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ILMENITE IN ALLUVIAL SANDS OF THE WICHITA MOUNTAIN SYSTEM, OKLAHOMA

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ILMENITE IN ALLUVIAL SANDS OF THE WICHITA MOUNTAIN SYSTEM. OKLAHOMA

By Gerald W. Chase

ABSTRACT

The occurrence of ilmagnetite (ilmenite intergrown in magnetite) in Pre-Cambrian gabbroic rocks of the Wichita Mountain system, and in Recent alluvial sands derived from them, has been previously reported. The recent discovery in the Pre-Cambrian rocks of small amounts of free ilmenite, valuable as a source of TiO_2, led to the present investigation of potential ilmenite deposits in the alluvial sands.

Seventy-one samples from major intermittent stream channels and samples from 13 test holes in an ancient filled channel were investigated. Plagioclase feldspar, orthoclase feldspar, quartz, augite, ilmenite, and ilmagnetite were found in varying amounts, and were separated for study by standard sink-float and magnetic methods.

Most of the present-day alluvial sands have no commercial possibilities as a source of ilmenite, as free ilmenite is rare or absent. Ilmagnetite ranged from 0 to 27.78 percent by weight of the sands, but contains only 2.8 to 17.8 percent TiO_2, and thus appears to have little value as a source of titanium dioxide at the present time.

A potentially economic deposit of ilmenite was discovered by drilling on the north shore of Lake Lawtonka, where an ancient stream channel of Medicine Creek was filled with approximately 180,000,000 cubic feet of sand that contains 3.4 to 6.8 percent ilmenite. The drilled part of the deposit is 9 to 25 feet thick and is covered by a soil overburden 4 to 16 feet thick. The deposit is at least 1 mile long and about three-fourths of a mile wide. The ilmenite concentrates from this sand deposit contain 44.12 percent TiO_2. The ilmenite particles range in size from 20 to 170 mesh, 70 percent being between the 20 and 60 mesh screens. From the 13 holes drilled it is estimated that the deposit contains approximately 370,000 short tons of ilmenite.

Undrilled parts of the deposit beneath Lake Lawtonka together with the bottom sediments of the lake probably will increase the known reserve materially.

INTRODUCTION

Purpose of report. The presence of ilmenite occurring as intergrowths in magnetite has been known in alluvial deposits of the Wichita Mountains for a number of years, but little information was available as to details of occurrence and possibilities of exploitation as an ore. Gabbroic rocks cropping out in the area were known to contain ilmenite-magnetite intergrowths, and recent field work by the writer has resulted in the discovery of free ilmenite. Sediments derived from these rocks are thus a possible source of commercial deposits of ilmenite.

The investigation on which this report is based was undertaken to determine whether deposits of ilmenite-bearing sands have sufficient volume to offer economic possibilties. Studies also were made to determine the nature of the sands and their mode of occurrence, as a guide to future prospecting and possible exploitation.

Location of area. The area investigated is in northwest Comanche County and east-central Kiowa County of southwestern Oklahoma (Fig. 1), and includes the Wichita, Quanah, and Raggedy Mountain groups of the Wichita Mountain system.

The western part of the area is served by the Enid, Oklahoma, to Vernon, Texas, branch of the Frisco Railroad (St. Louis-San Francisco Railway) which connects the town of Roosevelt with the surrounding territory. The eastern part of the Wichita Mountains is served by the branch of the Rock Island Railroad (Chicago-Rock Island-Pacific Railway) that connects Lawton with Anadarko and Waurika, Oklahoma.

Previous investigations. The occurrence of black sand in the alluvial deposits of the Wichita Mountain system was first mentioned in a report by Captain Marcy[1] in 1854. The presence of massive magnetite in these mountains was noticed by Vaughan[2]

1. Marcy, R. B., "Exploration of the Red River of Louisiana in the Year 1852": *U. S. 33rd Congress, 1st Session*, Senate Ex. Doc., p. 158, 1854.
2. Vaughan, T. W., "Geological Notes on the Wichita Mountains, Oklahoma, and Arbuckle Hills, Indian Territory": *Am. Geologists*, Vol. 24, pp. 44-46, 1899.

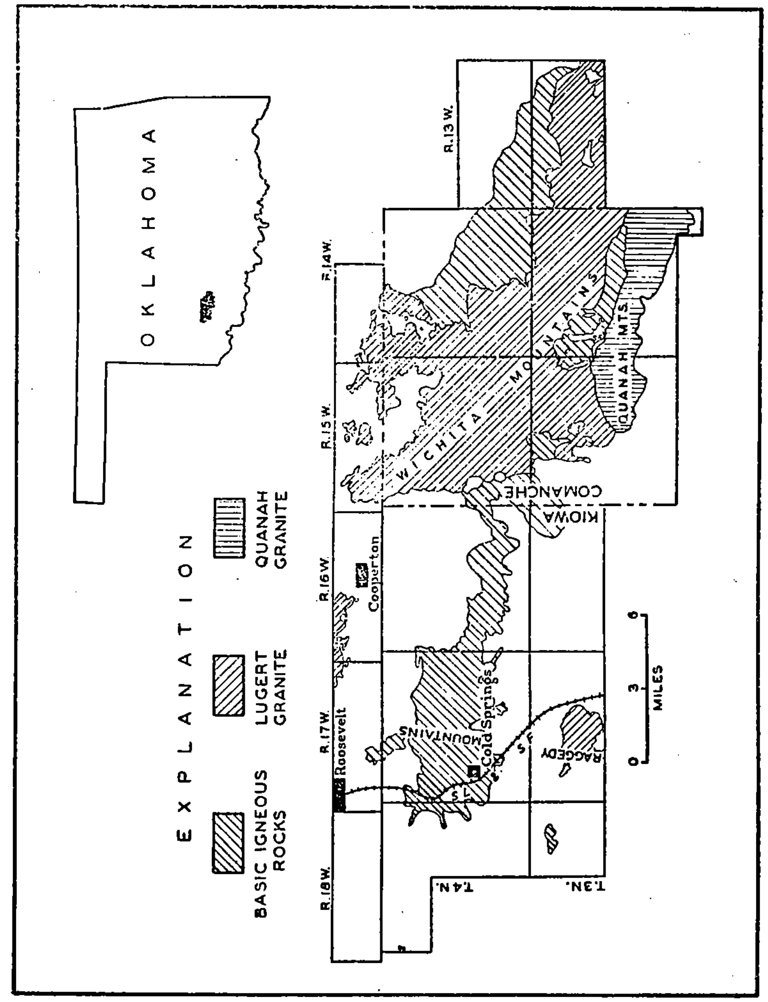


FIG 1. Generalized geologic map of eastern part of Wichita Mountain system, modified after C. H. Taylor, Okla. Geol. Survey Bull. 20, 1915. Ruled areas, Pre-Cambrian igneous rocks; blank area, Permian red beds.

in 1898 and specimens were examined by Spencer.[3] It was not until the investigation of the iron ores by Merritt[4] that the presence of ilmenite in the Wichita Mountains was established. Merritt's purpose was to study the sands and deposits of primary magnetite as a possible source of iron ore. His work revealed the presence of ilmenite intergrown in the magnetite, which is a serious detriment to its use as an iron ore. No studies were made of ilmenite as potential ore.

Present investigation. The investigation of the alluvial sands in the Raggedy, Wichita, and Quanah Mountain groups was started in 1949. Sand samples were collected from all streams whose head waters originated in the gabbro hills of Kiowa and Comanche Counties. These samples were examined to learn whether free ilmenite occurs in the stream sediments and to trace this mineral back to potential ore deposits in the country rock contributing it. No commercial deposits in alluvial sands were found in this phase of the investigation.

The second phase of this work was an investigation of alluvium-filled valleys to evaluate the possibilities of commercial concentrations of ilmenite-bearing sands. One deposit near Lake Lawtonka was found by drilling to have commercial possibilities.

Acknowledgments. The writer wishes to express his appreciation to officials of the City of Lawton and individual land owners along the north shore of Lake Lawtonka for permission and cooperation given for drilling on their property, and to Jerry Soukup for his interest and valuable assistance during the drilling of test holes.

The interest and advice given by Paul Allen of National Lead Company and J. L. Gillson of E. I. du Pont de Nemours and Company are appreciated, and chemical analyses and samples furnished by National Lead Company were found to be of great value during this investigation.

Plates and figures for this report were drafted by R. E. Owen, W. G. Williams, and Mrs. Virginia R. Kelting; parts of the mineral separations were made by Mitat Y. Tolgay, and chemical analyses were by A. L. Burwell, to whom thanks are extended.

3. Spencer, A. C., "Report upon Rocks of the Wichita Mountains," in T. W. Vaughan's "Geological Notes on the Wichita Mountains, Oklahoma, and Arbuckle Hills, Indian Territory": *Am. Geologists*, Vol. 24, pp. 47-48, 1899.

4. Merritt, C. A., "Iron Ores of the Wichita Mountains, Oklahoma": *Econ. Geology*, Vol. XXXIV, pp. 268-286, 1930.

Geography

Topography. East-central Kiowa County contains a number of disconnected hills composed of anorthosite that rise to a maximum height of 450 feet above the surrounding plains. These hills are part of what Taff[5] called the Raggedy Mountain group (Fig. 1). They trend southeast and extend into northwest Comanche County, where the igneous rocks are of both granitic and gabbroic types. The hills in Comanche County are divided into (1) the Wichita Mountain group and (2) the Quanah Mountain group, composed mostly of granitic rocks. These mountains reach a maximum height in the eastern part of the Wichita Mountain group where Mount Scott rises 1,130 feet above Lake Lawtonka. The top of Mount Scott is 2,480 feet above sea level.

The hills in Kiowa County are rounded and have gentle slopes whereas those in Comanche County have steep slopes and sheer cliffs 200 to 300 feet high. These igneous hills are surrounded by a Permian red bed plain.

Drainage. The drainage system of the area is composed of intermittent streams that, with the exception of a few water holes, are dry during all but the spring and fall rainy seasons. Elk Creek, Otter Creek, Glen Creek, and Dry Otter Creek (Plate I) make up the main drainage in the Raggedy Mountain group and flow southward as tributaries of the North Fork of Red River.

The Wichita and Quanah Mountain groups are drained by three main intermittent drainage systems. Sugar Creek, the main stream in the northwest part of the Wichita Mountain group, flows northward as a tributary of Washita River. Medicine Creek flows southeastward along the northern flank of the Wichita Mountain group, and is the principal drainage basin for Lake Lawtonka. Sandy Creek, Post Oak Creek, Rock Creek, and West Cache Creek drain the southern half of the Wichita and Quanah Mountains and flow southward to the North Fork of Red River.

5. Taff, J. A., "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma": *U. S. G. S. Prof. Paper* 31, 1904; reprinted as *Oklahoma Geological Survey Bulletin* 12, pp. 57-59, 1928.

Climate. Kiowa and Comanche Counties have a dry subhumid climate.[6] The average annual mean temperature as recorded by U. S. Weather Bureau observers[7] is 60.4° F. in the United States Wildlife Refuge and 61.2° F. at Hobart, Oklahoma. The summer months of July and August have the highest temperatures (Table I). The normal annual precipitation is 30.94 inches in the U. S. Wildlife Refuge and 27.97 inches at Hobart. The greatest rainfall occurs during the month of May (Table II).

TABLE I
AVERAGE MONTHLY TEMPERATURE IN DEGREES FAHRENHEIT AT THE U. S. WILDLIFE REFUGE AND HOBART, OKLAHOMA

Month	U. S. Wildlife Refuge	Hobart
January	39.0	39.0
February	42.9	40.5
March	51.3	52.2
April	60.5	60.8
May	67.5	69.0
June	76.5	78.3
July	81.1	83.1
August	80.9	82.6
September	73.2	75.0
October	61.6	63.0
November	49.7	50.1
December	40.1	40.4

TABLE II
AVERAGE MONTHLY PRECIPITATION AT U. S. WILDLIFE REFUGE AND HOBART, OKLAHOMA

Month	U. S. Wildlife Refuge	Hobart
January	0.97	0.86
February	1.20	1.00
March	1.72	1.53
April	3.29	3.01
May	4.32	4.25
June	3.64	3.54
July	2.40	1.96
August	3.05	2.48
September	3.21	2.78
October	3.20	3.83
November	1.96	1.51
December	1.46	1.22

The average annual rate of evaporation[8] from April, 1937, to October, 1947, at Lawton, Oklahoma, is 53.9 inches.

6. Thornthwaite, C. W., "Atlas of Climatic Types in the United States, 1900-1939": *U. S. Dept. Agri. Misc. Pub.* 421, Pl. 3, 1941.
7. "Climatological data, Oklahoma, annual summary, 1950": U. S. Weather Bureau, Vol. LIX, No. 13, 1951. (Source of all climatological data cited.)
8. "Evaporation data for Oklahoma stations": *U. S. Dept. of Commerce, Weather Bureau,* Oklahoma City, May 25, 1948.

GENERAL GEOLOGY OF WICHITA MOUNTAINS

STRATIGRAPHY

The Pre-Cambrian igneous rocks exposed in the Wichita Mountains are flanked by a series of folded Cambrian and Ordovician sedimentary rocks. All these are surrounded by red beds of Permian age and are locally covered by unconsolidated Quaternary sediments (Table III).

PRE-CAMBRIAN

The oldest rock in the region is the Meers quartzite,[9] which occurs as inclusions in the gabbro and granite. The Raggedy Mountain group is composed of anorthosite that grades downward into augite gabbro. These two rock phases are cut by later intrusion of olivine gabbro which contains the major portion of the ilmenite and magnetite, as small pegmatite dikes and irregularly shaped bodies.

The Wichita Mountain group is made up primarily of the Lugert granite which rests as a sill-like body on gabbro and the Carlton porphyry. The contact phase of this granite with the gabbro ranges from a few inches to several feet in thickness and contains ilmenite both as intergrowth in magnetite and as crude euhedral crystals. The Quanah granite makes up a major part of the Quanah Mountain group and rests in a sill-like position on the Lugert granite. All the igneous rocks are cut by pegmatites and quartz veins.

CAMBRIAN AND ORDOVICIAN

The major exposures of the Cambrian and Ordovician sedimentary rocks occur on the north flank of the Wichita Mountain group in the physiographic province referred to as limestone hills by Taff.[10]

9. Hoffman, M. G., "Geology and Petrology of the Wichita Mountains": *Oklahoma Geological Survey Bulletin* 52, 1930.
10. Taff, J. A., "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma": *U. S. Geological Survey, Prof. Paper* 31, 1904; reprinted as *Oklahoma Geological Survey Bulletin* 12, pp. 60-62, 1928.

TABLE III
Generalized Chart of Rocks Exposed in the Eastern Part of Wichita Mountain System

Sedimentary Rocks			
Period	Epoch or rock group	Thickness (feet)	Lithology
Quaternary	Recent	0-40	Alluvium containing ilmenite and ilmagnetite
	Pleistocene	0-60	Gravel terrace deposits, volcanic ash
Permian	Undifferentiated	?	Red shale, conglomerate, and sandstone
Ordovician	Arbuckle group	2218-3243	Limestone, dolomite
Cambrian	Timbered Hills group	44-400	Limestone, dolomite, sandstone

Igneous and Metamorphic Rocks		
	Rock unit	Lithology
Pre-Cambrian	Pegmatite dikes with aplite phases	Granite pegmatites containing zircon and riebeckite
	Quanah	Pink, medium to coarse-grained riebeckite granite
	Lugert	Pink, medium to fine-grained leucogranite
	Carlton	Pink to red rhyolite porphyry
	Microdiorite dikes	Black fine-grained diorite containing traces of ilmenite and ilmagnetite
	Olivine gabbro	Black to pinkish-gray, coarse-grained gabbro containing small segregations of ilmenite and ilmagnetite
	Augite gabbro	Black to dark gray, coarse-grained gabbro containing small amount of ilmenite and ilmagnetite
	Anorthosite	Light gray medium to fine-grained labradorite-bytownite rocks containing traces of ilmenite and ilmagnetite
	Meers quartzite	Black to nearly white medium-grained quartzite occurring as xenoliths in gabbro and Lugert granite

The larger part of the Cambrian sediments fall within the Timbered Hills group[11] and the basal members, where exposed, rest on the Carlton porphyry. The Cambrian rocks are composed of limestones, dolomites, and sandstones, and some of the sandstones locally contain a glauconite or hematite cement.

The upper part of the Cambrian and all the Lower Ordovician sediments are in the Arbuckle group and consist of a thick series of limestones.

PERMIAN

Most of the Permian rocks surrounding the mountains are composed of red shale. On the north side of the Raggedy and Wichita Mountain groups, the Permian shale is interbedded with thin layers of limestone, and on the south side the shale is interbedded with thin beds of arkosic sandstone and limestone. Some of these sandstones contain lenses of ilmenite and magnetite as much as 2 inches thick.

QUATERNARY

Deposits of Quaternary age are present in the area as high terraces of Pleistocene age and in the streams and valleys as alluvium of Recent age.

Most of the Pleistocene gravel terraces within the mountains have been removed by Recent erosion and only small local areas still contain remnants of these gravels. Most of the gravel terraces of this age are found south and west of the Raggedy Mountain group.

The Recent sediments occur as alluvium in the ancient stream channels and valleys and, on the north side of the Wichita Mountains, as talus materials which fill some of the valleys. Otter Creek, a major intermittent stream in the western part of the area, has cut and filled its channel south of the Raggedy Mountain group over a width of 1 mile and for a distance of 5 miles between Mountain Park and Cold Springs. This body of Recent sediments ranges from a few feet to 50 feet in thickness. Medicine Creek

11. Decker, C. E., "Progress Report on the Classification of the Timbered Hills and Arbuckle Groups of Rocks, Arbuckle and Wichita Mountains, Oklahoma": *Oklahoma Geological Survey Circular 22*, 1939.

on the north flank of the Wichita Mountain group has deposited a large amount of sediments in the lower reaches of its channel and in some places these sediments have a thickness of 35 to 40 feet. The Recent sediments form a thin cover concealing a large part of the igneous rocks of the area.

STRUCTURE

The orogeny producing the Wichita Mountains began in early Pennsylvanian time and continued into Permian time. The igneous rock composing the basement was thrust upward, forming a group of shatter fault blocks, whereas the overlying Paleozoic sediments were thrown into folds and distorted fault blocks. Numerous horsts and grabens were formed by this faulting.[12]

12. Harlton, B. H., "Faults in Sedimentary Part of Wichita Mountains of Oklahoma": *Amer. Assoc. Pet. Geol. Bull.*, Vol. 35, pp. 988-999, 1951.

ECONOMIC GEOLOGY OF ILMENITE-BEARING SANDS

NATURE AND USES OF ILMENITE

Ilmenite is a ferrous titanate and has the theoretical formula $FeTiO_3$. The extreme variations in chemical composition of this mineral as given by Dana[13] are partly reproduced in Table IV.

TABLE IV
VARIATIONS IN CHEMICAL COMPOSITION OF ILMENITE

TiO_2	48.64	52.66	54.20
FeO	41.76	47.34	42.85
MgO	0.88		2.58
MnO	1.10		
Fe_2O_3	5.57		
Rem	1.66		

Ilmenite ranges in color from iron-black to brownish black and has a metallic to sub-metallic luster. The specific gravity ranges from 4.5 to 5. The mineral is very stable under normal weathering conditions. It occurs in basic igneous rocks generally associated with magnetite, or as detrital sand grains in beach sands derived from such rocks. Ilmenite in basic igneous rocks normally occurs intergrown with magnetite, and the separation of these two minerals by mechanical means is not commercially feasible. In a few places, where ilmenite and magnetite occur in intrusive bodies which chilled rapidly, the ilmenite is not entirely intergrown with the magnetite and may be mechanically separated.

The largest sources of ilmenite in this country are from Pre-Cambrian ilmenite-magnetite deposits such as at Tahawus, New York, and from beach sands such as those found along the coast of Florida and in Los Angeles County, California. The largest supplier of ilmenite to the United States is India, from beach sands at Travancore.

The average percent TiO_2 in ilmenite concentrates shipped from some localities around the world are given by Taggart.[14]

13. Palache, E.; Berman, H.; and Frondel, C., "Dana's System of Mineralogy," 7th Edition, Vol. I, p. 537, *John Wiley and Sons*, New York, 1944.
14. Taggart, A. F., "Handbook of Mineral Dressing Ores and Industrial Minerals": College Edition, pp. 2-241, *John Wiley and Sons*, New York, 1945.

TABLE V
PERCENT TITANIUM DIOXIDE IN ILMENITE CONCENTRATES FROM DIFFERENT LOCALITIES IN THE WORLD

Location	Percent TiO_2 in Ilmenite Concentrates
Roseland, Va.	54
Piney River, Va.	48-50
Travancore, India	50-53
Brazil	52.7
Norway	42-43
Tahawus, New York	44

Ilmenite is the major source of titanium dioxide, which is industrially important as a white pigment that is widely used in the manufacture of paint, paper, floor coverings, coated fabrics and textiles, and rubber. Titanium dioxide also is used in alloys and as a carbide, in welding-rod coatings, and in ceramics.

The metal titanium, derived from titanium dioxide, has highly desirable properties and has been produced in the United States on a small scale since 1948. A promising future is expected for this metal and for new alloys that are currently being developed.

Consumption of ilmenite in the United States for the period 1941-1949 is shown in Table VI.[15]

TABLE VI
CONSUMPTION OF ILMENITE IN THE UNITED STATES, 1941-1949, IN SHORT TONS

Year	Short tons
1941	275,106
1942	257,535
1943	302,822
1944	360,941
1945	381,178
1946	401,283
1947	479,524
1948	565,000
1949	510,608

The most recent consumption data are for 1951, given as follows by Allen[16]: "Further expansion of the titanium pigment industry in 1951 called for still greater production of ilmenite which

15. *U. S. Bureau of Mines*, "Minerals Yearbook, 1949," p. 1224.
16. Allen, P. W., "Titanium": *Mining World*, Vol. 14, No. 5, p. 54, April 15, 1952.

reached a record total of about 483,000 gross tons. An additional 164,000 gross tons of ilmenite were received from Indian sources. Other foreign countries supplied minor quantities. The total ilmenite available in the United States was, therefore, about 650,000 gross tons, but pigment plant demands were such that stockpiles of ilmenite had to be depleted to some extent."

Last available prices for ilmenite are those given by Meyer[17] for 1949: "The average quotation per gross ton for ilmenite containing 56-59 percent TiO_2, f.o.b. Atlantic seaboard, dropped from \$18-\$20, according to grade and impurities, on January 1 to \$16-\$18 in early October, to \$15-\$17 late in that month, and further to \$14-\$16 in the first half of November."

Since 1949 there has been an apparent increase in prices, although quotations are no longer published.

METHODS OF THIS INVESTIGATION

Field sampling. Two types of sampling were employed during the investigation, one consisting of sampling alluvial sands along stream channels and the second in collecting samples from test holes drilled in alluvium-filled valleys.

The samples from stream channels were collected on sand bars where obstructions were not present upstream from the bars for distances of 300 yards, as any obstructions would have resulted in at least partial deposition of heavy minerals in the lee of the obstructions. Samples of about 25 pounds were taken from the down-stream end of the bars, where the heavy mineral concentrations were the greatest. Where a tributary entered the main stream, samples were collected above and below the mouth of the tributary. In a few places banks of the streams were sampled to ascertain the percentage of heavy minerals in the soil.

The boring of test holes in old stream channels was first undertaken with a hand-operated basket auger, but was unsuccessful as the sands were saturated with water and the samples escaped from the auger before they could be brought to the surface. Sampling with a portable rotary drilling unit was more successful. The

17. Meyer, Helen M., "Titanium": *Eng. & Min. Jour.*, Vol. 151, No. 2, p. 96, Feb. 1950.

test holes were drilled one foot at a time, each foot of sample being collected by stopping the bit's rotation and continuing water circulation until all sand or clay particles had been recovered. The next foot was then drilled and the same procedure repeated. Two of the test holes drilled in these sands were failures, owing to the coarseness of the sands whose lack of cohesion permitted the walls of the holes to cave in before the test could be completed. The material recovered from each foot of test hole was split to obtain a 15 pound sample which was sent to the laboratory for further studies.

Methods of mineral separation. The sand samples were air dried in the laboratory and quartered on a Jones sample splitter until a sample weighing approximately 100 grams was obtained. The samples were composed of ilmenite, ilmagnetite, augite, plagioclase feldspar, orthoclase feldspar, and quartz, and were separated by the sink-float method recommended by Krumbein and Pettijohn.[18] Parts of the separation were made by Mitat Y. Tolgay, graduate student at the University of Oklahoma, under supervision of the author.

The sands were placed in bromoform (Sp. Gr. 2.89), in which quartz, orthoclase, and plagioclase feldspars were separated from the the heavy minerals by floating. This light fraction was further separated by using bromoform whose gravity was adjusted with acetone to just float orthoclase feldspar and yet allow quartz and plagioclase feldspar to sink. The heavy mineral fraction was placed in Clerici's solution (Sp. Gr. 4.2-32° C.) which floated augite and allowed ilmenite and ilmagnetite to sink. Ilmagnetite was then removed magnetically from ilmenite. All fractions of like minerals were combined from each one-foot sample to form a composite. These composite fractions representing each separate mineral were sieved to determine their size frequency distribution in the sands.

Identification of minerals. The magnetic and nonmagnetic fractions of the opaque minerals were identified by chemical analysis,[19] and the silicate minerals were identified by their indices

18. Krumbein, N. C., and Pettijohn, F. J., "Manual of Sedimentary Petrography": pp. 319-356, *Appleton-Century-Crofts Company*, New York, 1938.
19. Chase, G. W., Reed, R. R., and Burwell, A. L., "Analytical Procedure for the Determination of Titanium and Iron in Titaniferous Ores": *Oklahoma Acad. Sci. Proc.*, Vol. XXX, pp. 131-134, 1949.

of refraction, using the oil immersion method with a petrographic microscope.

The chemical analyses were made in the laboratory of the Oklahoma Geological Survey by A. L. Burwell, industrial chemist of the Oklahoma Geological Survey, or under his supervision.

MINERAL COMPOSITION OF THE ALLUVIAL SANDS

The alluvial sands in the Wichita Mountains contain plagioclase feldspar, orthoclase feldspar, quartz, augite, ilmagnetite, ilmenite, and traces of zircon, olivine, and leucoxene. There is a wide range in composition of the sand deposits throughout the mountains owing to the differences in composition of the country rock in different areas.

The plagioclase feldspar in the sands is dark gray to black and ranges in composition from An_{56} to An_{74}. The specific gravity of the feldspar is near 1.70. The alluvial sands contain 10 to 50 percent of this mineral.

Orthoclase feldspar is light pink to red and contains intergrowths of quartz and magnetite. The outer part of some of the feldspar crystals contain a larger percentage of hematite than the inner part, a feature that can be easily detected under the microscope. The incorporation of the iron in the feldspar prevents its removal by acid treatment.

Quartz contains numerous inclusions of magnetite and some riebeckite. In a few locations needle-like crystals of rutile were noted in the quartz, but in general this occurrence is rare. Quartz sand forms 20 to 40 percent of the alluvium.

Augite is dark gray, black, greenish black, and bronze and has a pearly to metalloidal luster. This mineral occurs as cleavage fragments in the alluvial sands. In the field, where the sands are moist, the augite can be easily mistaken by its color and specific gravity for ilmagnetite or ilmenite. The augite is most abundant in alluvial sands of the Raggedy Mountains and especially along Glen Creek. This mineral has a specific gravity of 3.4-3.5 and has a microscopic schiller structure owing to inclusions of numerous red to brownish-red tabular plates. Some of the optical properties of the augite are shown in Table VII.

TABLE VII
OPTICAL PROPERTIES OF AUGITE FROM ALLUVIAL SANDS IN WICHITA MOUNTAIN SYSTEM

Z ∧ c	Dispersion	Optical Sign	Birefringence	α	β	γ
44°	ρ > v	+	.026	1.697	1.703	1.723
43°	ρ > v	+	.026	1.694		1.720
42°	ρ > v	+	.026	1.690		1.716
40°	ρ > v	+	.026	1.684		1.710

Ilmagnetite is dull black to brownish black and has a metallic luster. These black sand grains are composed of ilmenite plates 0.1 mm wide intergrown in magnetite. The plates of ilmenite are easily recognized under the microscope by their blue-black color and narrow plate-like appearance in the magnetite. The TiO_2 in the ilmagnetite ranges from 2 to 17 percent, depending on the amount of ilmenite intergrowth.

Ilmenite is blue black, has a bright metallic luster, and occurs in the sands as flat plates and as crude euhedral crystals. The specific gravity of the ilmenite is 4.7 and the mineral is weakly magnetic. A thin coating of leucoxene was observed on a few of the ilmenite sand particles.

SAMPLES FROM STREAM CHANNELS

Samples of alluvial sands from eight major intermittent streams show ilmenite to be present in only two streams. Streams containing no ilmenite or only a trace were Dry Otter Creek, Deep Red Creek, Sandy Creek, Post Oak Creek, Rock Creek, and West Cache Creek. These streams drain the southern part of the Wichita and Quanah Mountain groups and head in granite hills. Such ilmenite as was found in samples collected from these streams (Plate I) is intergrown with magnetite showing there has been no natural separation of the two minerals (Table VIII, Nos. 15-46).

GLEN CREEK

Glen Creek in Kiowa County flows southwestward through the eastern half of T. 4 N., R. 17 W. and was the first stream chosen for study, as the black sands are in greater concentration in this stream than in any other. The stream heads near Iron Mountain in sec. 7, T. 4 N., R. 16 W. where irregular zones of magnetite

occur in gabbro. The stream flows southward through sec. 14, T. 4 N., R. 17 W., passing over a body of hornblende-olivine-magnetite rock.

Samples 1 to 14 (Plate I) were collected along Glen Creek at half mile intervals. The results of studies made on these samples are shown in Table VIII. The heavy mineral fractions of the sand samples contain 26 to 58 percent augite and 2 to 16 percent ilmagnetite with free ilmenite not present.

The ilmagnetite sand grains contain ilmenite intergrown along the octahedral planes of the magnetite as long flat plates, which are so locked with the magnetite that stream abrasion does not separate the two minerals.

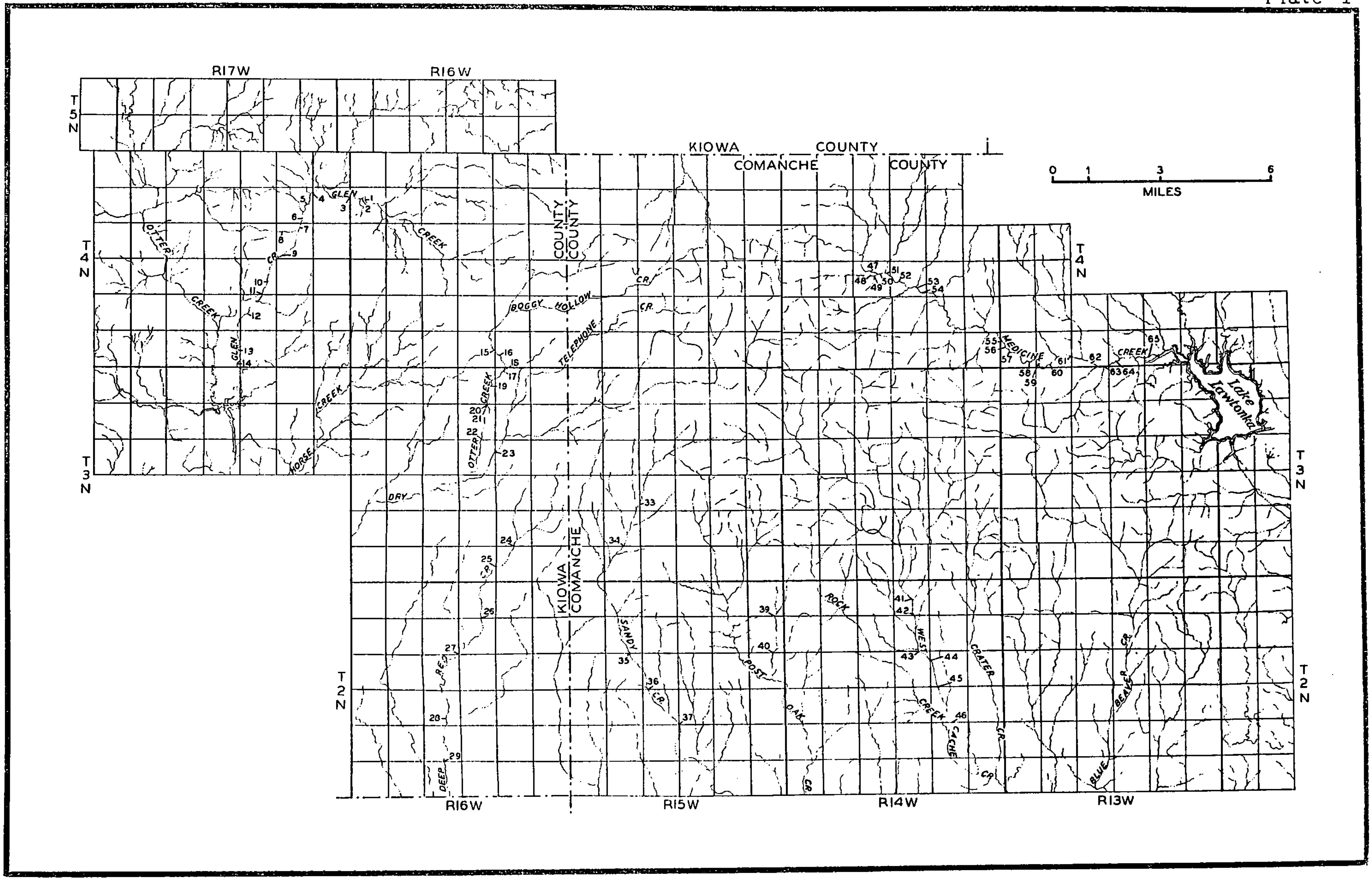
The augite and ilmagnetite are contributed to the alluvial sediments from the weathered gabbro that crops out in the drainage system. The anorthosite and granite of the area contribute to the sands of Glen Creek a very small amount of ilmagnetite but no ilmenite or augite.

MEDICINE CREEK

Medicine Creek, in Comanche County, flows eastward along the northern flank of the Wichita Mountain group through T. 4 N., Rs. 14 and 13 W., forming the main drainage basin for Lake Lawtonka. Sediments contributed to the stream come from weathered gabbro and granite exposed in the area.

Samples 47 through 61 (Plate I) were collected from the alluvial deposits in the upper reaches of the stream channels, and studies show that ilmenite is absent or present only as a trace in the heavy mineral fraction (Table VIII). Samples 62 to 65 contain free ilmenite in small quantities, indicating contribution from a local source.

Examination of the sands occurring in the road ditch on the east side of Mount Sheridan, and samples of alluvial sand from beneath the Medicine Creek bridge south of the Meers Post Office, revealed the presence of ilmagnetite and ilmenite in nearly equal amounts. The chemical analyses of these heavy mineral fractions, after removal of the augite, are given in Table IX.



Map showing location of alluvial stream samples.

TABLE VIII

HEAVY MINERALS IN ALLUVIAL STREAM DEPOSITS OF THE WICHITA MOUNTAIN SYSTEM, IN WEIGHT PERCENT

Sample Number (see Fig. 2)	Laboratory Number	Total Heavy Minerals	Augite	Free Ilmenite	Ilmagnetite	Partial Analysis of Ilmagnetite*	
						TiO_2	Fe_2O_3
1	9705	44.86	36.10	none	8.76	7.5	59.3
2	9706	58.0	38.92	none	19.16	2.8	86.7
3	9707	37.7	26.60	none	11.10	7.0	76.0
4	9708	56.84	48.84	none	8.0	17.8	71.7
5	9709	45.4	39.00	none	6.3	10.0	62.1
6	9710	66.0	58.60	none	7.30	10.1	76.4
7	9711	69.74	47.28	none	22.40	14.1	76.2
8	9714	62.38	45.78	none	16.60	16.01	70.5
9	9715	49.96	36.58	none	13.38	16.01	72.6
10	9716	42.58	30.84	none	11.74	3.5	90.2
11	9717	38.32	25.58	none	12.74	9.6	78.06
12	9718	0.53		none	0.01	11.8	52.4
13	9719	36.14	26.28	none	9.86	9.3	66.6
14	9720	72.18	44.40	none	27.78	12.1	78.3
15	9736	1.32	0.3	none	1.22		
16	9737	3.26	1.5	none	1.76		
17	9738	4.05	2.0	none	2.0		
18	9739	1.1	1.0	none	0.4		
19	9740	1.82	1.4	none	0.58		
20	9741	0.0	0.0	none	0.0		
21	9742	6.00	2.7	none	3.28		
22	9743	3.92	1.4	none	2.50		
23	9744	3.26	0.9	none	2.36		
24	9752	1.42	0.1	none	1.28		
25	9751	0.5	0.5	none	trace		
26	9750	0.14	0.14	none	trace		
27	9746	0.22	0.22	none	trace		
28	9745	3.52	0.1	none	3.38		
29	9809	1.9	1.9	none	trace		
30	9810	0.24	0.21	none	trace		
31	9811	1.3	1.3	none	trace		
32	9812	0.01	0.01	none	trace		
33	9754	4.3	1.1	none	3.1		
34	9753	5.1	2.0	none	3.0		
35	9756	0.26	0.26	none	trace		
36	9757			none	trace		
37	9755	1.38	0.5	none	0.86		
38	9758	3.64	0.8	none	2.78		
39	9760	0.06	0.06	none	trace		

* Analyses by A. L. Burwell and G. W. Chase.

TABLE VIII—(Continued)

HEAVY MINERALS IN ALLUVIAL STREAM DEPOSITS OF THE WICHITA MOUNTAIN SYSTEM, IN WEIGHT PERCENT

Sample Number (see Fig. 2)	Laboratory Number	Total Heavy Minerals	Augite	Free Ilmenite	Ilmagnetite	Partial Analysis of Ilmagnetite*	
						TiO_2	Fe_2O_3
40	9759	0.32	0.32	none	trace		
41	9819	0.46	0.46	none	trace		
42	9818	0.62	0.62	none	trace		
43	9817	0.52	0.52	none	trace		
44	9816	1.3	1.3	none	trace		
45	9815	0.08	0.08	none	trace		
46	9814	0.1	0.1	none	trace		
47	9881	4.48	3.5	none	1.3		
48	9882	9.5	7.6	none	1.8		
49	9883	8.4	6.2	none	2.2		
50	9884	21.0	16.7	none	4.5		
51	9885	11.0	9.3	none	1.7		
52	9886	5.84	4.9	none	0.8		
53	9887	5.6	4.6	none	1.0		
54	9888	8.6	7.3	none	1.3		
55	9838	28.82	28.82	none	23.4		
56	9840	15.1	12.3	none	2.74		
57	9837	11.6	10.94	none	2.64		
58	9836	17.5	14.0	none	3.50		
59	9835	18.36	13.72	none	4.74		
60	9834	14.0	11.6	none	2.46		
61	9833	15.78	12.8	none	2.9		
62	9832	24.0	20.4	trace	3.6		
63	9831	18.24	16.7	trace	3.4		
64	9829	27.54	21.54	trace	6.0		
65	9841	27.6	21.8	trace	5.7		
66	9889	21.4	18.8		2.6		
67	9890	0.2					
68	9891			trace			
69	9892			trace			
70	9839	33.54	26.0		7.5		
71	9830	17.8	15.6		2.0		

66 — Sand sample from stream in Center NW¼, NW¼, NE¼, sec. 26, T. 4 N., R. 14 W.
67 — Sand sample from stream in NW¼, NE¼, NE¼, NE¼, sec. 25, T. 4 N., R. 14 W.
68 — Soil sample from stream bank NW¼, SE¼, SE¼, sec. 22, T. 4 N., R. 14 W.
69 — Soil sample from stream bank NE¼, NW¼, NW¼, SW¼, SE¼, sec. 22, T. 4 N., R. 14 W.
70 — Sand from stream bed, Center sec. 36, T. 4 N., R. 14 W.
71 — Sand from stream bed NE¼, SW¼, SW¼, sec. 34, T. 4 N., R. 13 W.

* Analyses by A. L. Burwell and G. W. Chase.

TABLE IX
CHEMICAL ANALYSIS OF ILMAGNETITE AND ILMENITE FROM WICHITA MOUNTAINS

	9761A	9761B	C
Fe	60.9	33.9	34.0
TiO_2	13.8	42.8	44.0
V_2O_3	0.6	0.16	

9761A —Magnetic (ilmagnetite) heavy mineral fraction from sand in road ditch on east side of Mount Sheridan. A. L. Burwell, analyst.
9761B —Nonmagnetic (ilmenite) heavy mineral fraction from sand in road ditch on east side of Mount Sheridan. A. L. Burwell, analyst.
C —Ilmenite fraction from alluvial sand collected beneath the Medicine Creek bridge south of Meers Post Office. Analysis by National Lead Company.

Examination of the gabbro forming the lower part of Mount Sheridan and surrounding the Meers quartzite disclosed a small amount of free ilmenite in these basic rocks. Deterioration by weathering of these rocks allows the ilmagnetite and ilmenite to be released and transported with other sediments down Medicine Creek, as far as Lake Lawtonka.

ALLUVIUM-FILLED VALLEYS

Following the discovery of free ilmenite in the alluvial sands of Medicine Creek a search was begun to find a filled valley or basin in which a large body of these ilmenite-bearing sediments might have been deposited.

LAKE LAWTONKA DEPOSIT

The most promising area appeared to be around Lake Lawtonka, which was created as a water reservoir for the City of Lawton by damming Medicine Creek in the northern part of sec. 18, T. 3 N., R. 12 W. The lake covers parts of secs. 6, 7, 8, and 18, T. 3 N., R. 12 W.; the eastern half of sec. 1, T. 3 N., R. 13 W.; and parts of secs. 35 and 36, T. 4 N., R. 13 W. It is a catch basin for sediments carried by that part of Medicine Creek located above the lake (Plate II).

Along the north shore of Lake Lawtonka is a flat area that antedates the lake. This area was chosen for test drilling because it apparently was a site of deposition for sediments brought down in fairly recent geologic time by Medicine Creek, and is easily accessible to drilling equipment. Thirteen test holes were drilled in the area, covering the S½ of sec. 36, T. 4 N., R. 13 W.; SW¼ sec. 31, T. 4 N., R. 12 W.; and NE¼ NE¼ sec. 1, T. 3 N., R. 13 W. The locations of these test holes are shown in Fig. 2 and the logs of each hole are recorded in Table X. All test holes except K, H, Q, and L encountered a layer of ilmenite-bearing sands.

Geology as determined by test drilling. An isopach map (Fig. 2) compiled from logs of the test holes shows that the ilmenite-bearing sands fill a northwest-trending valley or channel and range in thickness from 10 to 25 feet. The soil and clay overlying this sand ranges in thickness from 4 to 16 feet, and three-fourths of the area of the sand has a soil cover of only 4 to 6 feet (Fig. 3).

As determined by drilling, the original channel of this stream is at least three-fourths of a mile wide and has a northeast trend through the western half of sec. 36, T. 4 N., R. 13 W. to the center of the section, where it abruptly assumes a southeasterly direction. This channel was cut through Permian red beds and is floored on granite in the western part of the section. The eastern half of the sand deposit rests on shale and may thicken in a southeasterly direction, as the stream may have deepened its channel in the soft shale. The north side of the deposit ends abruptly against red-bed shales (Fig. 4), suggesting that the north side of the ancient channel was defined by a shale bluff 20 feet high. Southward the deposit thins and is covered by the bottom-sediment sands of Lake Lawtonka.

The location of the ilmenite-bearing sands in the old channel of Medicine Creek suggests that the channel was filled during flash floods when large quantities of sand were being moved by swift stream currents. The deposition in the present location was caused by the loss in velocity of the stream current, owing to narrowing of the stream channel and the change in its course from a northeast to a southeast direction. The gradual filling of the channel forced the normal flow of water to seek a new escape route. This it did by cutting a new channel in a southeasterly direction beginning near the cen. E½ sec. 35, T. 4 N., R. 13 W.

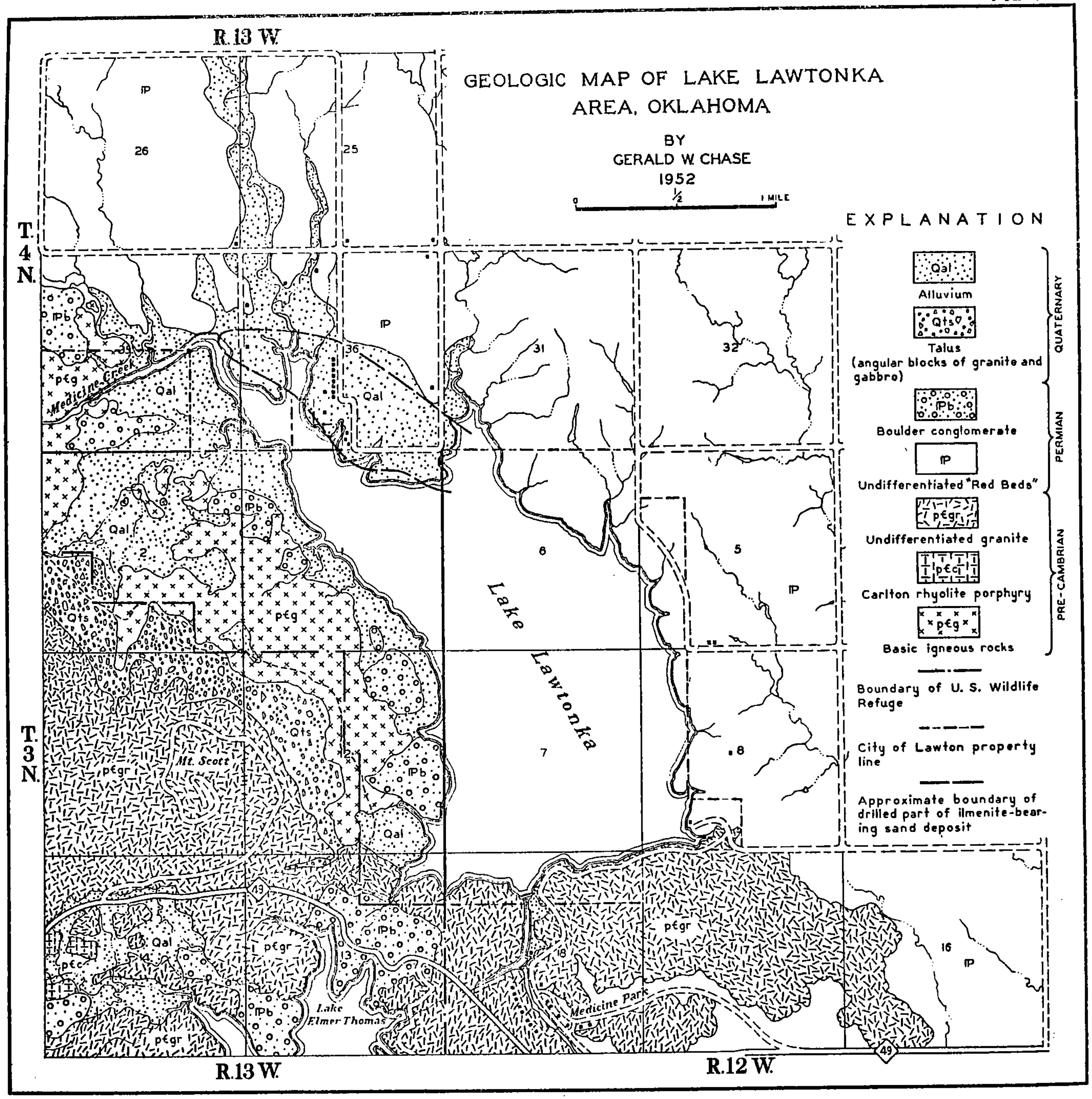

GEOLOGIC MAP OF LAKE LAWTONKA AREA, OKLAHOMA
BY
GERALD W. CHASE
1952
0
½
1 MILE
EXPLANATION
Qal
Alluvium
Qts
Talus
(angular blocks of granite and gabbro)
QUATERNARY
Pb
Boulder conglomerate
P
Undifferentiated "Red Beds"
PERMIAN
p€gr
Undifferentiated granite
p€c
Carlton rhyolite porphyry
p€g
Basic igneous rocks
PRE-CAMBRIAN
Boundary of U. S. Wildlife Refuge
City of Lawton property line
Approximate boundary of drilled part of ilmenite-bearing sand deposit
R.13 W.
R.12 W.
T.4 N.
T.3 N.
Lake Lawtonka
Medicine Creek
Mt. Scott
Lake Elmer Thomas
Medicine Park
49

TABLE X

Logs of Test Holes on the North Shore of Lake Lawtonka

Depth of Hole in ft.	Hole A *	Hole B *	Hole E *	Hole G *	Hole H	Hole J *
1	black clay	Soil	soil	soil	red clay	soil
2	brown clay	Soil	soil	soil	red clay	soil
3	brown clay	gray clay	red clay	brown clay	red clay	brown clay
4	brown clay	gray clay	red clay	brown clay	red clay	brown clay
5	gray clay	gray clay	rd.clay&sand	brown clay	red clay	sand gravel
6	gray clay	gray clay	sandy clay	sand clay	red clay	ls. sand
7	sand	red clay	sand	sand	ls. sand	ls. sand
8	sand	red clay	sand	sand	ls. sand	ls. sand
9	sand	red clay	sand	sand	ls. sand	ls. sand
10	sand	red clay	sand	sand	ls. sand	ls. sand
11	sand	red sd. clay	sand	sand	sd. yel. clay	ls. sand
12	sand	br. sd. clay	sand	sand	sand clay	ls. sand
13	sand	red clay	sand	sand	sand clay	gray clay
14	sand	sand clay	sand	sand	sand clay	yellow clay
15	sand	sand clay	sand	sand	bl. clay sd.	clay & sd.
16	sand	sand	sand	sand	bl. clay sd.	gravel & sd.
17	sand	sand	sand	igneous rock	bl. clay sd.	sand
18	sand	sand	sand		bl. clay sd.	sand
19	sand	sand	sand		yellow clay	sand
20	sand	sand	sand		yellow clay	sand
21	igneous rocks	sand	sand		yellow clay	sand
22		sand	sand			sand
23		sand	sand			sand
24		sand	sand			sand
25		sand	sand			sand
26		sand	sand			sand
27		igneous rock	sand			sand
28			sand			sand
29			sand			sand
30			sand			sand
31			sand			sand
32			igneous rock			sand
33						sand
34						sand
35						sand
36						sand
37						
38						
39						
40						

* Test holes containing ilmenite-bearing sands.
† Separations not made owing to excessive contamination from caving hole wall.

Hole K	Hole L	Hole M *	Hole N * †	Hole O * †	Hole P *	Hole Q
soil	red clay	soil	soil	soil	brown clay	soil
soil	red clay	soil	soil	soil	brown clay	soil
brown clay	red clay	brown clay	brown clay	brown clay	brown clay	brown clay
brown clay	red clay	brown clay	brown clay	brown clay	brown clay	brown clay
brown clay	sand	brown clay	sand	brown clay	brown clay	brown clay
brown clay	sand	sand	sand	ls. pebbles	brown clay	brown clay
ls. sand	yellow clay	sand	sand	sand	brown clay	brown clay
ls. sand	yellow clay	sand	sand	sand	yellow clay	brown clay
ls. sand	yellow clay	sand	sand	sand	yellow clay	yellow clay
ls. sand	blue clay	sand	sand	sand	sand	yellow clay
ls. sand	red clay	sand	sand	sand	sand	yellow clay
ls. sand	red clay	sand	sand	sand	sand	yellow clay
ls. sand		sand	sand	sand	clay	blue clay
ls. sand		sand	sand	sand	clay	red clay
ls. sand		igneous rock	sand	sand	sand	
ls. sand			sand	sand	sand	
ls. sand			sand	sand	sand	
ls. sand			sand	sand	sand	
ls. sand			sand	sand	sand	
blue clay			ls. pebbles	sand	sand	
blue clay			sand	sand	blue shale	
			sand	sand	blue shale	
			sand	sand		
			sand	sand		
			red shale	sand		
			ls. pebbles	blue clay		
			clay sand			
			clay sand			
			clay sand			
			clay sand			
			ls. pebbles			
			ls. pebbles			
			ls. sand			
			ls. sand			
			ls. sand			
			blue clay			
			blue clay			
			ls. sand			
			ls. sand			

* Test holes containing ilmenite-bearing sands.
† Separations not made owing to excessive contamination from caving hole wall.

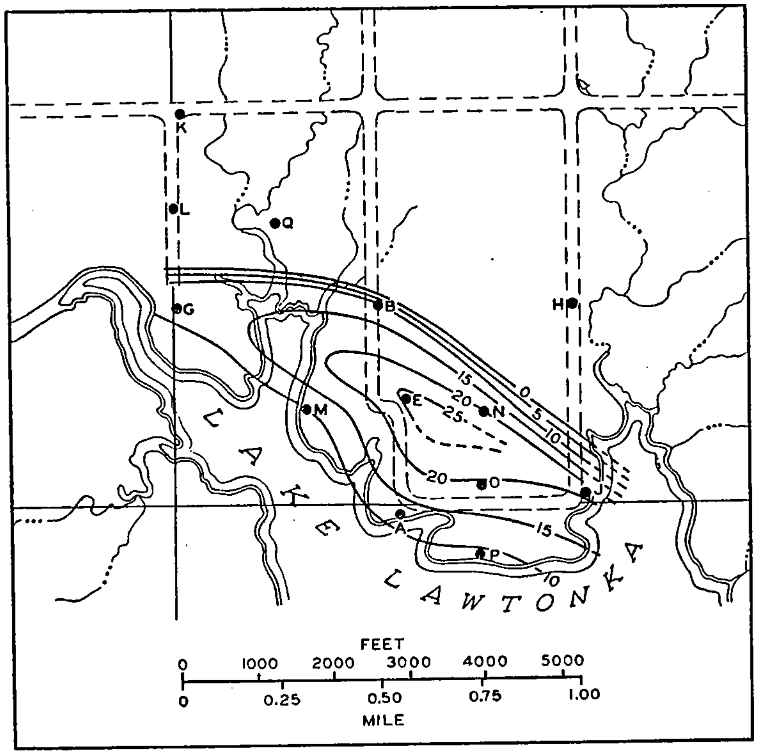


FIG. 2. Isopach map showing thickness of the ilmenite-bearing sands, based on drilled holes A-Q, in sec. 36, T. 4 N., R. 13 W. and adjoining sections. Contour interval 5 feet.

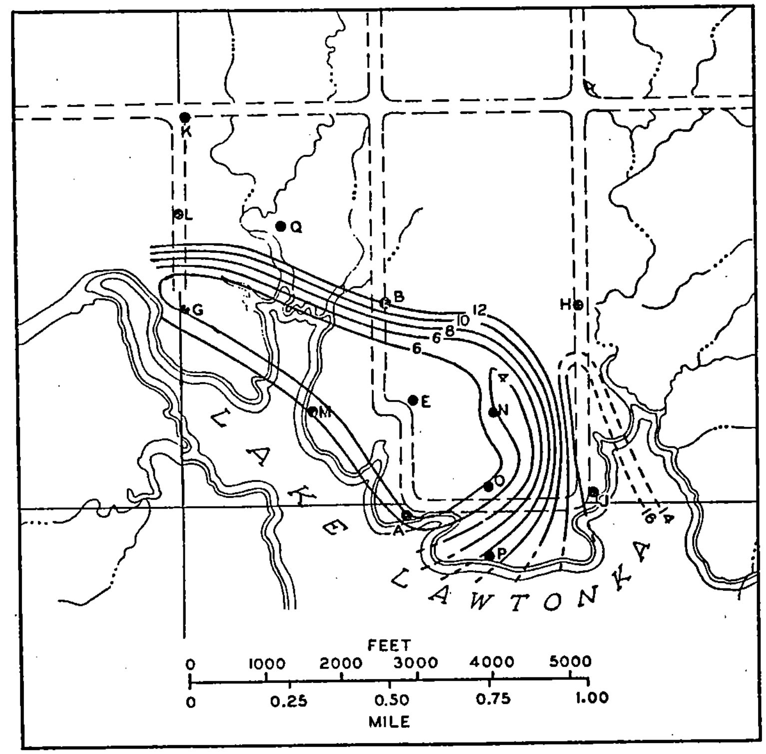


FIG. 3. Isopach map showing the thickness of soil and clay cover, based on drilled holes A-Q, overlying the ilmenite-bearing sands in sec. 36, T. 4 N., R. 13 W. and adjoining sections. Contour interval 2 feet.

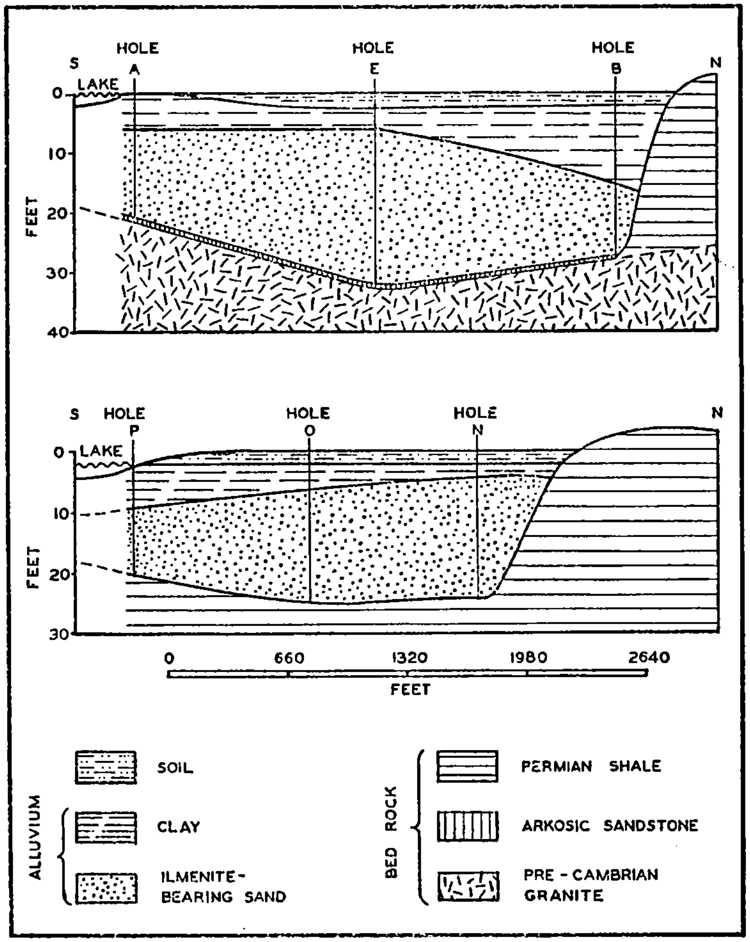


FIG. 4. Sections of the drilled ilmenite-bearing sand deposit on north shore of Lake Lawtonka.

This new channel isolated the old sand-filled channel, producing a shallow ox-bow lake. Silt from erosion of the surrounding shale beds eventually filled the ox-bow lake and obscured all traces of the old channel.

On the basis of 9 holes, the volume of sand contained in this valley is estimated to be approximately 180,000,000 cubic feet and represents on dry basis 7,620,000 long tons. The overburden ranges from 4 to 16 feet in thickness and contains such a small percentage of heavy minerals that it has no value as a source of ilmenite. Ancient tributaries flowing southward from the limestone hills north of Lake Lawtonka cut channels across the sand body, replacing a part of the ilmenite-bearing sands with limestone sand and gravel. In general, where the overburden is more than 8 feet thick, it is composed of these types of sediments.

Ilmenite and associated minerals from test holes. The percentages by weight of individual minerals found in each foot of sand from test hole samples are recorded in Table XI and are summarized as bar graphs in Figs. 5, 6 and 7. The plagioclase feldspar and quartz are shown together, as no attempt was made to separate these two minerals. Augite is the predominant heavy mineral. Ilmenite and ilmagnetite are less abundant and occur in nearly equal amounts. Test holes J and M contained the highest percentages of ilmenite, J having an overall average for the hole of 6.8 percent, and hole M an average of 5.5 percent. The remaining test holes averaged 3.5 percent recoverable ilmenite. The average percentage of ilmenite recoverable from this body of sand, based on test holes drilled, is 4 percent.

The size frequency distribution curves of the minerals found in the composite sand samples of each test hole are given in Figs. 8, 9 and 10. The ilmenite grains range in size from 20 to 170 mesh, 70 percent falling within the 20 to 60 mesh screens.

TABLE XI

Mineral Content of Ilmenite-Bearing Sands in Test Holes on North Shore of Lake Lawtonka

Depth of Hole in feet	Hole A						Hole B					
	Log	PERCENT					Log	PERCENT				
		Plag. Feld-spar	K—Feld-spar	Augite	Ilmag-netite	Ilmen-ite		Plag. Feld-spar	K—Feld-spar	Augite	Ilmag-netite	Ilmen-ite
1	black clay						soil					
2	brown clay						soil					
3	brown clay						gray clay					
4	brown clay						gray clay					
5	gray clay						gray clay					
6	gray clay						gray clay					
7	sand	36.5	50.3	3.7	5.0	4.3	red clay					
8	sand	52.0	30.0	7.8	4.8	5.7	red clay					
9	sand	48.4	37.0	8.6	3.0	3.0	red clay					
10	sand	43.1	35.6	9.5	5.5	6.3	red clay					
11	sand	40.8	36.4	10.0	6.0	6.6	red sandy clay					
12	sand	56.7	26.4	8.8	4.1	4.0	sandy clay					
13	sand	37.9	44.7	8.9	4.6	3.9	red clay					
14	sand	39.6	44.1	7.1	5.2	4.0	sand clay					
15	sand	37.8	45.6	7.2	4.8	4.6	sand clay					
16	sand	56.6	32.5	7.0	2.2	1.6	sand	28.6	58.0	6.1	3.5	3.6
17	sand	48.4	37.1	7.5	3.5	3.5	sand	33.0	50.6	9.2	3.4	3.8
18	sand	44.2	42.7	5.9	3.6	3.6	sand	39.8	44.7	6.0	4.4	5.1
19	sand	39.4	51.6	5.0	2.1	1.9	sand	48.8	37.0	6.4	3.4	4.4
20	sand	32.5	54.1	7.7	3.0	2.7	sand	23.1	61.0	5.5	4.2	5.2
21	igneous rocks						sand	36.1	55.2	4.6	2.0	2.1
22							sand	15.8	74.2	4.4	2.4	2.9
23							sand	40.8	50.8	4.3	1.8	2.3
24							sand	41.4	49.0	3.8	1.0	1.8
25							sand					
26							sand					
27							igneous rocks					
28												
29												
30												
31												
32												

Analysis based on 100 gram sample; mineral percentage on weight basis.

Average Composition

	Hole A Percent	Hole B Percent
Heavy minerals in composite sample	15.6	12.0
ilmenite	3.9	3.4
ilmagnetite	4.1	2.9
augite	6.8	5.5
K-Feldspar	35.0	50.0
Plagioclase Feldspar + (quartz)	49.4	38.
Total	100.0	100.0

TABLE XI—(Continued)

Mineral Content of Ilmenite-Bearing Sands in Test Holes on North Shore of Lake Lawtonka

Depth of Hole in feet	Hole E						Hole G					
	Log	PERCENT					Log	PERCENT				
		Plag. Feld-spar	K—Feld-spar	Augite	Ilmag-netite	Ilmen-ite		Plag. Feld-spar	K—Feld-spar	Augite	Ilmag-netite	Ilmen-ite
1	soil						soil					
2	soil						soil					
3	red clay						brown clay					
4	red clay						brown clay					
5	red clay						brown clay					
	with sand											
6	sandy clay						sand clay					
7	sand	39.9	50.0	6.0	1.8	2.3	sand	60.9	36.7	6.8	1.9	4.0
8	sand	49.8	35.1	7.4	3.6	4.1	sand	63.0	22.0	8.5	2.6	3.9
9	sand	39.1	49.6	7.1	2.1	2.1	sand	68.3	17.4	9.9	1.9	2.5
10	sand	66.6	25.0	4.6	1.7	2.1	sand	21.2	55.5	12.5	3.8	7.0
11	sand	49.1	36.3	6.4	3.8	4.4	sand	26.0	60.2	7.1	2.5	4.2
12	sand	33.7	50.1	6.1	5.1	5.0	sand	61.3	22.2	8.1	3.1	5.3
13	sand	28.4	60.0	6.3	2.8	2.5	sand	60.8	24.5	6.7	2.9	5.1
14	sand	33.4	54.7	6.6	2.9	2.4	sand	48.9	35.9	5.8	3.1	6.3
15	sand	27.0	61.3	7.4	2.2	2.0	sand	40.2	48.1	5.7	2.4	3.6
16	sand	43.6	44.8	6.7	2.6	2.3	sand	35.4	58.6	4.1	1.1	0.8
17	sand	36.7	52.2	6.3	2.5	2.3	igneous rock					
18	sand	33.7	52.2	6.5	3.6	3.9						
19	sand	33.6	43.6	6.7	3.1	3.0						
20	sand	39.1	47.6	7.7	2.8	2.8						
21	sand	33.5	50.0	7.3	4.1	5.1						
22	sand	26.4	60.1	7.4	2.3	2.8						
23	sand	23.1	63.0	5.2	3.8	4.9						
24	sand	26.2	59.9	4.7	2.9	6.4						
25	sand	21.1	62.6	7.1	3.5	5.7						
26	sand	32.5	50.0	7.1	4.0	6.4						
27	sand			5.3	3.1	4.1						
28	sand			8.0	3.3	4.3						
29	sand			6.0	2.4	3.7						
30	sand			6.2	3.9	5.0						
31	sand			4.5	2.4	2.7						
32	igneous rock			3.0	1.6	1.9						

Analysis based on 100 gram sample; mineral percentage on weight basis.

Average Composition

	Hole E Percent	Hole G Percent
Heavy minerals in composite sample	12.7	14.3
ilmenite	3.6	4.2
ilmagnetite	2.9	2.5
augite	6.2	7.5
K-Feldspar	38.7	38.
Plagioclase Feldspar + (quartz)	48.6	47.7
Total	100.0	100.0

TABLE XI—(Continued)
MINERAL CONTENT OF ILMENITE-BEARING SANDS
IN TEST HOLES ON NORTH SHORE OF LAKE LAWTONKA

Depth of Hole in feet	Hole J Log	Hole J Plag. Feld-spar (percent)	Hole J K—Feld-spar (percent)	Hole J Augite (percent)	Hole J Ilmag-netite (percent)	Hole J Ilmen-ite (percent)	Hole M Log	Hole M Plag. Feld-spar (percent)	Hole M K—Feld-spar (percent)	Hole M Augite (percent)	Hole M Ilmag-netite (percent)	Hole M Ilmen-ite (percent)
1	soil						soil					
2	soil						soil					
3	brown clay						brown clay					
4	brown clay						brown clay					
5	sand gravel						brown clay					
6	limestone sd.						sand			3.8	2.1	2.2
7	limestone sd.						sand			3.2	2.3	2.8
8	limestone sd.						sand			4.0	3.1	4.5
9	limestone sd.						sand			5.1	4.9	7.3
10	limestone sd.						sand			7.1	5.5	8.3
11	limestone sd.						sand			5.4	6.0	8.0
12	limestone sd.						sand			8.3	5.2	7.3
13	gray clay						sand			5.6	4.3	5.8
14	yellow clay						sand			3.5	2.4	3.3
15	clay and sand						igneous rock					
16	gravel and sd.											
17	sand	4.0	89.2	2.4	1.3	3.0						
18	sand	1.8	83.9	3.7	3.5	7.1						
19	sand	3.8	80.1	3.7	4.1	8.3						
20	sand	3.1	83.9	3.2	3.0	7.3						
21	sand	1.3	89.4	0.0	2.0	7.6						
22	sand	1.5	85.5	2.7	2.6	7.7						
23	sand	1.1	88.0	2.9	2.5	5.5						
24	sand	1.5	84.0	3.3	3.6	7.6						
25	sand	0.6	86.4	2.8	3.0	7.2						
26	sand	hole caved										
27	sand											
28	sand											
29												
30												
31												
32												

Analysis based on 100 gram sample; mineral percentage on weight basis.

AVERAGE COMPOSITION

	Hole J Percent	Hole M Percent
Heavy minerals in composite sample	12.3	14.5
ilmenite	6.8	5.5
ilmagnetite	2.8	3.9
augite	2.7	5.0
K-Feldspar	85.5	
Plagioclase Feldspar + (quartz)	2.2	
Total	100.0	

TABLE XI—(Continued)
MINERAL CONTENT OF ILMENITE-BEARING SANDS
IN TEST HOLES ON NORTH SHORE OF LAKE LAWTONKA

Depth of Hole in feet	Hole P Log	Plagioclase Feldspar (percent)	K—Feldspar (percent)	Pyroxene (percent)	Ilmagnetite (percent)	Ilmenite (percent)
1	brown clay					
2	brown clay					
3	brown clay					
4	brown clay					
5	brown clay					
6	brown clay					
7	brown clay					
8	yellow clay					
9	yellow clay					
10	sand			3.3	1.9	2.6
11	sand			3.7	2.2	2.9
12	sand			5.8	3.9	5.6
13	clay					
14	clay					
15	sand			6.4	3.0	3.2
16	sand					1.3
17	sand			5.4	3.0	3.0
18	sand			6.0	3.5	3.7
19	sand			6.6	4.8	3.5
20	sand			7.5	3.7	3.2
21	blue shale					
22	blue shale					
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						

Analysis based on 100 gram sample; mineral percentage on weight basis.

AVERAGE COMPOSITION

	Hole P Percent
Heavy minerals in composite sample	11.9
ilmenite	3.2
ilmagnetite	3.2
augite	5.5

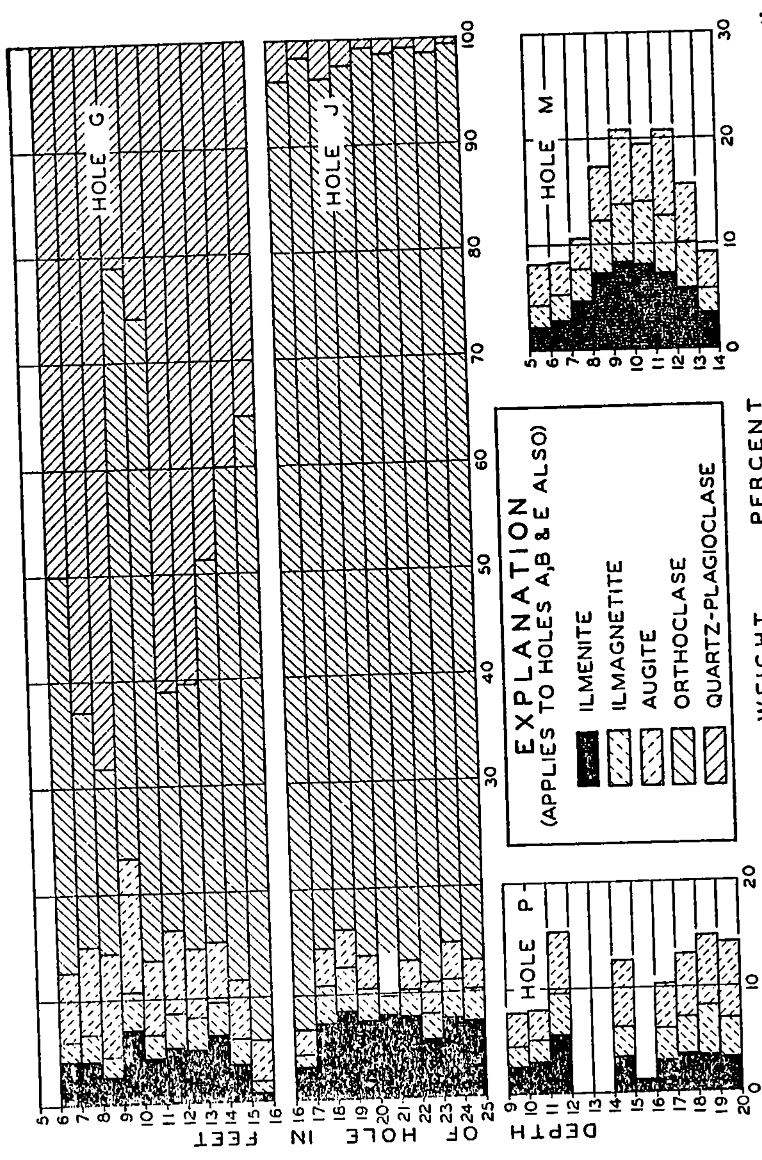


FIG. 5. Bar graphs showing weight percentage of minerals in ilmenite-bearing sands from test holes on north shore of Lake Lawtonka.

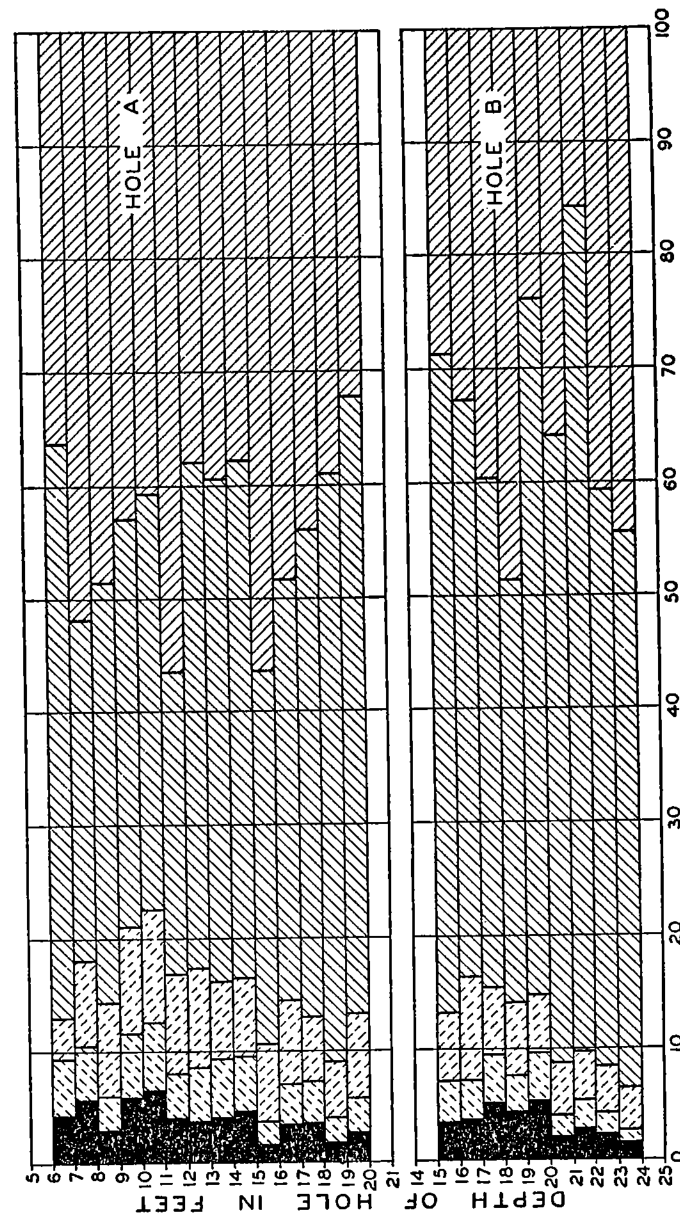


FIG. 6. Bar graphs showing weight percentage of minerals in ilmenite-bearing sands from test holes on north shore of Lake Lawtonka.

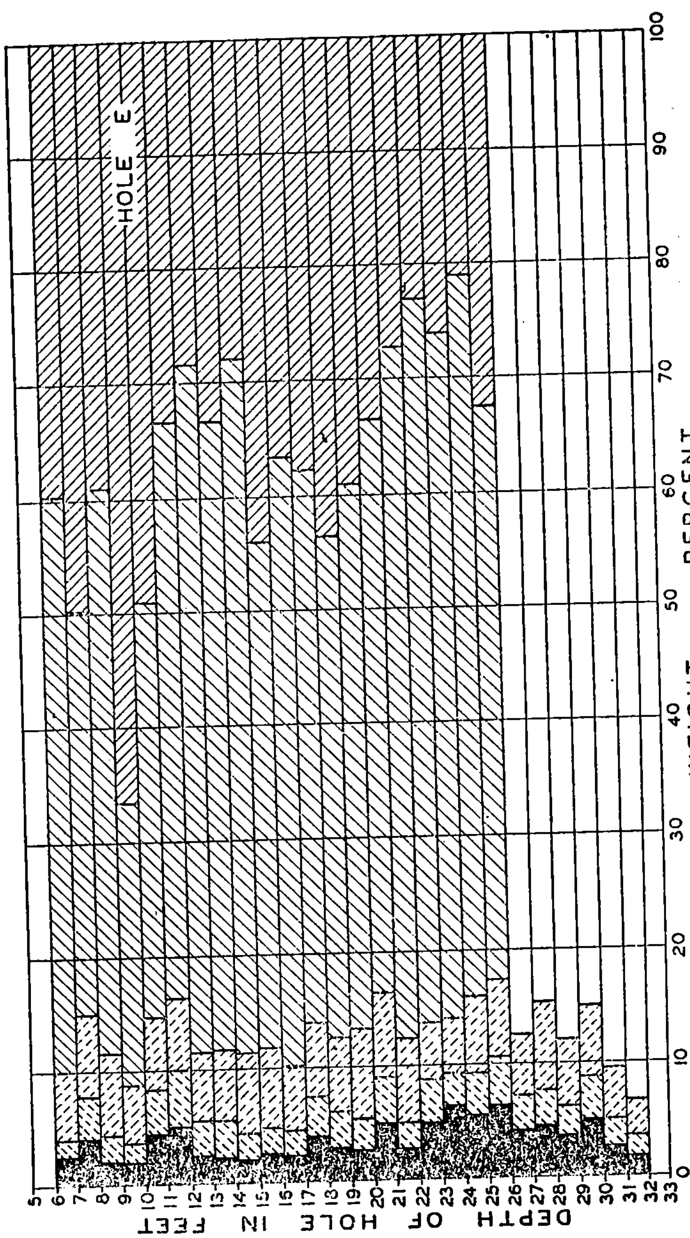


FIG. 7. Bar graph showing weight percentage of minerals in ilmenite-bearing sands from test hole on north shore of Lake Lawtonka.

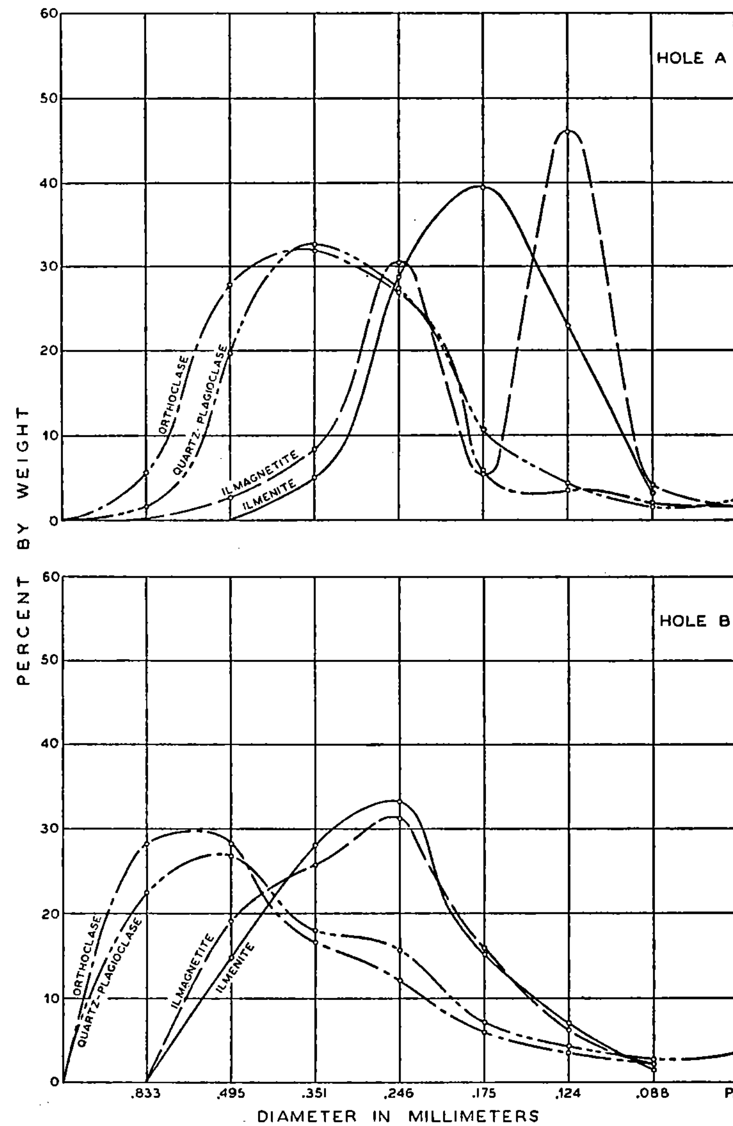


FIG. 8. Mineral size frequency distribution curves of ilmenite-bearing sands from composite samples of test holes on north shore of Lake Lawtonka.

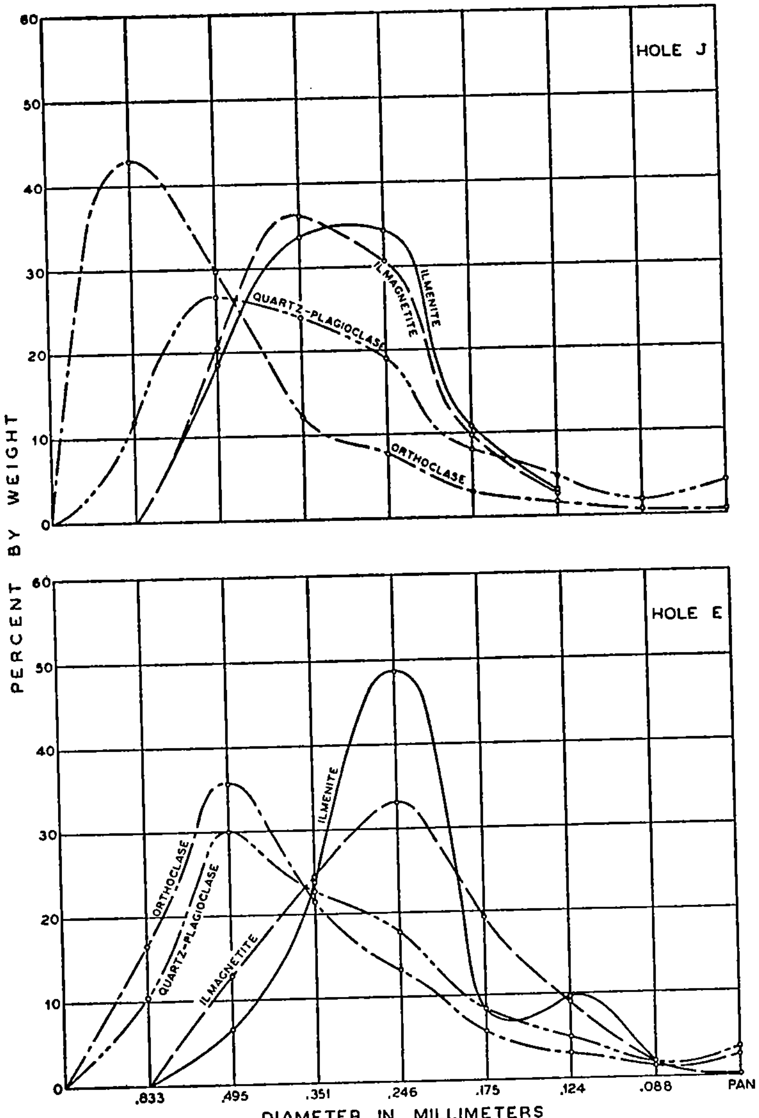


FIG. 9. Mineral size frequency distribution curves of ilmenite-bearing sands from composite samples of test holes on north shore of Lake Lawtonka.

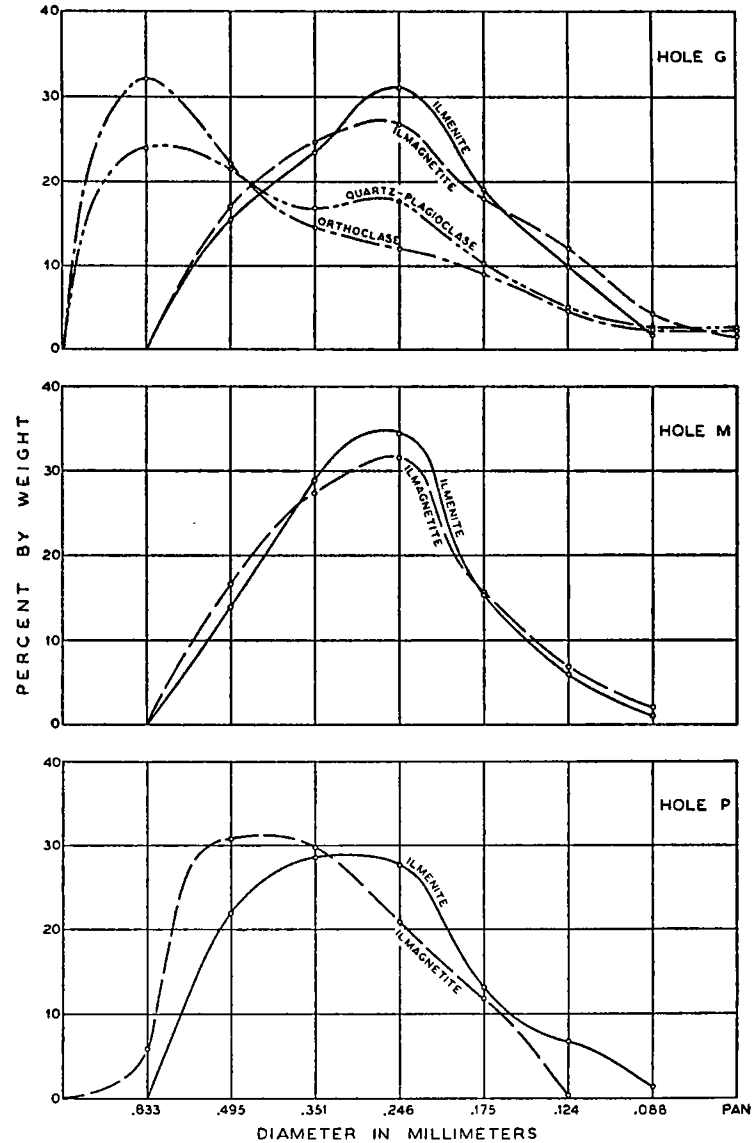


FIG. 10. Mineral size frequency distribution curves of ilmenite-bearing sands from composite samples of test holes on north shore of Lake Lawtonka.

Chemical composition of ilmenite concentrates. The chemical composition of the ilmagnetite and ilmenite concentrates was determined from separations made on a composite sample of hole E. This concentrate is believed to be representative of the ilmenite and ilmagnetite occurring in this deposit.

As shown in Table XII the ilmenite concentrate (Lab. 10030) contains 44.1 percent TiO_2, which corresponds closely to the ilmenite concentrate (A) furnished the Oklahoma Geological Survey by the National Lead Company from their Wetherill mine at Tahawus, New York. The magnetite concentrate (Lab. 10031) contained 9.84 percent TiO_2 and is an ilmagnetite.

TABLE XII

CHEMICAL ANALYSIS OF ILMENITE AND ILMAGNETITE CONCENTRATES

Lab. No.	10030	10031	A
TiO_2	44.14	9.84	44.78
Fe	37.04	62.42	33.15

10030—Ilmenite concentrates from Hole E. A. L. Burwell, analyst.
10031—Ilmagnetite concentrates from Hole E. A. L. Burwell, analyst.
A —Ilmenite concentrates from Wetherill Mine, Tahawus, New York. A. L. Burwell, analyst.

RESERVES OF ILMENITE

Heavy minerals in the alluvial sands from stream channels of east-central Kiowa County and northwestern Comanche County consist of augite and ilmagnetite and contain only a trace of ilmenite. Medicine Creek in northwestern Comanche County is the only stream in which ilmenite was found in appreciable amounts in alluvial sands. During floods a large amount of ilmenite-bearing sand is carried down Medicine Creek to be deposited in Lake Lawtonka. Thus, the lake itself is a potential source of ilmenite-bearing sands.

South of Lake Lawtonka, in the United States Army reservation, numerous flat areas occur along Medicine Creek that may contain ilmenite-bearing sands. The area south of the Army reservation has not been examined for ilmenite-bearing sands, as most of the alluvial sediments probably are derived from Permian sandstones and shales.

Future drilling in the flat areas south and north of Medicine Park, Oklahoma, may reveal ilmenite-bearing sand although the alluvial sands of Recent geologic time in this area contain very little free ilmenite. The sands of Permian and Pleistocene age which may lie below Recent alluvial sand could possibly contain free ilmenite but no drilling has been undertaken in this area.

The test holes drilled in the flat plain on the north shore of Lake Lawtonka has revealed the presence of an estimated 370,000 short tons of ilmenite and is the only large body found to date. The ilmenite concentrates contain 44.1 percent titanium dioxide, which is about average for ilmenite concentrates being processed by industry today.

The Lake Lawtonka area is not far removed from railroad transportation, being 9 miles west of Porter Hill, the nearest point on the Chicago-Rock Island-Pacific Railway. Graveled county roads, which can be traveled at all times except during and immediately following heavy rains, connect the area with Porter Hill.

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