OKLAHOMA GEOLOGICAL SURVEY

Robert H. Dott, Director

Mineral Report No. 2

PHOSPHATE

Compiled by

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NORMAN

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Mineral Reports:

No. 1, Volcanic Ash and Tripoli

No. 2, Phosphate

In Preparation:

Glass Sand

Limestone

Dolomite

Iron Ore

Asphalt

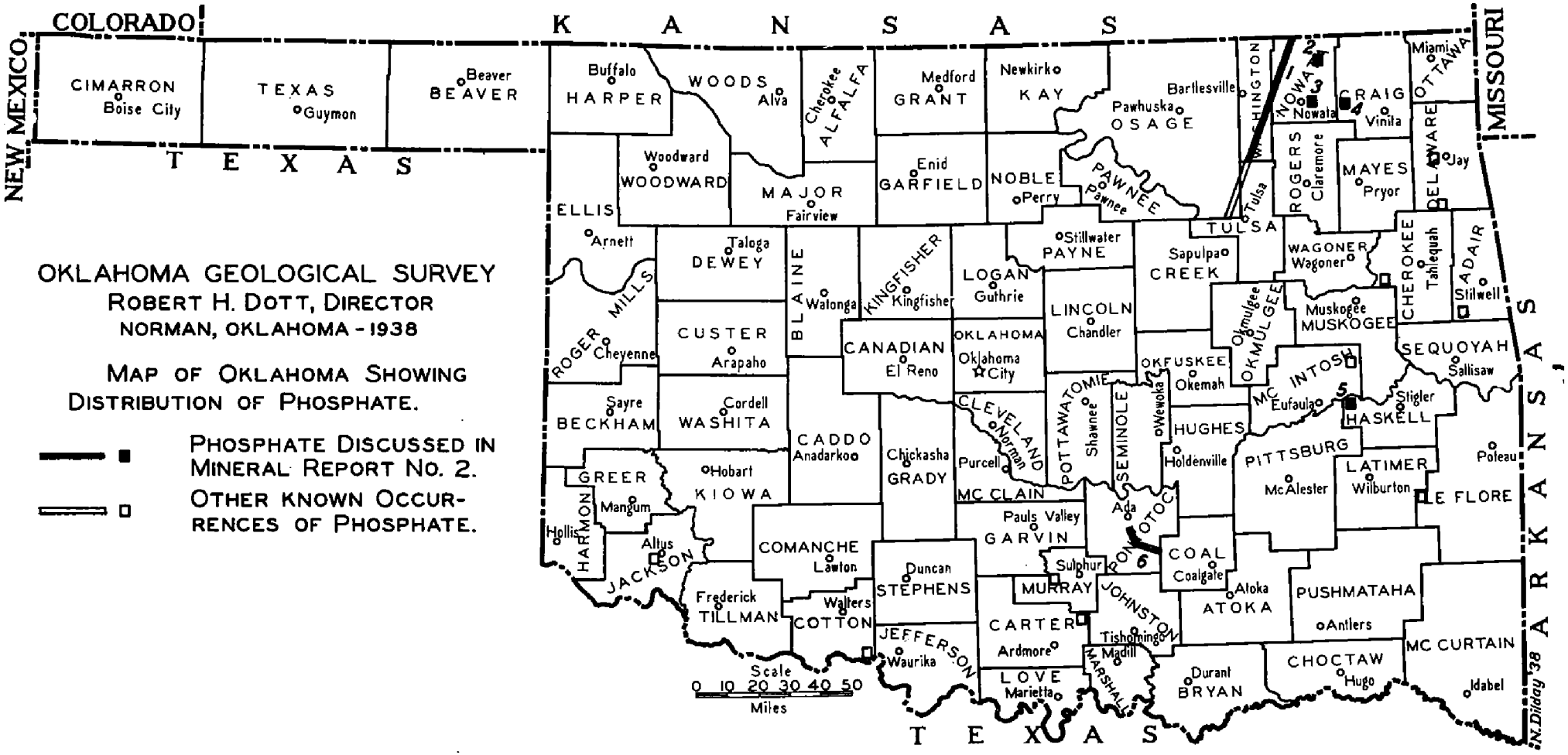
FOREWORD

The purpose of this report is to make available a summary of known data on occurrences of phosphate in Oklahoma. It is believed that a pamphlet giving brief descriptions of available materials, locations of known deposits in Oklahoma, and other data regarding them will serve a useful purpose. The information contained in this pamphlet is a compilation of data obtained in the course of field work done by members of the Survey staff, supplemented by information from private sources and from reports of the United States Geological Survey.

Small deposits of phosphate have been known in Oklahoma since early in the present century but have received little attention heretofore. Field investigations have been made recently and samples taken to extend our knowledge of the distribution, extent and character of Oklahoma phosphates. These investigations will be continued as opportunity permits. All analyses included in this report have been made in the chemical laboratory of the Survey.

Representative lots of the richer materials were collected by the Agricultural Experiment Station, of the Oklahoma A. and M. College, and applied to plots for growing tests during the summer of 1938. Owing to unfavorable conditions prevailing during spring and early summer, results to date are inconclusive. Several seasons are necessary to obtain definite results on such tests.

Additional details on many deposits of these materials are available in the offices of the Oklahoma Geological Survey; including numerous analyses of limestones and shales containing less than one-half of one percent P_2O_5, location, size, and availability of individual deposits, leads to deposits not yet investigated, etc. Persons interested in individual deposits may secure additional information, so far as it is available, by writing or visiting the Survey offices.



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ROBERT H. DOTT, DIRECTOR

NORMAN, OKLAHOMA - 1938

MAP OF OKLAHOMA SHOWING DISTRIBUTION OF PHOSPHATE.

PHOSPHATE DISCUSSED IN MINERAL REPORT NO. 2.

OTHER KNOWN OCCURRENCES OF PHOSPHATE.

OCCURRENCE OF PHOSPHATE

General

Phosphate of lime is most often found in the form of concretions. These are masses of spherical, oval, or "pancake" shape, and usually show concentric structure, being made up of layer on layer, as if the mass had grown by successive external additions of the material, each layer being of slightly different texture or color from preceding and succeeding layers. These masses are also called nodules. Often the "pancake" shapes are best described as "plates". Individual concretions vary in size from microscopic to masses weighing a ton or more. Phosphate deposits often resemble fish roe and many are described as "oolitic" or "sandy". Some deposits take the form of conglomerates composed of relatively large concretions cemented by finer-grained phosphate to form relatively pure phosphate beds. There are also beds of phosphatic limestone, marl, shale, and even sandstone, the phosphate being in the form of discernible nodules or so finely disseminated as to require chemical tests to distinguish the phosphatic from the non-phosphatic varieties. Phosphate itself, being white, takes on the color of its impurities, so that color is only a local guide to its recognition.

Typical occurrences of phosphate in Oklahoma:

(A) Phosphatic limestone in which the phosphate is in the form of discernible nodules or is finely disseminated. The outstanding example of this type is the basal bed of the Hogshooter limestone of northeast Oklahoma, which crops out from the Kansas line to Arkansas River west of Tulsa, and possibly beyond. It averages no more than one foot in thickness. It is a good agricultural limestone, averaging 90% or more of calcium carbonate, but is low in phosphate, containing only 0.5 to 2% P_2O_5. This bed might be ground locally and used as agricultural limestone, the phosphate adding to its value.

(B) Black fissile shale containing phosphatic nodules, thin plates and oolitic lenses. These are widespread in eastern Oklahoma and around the Arbuckle Mountains. In eastern Oklahoma it may prove feasible to concentrate the phosphatic material to make a product containing 20% or more P_2O_5. Nowhere in that area do the phosphatic nodules and plates appear to comprise over 10% of the entire volume of the shale units, so that if the shale and nodules were ground together the product would probably not contain more than 2% P_2O_5.

Around the Arbuckle Mountains, also, it may be found feasible to concentrate the plates and nodules, but the entire shale unit could probably be ground to make a product containing about 8% P_2O_5.

(C) Clay shales, in which the phosphate occurs as nodules or disseminated. Such shales have been found around the Arbuckle Mountains where they may be of economic value in connection with the fissile shales with which they are associated, and in southwest Oklahoma, where those found to date are too low in phosphate to be of practical value.

Known Occurrences

Known occurrences of phosphate discussed in this report fall into three general regions which are as follows, in the order of discussion: Northeast Oklahoma, East-Central Oklahoma and the Arbuckle Mountains region. Occurrences of phosphate are discussed in ascending stratigraphic order, only beds and formations directly associated with the phosphate being described.

The areas discussed are indicated on the accompanying map by numbered rectangles in solid black and are referred to in text and tables by corresponding area numbers. Open rectangles on the map indicate areas in which phosphate deposits are known to occur

but are not discussed in this report. In some of these the phosphate is of very low grade (less than 0.5%), in others the concentration is much higher but the deposits are too little known, too small in volume, or appear to be otherwise economically unmineable.

Northeast Oklahoma

The Ft. Scott limestone crops out in a belt one to ten miles wide from the Kansas line to Arkansas River, south of which it thins rapidly and soon disappears. Its outcrop crosses Craig, Nowata, Rogers, and Tulsa counties.

It is composed of: Feet

(1) Upper limestone, white, semi-crystalline and massive. Average thickness....20.0

(2) Black fissile shale, containing PHOSPHATIC concretions. Thickness usually...6.0

(3) Lower limestone, white, semi-crystalline and massive. Thickness usually about.....5.0

The writer has seen the black fissile shale in the park north of Oswego, Kansas; at a point where U. S. Highway 60 crosses the outcrop east of Nowata, Oklahoma, sec. 31, T. 26 N., R. 18 E; and where State Highway 20 crosses the outcrop in T. 21 N., R. 15 E., west of Claremore, Oklahoma. At all three places this shale contains phosphatic concretions of the type described under (B).

East of Nowata, 0.3 miles west of the NE cor. sec. 31, T. 26 N., R. 18 E., (Area No. 4), the black shale is 6 feet thick, and the nodules and plates are most abundant in the upper half. A representative sample of these contained 26.20% P_2O_5. West of Claremore the black shale is thinner and coaly and the nodules are much less abundant.

It seems that the black fissile shale in the Ft. Scott limestone may be fairly uniform, both in thickness and in its content of phosphatic nodules, from the Kansas line to some point south of Nowata, Oklahoma, and that localities may be found where conditions are suitable for exploiting the phosphate, at least for local use.

At the locality east of Nowata, the black shale crops out on a dip slope from which the upper member of the Ft. Scott limestone has been eroded, leaving fifty acres or more free from overburden. The nodules and plates, being more resistent than the enclosing shale, have accumulated in the soil and along the minor drainage channels on the outcrop. When uncovered so that they are exposed to freezing and thawing they are broken into small fragments, and for this reason are never found in large accumulations along the larger streams. The soil and the shale itself are the only sources from which the nodules may be obtained in any quantity.

When the unweathered shale is dug, the nodules break with the shale, making it difficult to separate them. It might be possible to mine this shale by steam shovel or otherwise, to spread it on the ground to weather, and later separate the nodules by screening and washing.

Coal for power is available on the ground from a coal seam about one foot thick which lies about six feet below the black shale, from which it is separated by the lower member of the Ft. Scott limestone. At present the coal is mined by stripping off the limestone around the edges of the black shale outcrop. The coal and the black shale with its phosphate nodules could be taken from one pit by first removing the shale and then the limestone.

The Pawnee limestone crops out widely on the headwaters of Big Creek and in a band from a half to two miles wide west of Big Creek, from the Kansas line

to Verdigris River. It crops out in a narrower band west of Verdigris River to the vicinity of Oologah, and thence southward to Broken Arrow.

The Pawnee limestone is composed of the following:

	Feet
(1) Upper limestone member 20 feet thick at the Kansas line but gradually thickening southward to 30 feet or more in southern Nowata County and 65 feet east of Tulsa. Average thickness.....	40.0
(2) Black fissile shale, containing PHOSPHATIC concretions. Maximum thickness.....	12.0
(3) Lower limestone member hard, gray and partly crystalline. Thickness.....	6.0

The writer has seen the black shale member in one locality only, along U. S. Highway 60, east of Nowata, Oklahoma, in T. 26 N., Ranges 16 and 17 E. (Area No. 3). There the shale is 3 feet thick and contains an abundance of black phosphatic nodules and plates of the type described in (B). It is best exposed east of the Verdigris River but even there it is usually covered by about 3 feet of the upper limestone member which forms dip slopes on the hilltops. A representative sample of the nodules and plates from the south side of the road in the NW cor. sec. 32, T. 26 N., R. 17 E. contained 32.68% P_2O_5.

Owing to the wider exposures farther north it is hoped that areas may be found where the upper limestone member has been removed by erosion, leaving the black shale better exposed for winning the phosphate. If such exposures are found this shale has possibilities similar to those of the black shale in the Ft. Scott limestone, already described.

The Hogshooter limestone crops out from the Kan-

sas line southward across Nowata, Washington, Tulsa, Creek, and Okfuskee counties, to a point west of Okemah. Its outcrops are generally narrow except in T. 26 N., where it forms outliers east of Hogshooter Creek. It attains a maximum thickness of 26 feet on Hogshooter Creek in sec. 9, T. 26 N., R. 14 E. but is thinner both north and south of this point. Outside of Twps. 26 and 27 N. the entire thickness is seldom more than 12 feet and over much of the area of its outcrop from the Kansas line to Arkansas River it is less. The greater part of the Hogshooter is made up of gray to buff-colored limestone carrying a few crinoid stems, brachiopods and other fossils. A dark crinoidal bed which contains phosphatic concretions, or nodules, is always present at the base. It is usually one foot or less in thickness, but on the back of the school ground in Ramona it is $4\frac{1}{2}$ feet thick.

The Hogshooter has been mapped from the Kansas line to Arkansas River, and samples were taken for analysis. Available analyses seem to indicate that all of the Hogshooter is good agricultural limestone (above 90% $CaCO_3$), but the phosphate is confined to the lower, dark, crinoidal, nodular bed. Consequently the only places where it appears practical to mine phosphatic limestone, are along the outcrop of this basal bed. The most suitable places are on the dip slopes where the higher beds have been nearly or completely removed by erosion. Such places have been mapped and sampled with more than usual care, (see data on Washington and Nowata counties in the tabulation of analyses at the end of this report). This basal bed may be unusually valuable as an agricultural limestone if the contained phosphate proves to be available to growing crops.

Two localities near Brooken, (Area No. 5) in Haskell County, were visited by the writer and A. H. Hanson, Of Muskogee, Oklahoma, in October, 1937. The first is in the $SW\frac{1}{4}$ sec. 8, T. 9 N., R. 18 E. on unalloted land west of an abandoned clearing known locally as "the old Munn field". Ten feet west of the field fence is a bank of black fissile shale contain-

ing phosphatic nodules and plates. A representative sample of these contained 20.72% P_2O_5. Two hundred feet farther west across a draw, is an old pit, with a dump composed of shale and a small amount of hard granular shale, which contained 13.74% P_2O_5.

The second locality visited is 1,200 feet south of the NE cor. sec. 5, T. 9 N., R. 18 E. where there is an exposure of what appears to be the same black shale. This shale is possibly 50 feet thick and forms the lower part of an escarpment capped by the Bluejacket (?) sandstone. In the lower part of this shale is a five-foot bed containing phosphatic nodules and plates, which make up about 5% of its volume. Two representative samples of the material showed 23.08% and 23.68% P_2O_5. About twenty feet higher is a nodular shale bed 0.3 feet thick, dark brown to black in color, granular in texture and rather soft, which contained 12.82% P_2O_5.

Arbuckle Mountains Area

The Woodford formation crops out around the margin of the Arbuckle Mountains area in Pontotoc, Murray, Carter, and Johnston counties, and consists of black shales and interbedded chert. It lies unconformably on the Hunton limestone and is overlain by the Sycamore limestone on the south side of the Arbuckle Mountains and south of Davis, and by the Welden limestone on the Lawrence Uplift, south of Ada.

The best description of the Woodford formation is given by Taff, 1/ who says:

"The Woodford chert has an estimated average thickness of 650 feet. It varies somewhat in lithologic character. In places massive chert rests upon the limestone (Hunton); in other places black shale

1/ Taff, J. A., "The Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma": Okla. Geol. Survey Bull. 12, 1928. (Reprint of U. S. Geol. Survey Prof. Paper 31.)

occurs at the base of the formation. As a rule, however, the formation becomes less cherty from the base upward. It is usually even-bedded, occurring in layers from a few inches thick to thin laminae. In places, especially in the northeast side of the uplift, the formation is composed almost entirely of thin, fissile, siliceous and distinctly bituminous black shale. ****At various positions in the section, especially in the more cherty beds, are small, rounded, marble-like concretions of a calcareous nature. In places there are large segregations of a similar character, concentrically banded, which occur intersecting several layers of cherty shale."

According to Reeds 2/, "The small round nodules in the black to gray Woodford shale and chert contain phosphate. *******Owing to the sporadic occurrence of these nodules, it is believed, however, that the amount of phosphate present is very small."

Shead 3/ states: "The writer has found such material (phosphate nodules) concentrated in about six or eight inches of greenish-yellow clay at the contact between the Sycamore limestone and the underlying Woodford chert where the phosphate is of maximum purity and may be most easily obtained. Similar material occurs immediately under the Welden limestone southeast of Ada, Oklahoma. At this location, specifically in the A. T. & S. F. R.R. cut slightly east of the center of sec. 27, T. 3 N., R. 6 E., are to be found very thin, light gray phosphatic layers intercalated among the laminated shales below the Welden."

The writer has recently made some study of the

2/ Reeds, Chester A.; "A Report on the Geological and Mineral Resources of the Arbuckle Mountains of Oklahoma": Okla. Geol. Survey Bull. No. 3, p. 60, 1910.

3/ Shead, A. C., Associate Professor of Chemistry, University of Oklahoma: (No. 2, Oklahoma Chemical Survey Series, Chemistry Dept., University of Oklahoma, unpublished).

phosphate in the Woodford formation but the work is by no means complete. Phosphate occurs at several horizons wherever the Woodford is exposed, but the only one so far investigated in any detail is that described in the quotation from Shead. The greater part of the work has been done on the Lawrence Uplift southeast of Ada in Tps. 2 and 3 N., R. 6 E. Only cursory examination has been made of other localities which are in general, less suitable for winning the phosphate on account of their more cherty character and the steep dip of the beds, which in places is vertical.

On the Lawrence Uplift the beds dip rather gently to the northeast forming several dip slopes which could be stripped to advantage. Judging from several exposures along roads, there is generally a band of residual phosphatic material a foot thick and about sixty feet wide around the weathered edge of the Welden limestone. This residual material is composed of the nodules and thin plates or beds described below, and is to be found about a foot below the surface.

The following section is relatively uniform across the Lawrence Uplift:

Feet

(1) Welden limestone, weathers to a bright yellow, contains a few crinoid stems, non-phosphatic. Thickness..... 1-4

(2) Light-colored shale with a band of flat, light-colored, PHOSPHATIC nodules near the middle, and a hard, light-colored, granular PHOSPHATIC bed $\frac{1}{2}$ to 2 inches thick, at the bottom. Thickness..... 1.0

(3) Black fissile shale with spherical to flat PHOSPHATIC nodules, somewhat lighter colored than the shale, and thin laminae or beds of granular PHOSPHATIC material, also somewhat lighter colored than the shale. Thickness... 2.0 to 3.0

Feet

(4) Black shale bedded in layers $\frac{1}{4}$ to $\frac{1}{2}$ inch thick in which the PHOSPHATE seems to be disseminated, or possibly in the form of microscopic nodules, contains about 8.0% P_2O_5. Thickness.... 2.0

The percentage of phosphate decreases downward abruptly to a fraction of one percent. This section is shown graphically at three locations, with analyses, in figure 1.

There are three possibilities for developing the phosphate on the Lawrence Uplift.

First, the band of residual plates and nodules around the outcrop of the Welden limestone could be readily scooped up and cleaned by screening and washing. The resulting material would be relatively high grade, suitable for grinding for use as rock phosphate or even for the manufacture of super-phosphate. The supply, however, is rather limited and would soon be exhausted. From such scanty data as are at hand the writer estimates that the ultimate recovery would be between 1,500 and 3,000 long tons, averaging more than 20% P_2O_5.

Second, it may prove feasible to concentrate the plates and nodules from the bedded material to make a product similar to that above.

Third, the bedded material 4 to 5 feet thick below the Welden limestone could be mined and ground to make a low grade rock phosphate containing 7 to 8% P_2O_5 which might be suitable for local use.

CONCLUSIONS

While no large deposit of phosphate suitable for commercial exploitation has been found in Oklahoma, some material has been found that may prove to be valuable. The nodules in the black shales of Northeast Oklahoma might be separated by local labor and used

with the sulphuric acid available from the smelters of that section to make acid phosphate for local use. The basal bed of the Hogshooter limestone may prove to be useful as a combined rock phosphate and agricultural limestone and, if so, should be of decided value to the communities in which it is suitably situated for mining. The bed of phosphatic shale, 5 feet or more in thickness, which lies in the top of the Woodford formation and crops out on the northeast flank of the Arbuckle Mountains, may be useful as a low grade rock phosphate and, if so, could be prepared by local enterprise for use in that section of the state. It also may be possible to develop a process for concentrating the phosphate from this bed, thereby reducing bulk and transportation costs and making it available over a wider area, or even for the manufacture of superphosphate.

Information on deposits of low grade phosphate (less than 0.5%) from many areas not listed here is on file at the Geological Survey. Other deposits show much higher concentrations, but are too little known, too small in volume, or appear to be otherwise economically unmineable and are therefore not considered in this report. These are located in Adair, Carter, Cherokee, Cotton, Craig, Delaware, Haskell, Jackson, LeFlore, McIntosh, Murray, Nowata, Osage, Pontotoc, and Washington counties.

The combined area of known phosphate occurrences aggregate a very small percentage of the total area of Oklahoma, so that actually, little is known about the possibilities. Enough leads have been found to show that accumulations of phosphate are widespread and it is possible that other deposits, suitable at least for local use, may be discovered.

COLUMNAR SECTIONS WITH ANALYSES
Woodford Formation
Pontotoc County
Area No. 5

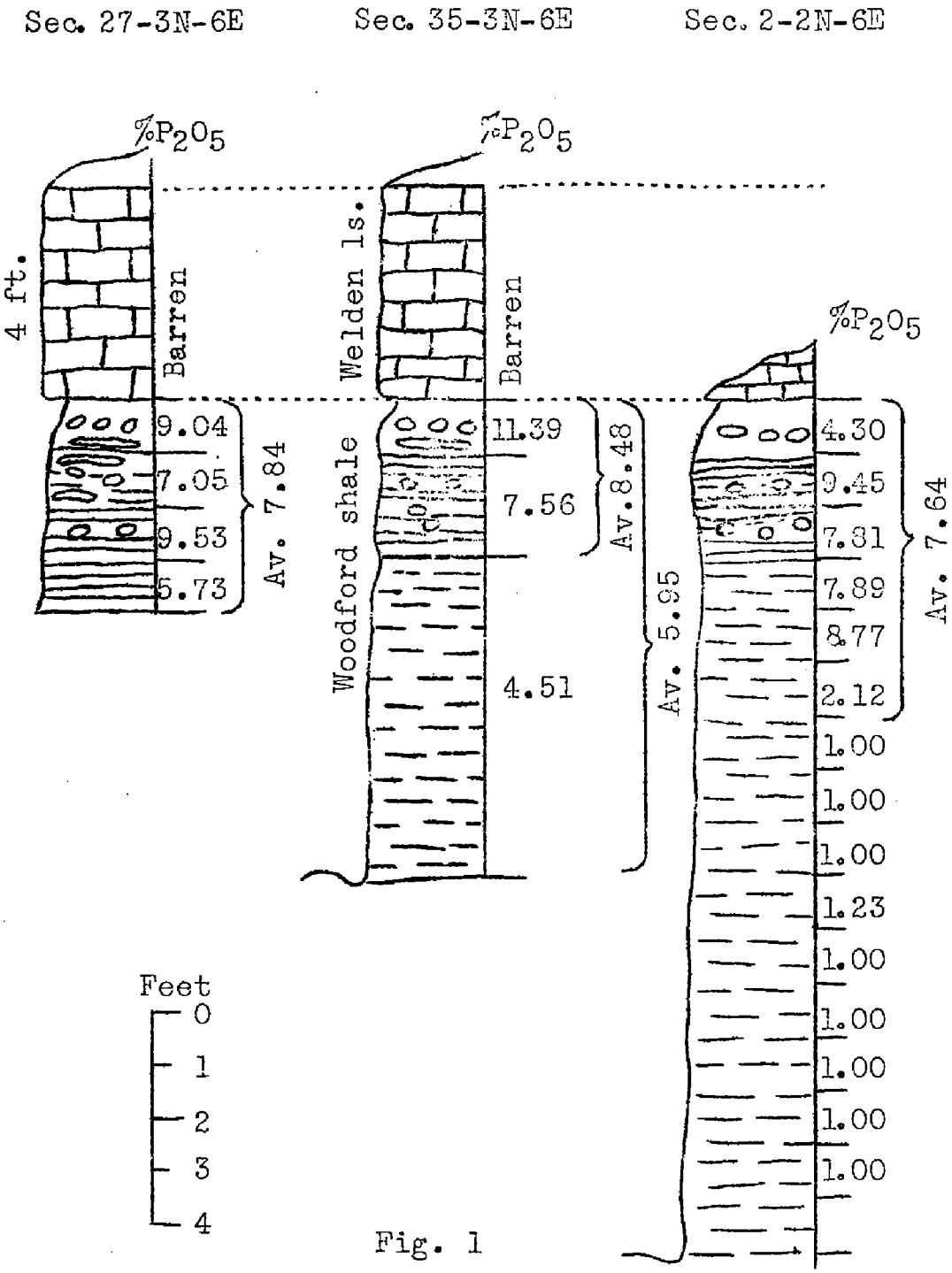

Fig. 1

PHOSPHATE ANALYSES
BY COUNTIES

The table on the following pages was compiled from analyses made in the chemical laboratory of the Oklahoma Geological Survey. Analyses showing less than 0.5% P_2O_5 are omitted, as well as others much higher in P_2O_5, if the deposits are too little known, too small in volume, or appear to be otherwise economically unmineable, and therefore are not considered in this report. Data on these latter are in the files of the Oklahoma Geological Survey, at Norman, and may be consulted by anyone interested.

TABLE I

Lab. No.	Percent P_2O_5	CaO	MgO	Area No.	Sec.	Twp.	Range	Character, Thickness, etc.
					CRAIG COUNTY			
7280	26.20			4	31	26N	18E	Nodules from the black shale in the Ft. Scott ls. A sample of nodules from this bed at Oswego, Kansas, contained 26.76% P_2O_5.
					HASKELL COUNTY			
7294	13.74			5	8	9N	18E	Hard granular shale from an old pit; Boggy formation.
7295	20.72			5	8	9N	18E	Nodules and plates from a dark fissile shale; Boggy formation.
7290	23.68			5	5	9N	18E	Concretions from black shale; Boggy formation.

7291	23.08			5	5	9N	18E	Same as 7290 taken from shale in place.
7292	12.82			5	5	9N	18E	Soft, dark, granular shale 0.3 ft. thick.
					NOWATA COUNTY			
6885	0.76	49.55	0.80	1	15	26N	14E	Basal bed of Hogshooter.*
7261	1.52	44.77	0.76	1	31	27N	15E	Basal bed of Hogshooter.
7266	0.81	46.00	0.92	1	18	27N	15E	Basal bed of Hogshooter.
6895	1.11			1	12	26N	14E	Basal bed of Hogshooter.
6899	0.79	47.25	1.42	1	14	26N	14E	Basal bed of Hogshooter.
6903	0.65	46.80	1.46	1	22	26N	14E	Basal bed of Hogshooter.
5845	2.31	42.09		1	30	27N	15E	Basal bed of Hogshooter.

* A dark crinoidal bed which contains phosphatic concretions, always present at the base of the Hogshooter limestone.

Table I (continued)

Lab. No.	Percent P_2O_5	CaO	MgO	Area No.	Sec.	Twp.	Range	Character, Thickness, etc.
7279	32.68			3	32	26N	17E	Nodules from shale in Pawnee limestone.
7281	28.94			3	35	26N	16E	Nodules from shale in Pawnee limestone.
6110	33.70			2	25	28N	15E	Nodules from shale above Checkerboard ls. (very small area).
					PONTOTOC COUNTY			
7378-80	5.95			6	35	3N	6E	Average of 9 ft. of Woodford shale next below the Welden limestone.
7364-68	7.64			6	2	2N	6E	Average of 5 ft. of Woodford shale next below the Welden limestone.

7383-85	4.12			6	1	1N	6E	Average of 3 ft. of Woodford shale, probably upper 3 ft.
7386	27.55			6	27	3N	6E	Nodules from soil along outcrop of top of Woodford.
7387-90	7.84			6	27	3N	6E	Average of 4 ft. of Woodford shale next below the Welden limestone.
7391	24.46			6	34	3N	6E	Nodules from soil along outcrop of top of Woodford.
				WASHINGTON COUNTY				
7257	2.06	44.43	1.13	1	34	25N	13E	Basal bed of Hogshooter.*
7260	1.29			1	34	25N	13E	Basal bed of Hogshooter.
6887	1.67	47.25	0.80	1	20	26N	14E	Basal bed of Hogshooter.
6888	2.15	48.63	0.24	1	21	26N	14E	Basal bed of Hogshooter.
6900	1.80			1	9	26N	14E	Basal bed of Hogshooter.

* A dark crinoidal bed which contains phosphatic concretions, always present at the base of the Hogshooter limestone.

Table I (continued)

Lab. No.	Percent P_2O_5	CaO	MgO	Area No.	Sec.	Twp.	Range	Character, Thickness, etc.
7263	1.79	45.20	1.14	1	10	24N	13E	Basal bed of Hogshooter.*
7268	1.32	48.27	0.94	1	28	24N	13E	3.0 feet of basal Hogshooter.
7269	1.10			1	28	24N	13E	1.5 feet of basal Hogshooter above 7268, this is the thickest observed occurrence of this bed, total thickness 4.5 feet.
6901	0.43	48.50	1.34	1	33	26N	14E	Basal bed of Hogshooter.
7272	0.77	42.06	1.12	1	34	24N	13E	Basal bed of Hogshooter.
7274	0.78	46.83	1.18	1	16	24N	13E	Lower 3 ft. of Hogshooter.
6106	3.70			1	34	24N	13E	Basal Hogshooter in railroad cut at Ramona.

* A dark crinoidal bed which contains phosphatic concretions, always present at the base of the Hogshooter limestone.