
20-21 Rock.
21-30 Blue clay.
30-31 Limestone.
31-34 Blue clay.
34-41 Limestone.
41-43 Sand.
43-46 Limestone.
46-48 White sand.

Hole 88. NW¼ NE¼ sec. 12, T. 2 S., R. 15 W.

Feet
0- 6 Sand.
6-14 Gravel.
14-46 Gray clay.

Hole 89. SE¼ NW¼ sec. 12, T. 2 S., R. 15 W.

Feet
0- 5 Sand.
5-14 Gravel.
14-32 Blue clay.
32-34 Rock.

Holes 90 to 102, inclusive, were drilled on property of State Hospital for Nervous Diseases, 4 miles southwest of Benton, in secs. 16, 17, 18, 19, 20, 21, 28, 29, 30, 31, and 32, T. 2 S., R. 15 W.

Hole 90. 650 feet east of western boundary of property and 800 feet north of southern boundary; 750 feet south of Hwy. 67.

Feet
0- 5 Sand and gravel.
5-10 Gravel.
10-42 Blue marl.

Hole 91. 225 feet east of western boundary and 750 feet north of southern boundary.

Feet
0- 5 Sand and gravel.
5-10 Yellow clay.
10-18 Dark clay.
18-21 Limestone.
21-40 Blue marl.

Hole 92. 1,500 feet east of western boundary of property and 1,000 feet south of Hwy. 67.

Feet
0-10 Sand and gravel.
10-13 Limestone.
13-42 Blue marl.

Hole 93. 400 feet east of hole 92.

                Feet
                0-10 Sand and gravel.
                  10 Porous limestone; hole could not be
                     completed.

Hole 94.   825 feet west of northwest corner of dairy plant.

                Feet
                0-12 Sand and gravel.
              12-14 Crumbly yellow stone.
              14-16 Soft yellow stone.
              16-28 Stone with yellow clay seams.
              28-40 Blue marl.

Hole 95.   1,300 feet east of western boundary of property and 825 feet south of Hwy. 67.

                Feet
                0- 8 Sand and gravel.
               8- 9 Sandrock.
               9-11 Dingy white stone.
              11-20 Yellow stone.

Hole 96.   1,800 feet east of western boundary of property and 1,900 feet south of northern boundary.

                Feet
                0- 5 Sand and gravel.
               5- 6 Slate.
               6-12 Yellow clay.
              12-13 Rock.
              13-20 Yellow clay.

Hole 97.   325 feet southwest of hole 96.

                Feet
                0- 6 Sand and gravel.
               6- 9 Brown stone.
               9-20 Yellow clay.

Hole 98.   350 feet east of western boundary and 2,700 feet south of northern boundary.

                Feet
                0- 4 Sand and gravel.
               4- 6 Gravel.
               6-20 Slate.

Hole 99.   325 feet west of cemetery in southern part of property.

                Feet
                0- 6 Sand and gravel.
               6- 9 Gravel.
               9-40 Yellow clay.

Hole 100.   500 feet southwest of dairy plant.

```
                        Feet
                        0- 6  Sand and gravel.
                        6- 7  Sandrock.
                        7-20  Yellow clay.
                          20  Porous yellow rock.
```

Hole 101. 1,800 feet east of western boundary of property and 100 feet
           south of Hwy. 67.

```
                        Feet
                        0- 5  Sand and gravel.
                        5- 7  Sandrock.
                        7-10  Gravel.
                        10-21  Gray clay.
                          21  Hard slate.
```

Hole 102. 50 feet south of Hwy. 67 where it crosses the western boundary
           of the property.

```
                        Feet
                        0- 6  Sand and gravel.
                        6- 9  Gravel.
                        9-28  Yellow clay.
```

Hole 103. NE¼ NW¼ sec. 16, T. 1 N., R. 12 W.; inside the city limits of
           Little Rock, 100 feet west of Chicago, Rock Island and Pacific
           Railway.

```
                        Feet
                        0- 3  Gravel.
                        3- 6  Yellow clay.
                        6- 7  Limestone.
                        7-16  Yellow clay.
                        16-17  Limestone.
                        17-23  Sand.
                        23-25  Limestone.
                        25-26  Sand.
                        26-29½  Limestone.
                        29½-31  Sand.
```

Hole 104. NE¼ NW¼ sec. 16, T. 1 N., R. 12 W.; inside the city limits of
           Little Rock; 100 feet west of Chicago, Rock Island and Pacific
           Railway.

```
                        Feet
                        0-11  Gravel.
                        11-29  Yellow clay.
                        29-31  Limestone.
                        31-33  Sand.
                        33-35  Limestone.
                        35-37  Sand.
```

Hole 105. NW¼ SW¼ sec. 20, T. 1 N., R. 12 W.; next to Missouri Pacific
           Railroad.

```
                        Feet
                        0-10  Sand and gravel.
                        10-12  Gravel; unable to finish hole.
```

Hole 106. SW¼ SW¼ sec. 20, T. 1 N., R. 12 W.; 300 feet southeast of Missouri Pacific Railroad.

        Feet
        0-10   Sand and gravel.
        10-20 Brown clay.
        20-45 Blue clay.

Hole 107. Center SE¼ sec. 19, T. 1 N., R. 12 W.

        Feet
        0- 5   Sand and gravel.
        5- 7   Gravel.
        7-12   Red clay.
        12-13 Hard sandrock.

Hole 108. NE¼ NE¼ sec. 25, T. 1 N., R. 13 W.; 400 feet northwest of Missouri Pacific Railroad.

        Feet
        0- 6   Hard rock; could not finish hole.

Hole 109. NE¼ SE¼ sec. 26, T. 1 N., R. 13 W.; 300 feet west of road.

        Feet
        0- 7   Sand and gravel.
        7-15   Blue clay.
        15-20 Hard rock.

Hole 110. NE¼ NW¼ sec. 36, T. 1 N., R. 13 W.; 200 feet south of road.

        Feet
        0-10   Sand and gravel.
        10-30 Brown clay.
        30-35 White clay.
        35-45 Blue clay.

Hole 111. NW¼ NE¼ sec. 36, T. 1 N., R. 13 W.; 400 feet northeast of junction of dirt road and Missouri Pacific Railroad.

        Feet
        0-10   Sand and gravel.
        10-25 Brown clay.
        25-50 Blue clay.

Hole 112. NW¼ NW¼ sec. 6, T. 1 S., R. 14 W.; 500 feet south of northwest section and 100 feet east of road.

        Feet
        0-10   Sand and gravel.
        10-43 Blue clay.

Hole 113. NE¼ NE¼ sec. 12, T. 1 S., R. 13 W.; 200 feet south of road.

        Feet
        0-10   Sand and gravel.
        10-40 Blue clay.

Hole 114. SW¼ SW¼ sec. 1, T. 1 S., R. 13 W.; 200 feet south of road.

```
              Feet
              0-10   Sand and gravel.
              10-20  Gray clay.
              20-40  Blue clay.
```

Hole 115. NE¼ NW¼ sec. 1, T. 1 S., R. 13 W.; 200 feet south of road.

```
              Feet
              0-10   Sand and gravel.
              10-35  Blue clay.
```

Hole 116. SW¼ NW¼ sec. 36, T. 1 N., R. 13 W.; 200 feet west of road.

```
              Feet
              0-10   Sand and gravel.
              10-13  Poor-grade limestone.
              13-25  Brownish-yellow clay.
                 25  Syenite.
```

Hole 117. SE¼ NE¼ sec. 35, T. 1 N., R. 13 W.; 100 feet south of road.

```
              Feet
              0-10   Sand and gravel.
              10-50  Blue clay.
```

Hole 118. NE¼ NE¼ sec. 35, T. 1 N., R. 13 W.; 500 feet west of creek and 300 feet north of road.

```
              Feet
              0-10   Sand and gravel.
              10-27  Brown clay.
              27-38  White clay.
              38-45  Red clay.
              45-50  Blue clay.
```

Hole 119. SE¼ NW¼ sec. 35, T. 1 N., R. 13 W.; 300 feet southeast of 90° bend in road.

```
              Feet
              0-10   Sand and gravel.
              10-30  Blue clay.
                 30  Hard rock.
```

Hole 120. NE¼ NE¼ sec. 2, T. 1 S., R. 13 W.; 150 feet south of base-line road.

```
              Feet
              0- 5   Sand and gravel.
              5- 6   Sandrock.
              6-20   Gray clay.
              20-45  Blue clay.
```

Hole 121. At halfway point on northern boundary of sec. 2, T. 1 S., R. 13 W.; 100 feet south of base-line road.

```
              Feet
              0- 9   Sand and gravel.
              9-18   Brown limestone (poor grade).
              18-28  Blue clay with layers of sand.
                 28  Hard crystal rock.
```

Hole 122. NE¼ SE¼ sec. 34, T. 1 N., R. 13 W.; 75 feet west of county road.

        Feet
        0-10 Sand and gravel.
      10-30 Blue clay.
         30 Hard rock.

Hole 123. 300 feet north of center of sec. 3, T. 1 S., R. 13 W.

        Feet
        0-18 Sandrock.

Hole 124. Center of sec. 3, T. 1 S., R. 13 W.; 350 feet north of road.

        Feet
        0-18 Sandrock; water would not stay in hole;
               could not be finished.

Hole 125. NW¼ SE¼ sec. 3, T. 1 S., R. 13 W.; 300 feet west of road.

        Feet
        0-10 Sand and gravel.
      10-20 Brown clay.
      20-30 Blue clay.

Hole 126. NE¼ SW¼ sec. 3, T. 1 S., R. 13 W.; east of county road.

        Feet
        0-10 Sand and gravel.
      10-27 Limestone; last 10 feet showed much white
               sand.

Hole 127. NW¼ SW¼ sec. 3, T. 1 S., R. 13 W.; 475 feet southeast of cemetery on county road.

        Feet
        0-10 Sand and gravel.
      10-14 Gravel.
      14-20 Blue clay.

Hole 128. SW¼ SE¼ sec. 4, T. 1 S., R. 13 W.; 900 feet north of county road.

        Feet
       0- 8 Sand and gravel.
       8-21 Blue clay.

Hole 129. NE¼ NW¼ sec. 9, T. 1 S., R. 13 W.; next to road running west from Mabelvale.

        Feet
       0- 8 Sand and gravel.
       8-10 White clay.
      10-24 Blue and brown clay.

Hole 130. NE¼ NW¼ sec. 9, T. 1 S., R. 13 W.; 300 feet west of dirt road.

Feet
0- 8 Sand and gravel.
8-18 Brown clay.
  18 White crystal rock.