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REPORT OF INVESTIGATIONS—NO. 130

OMAHA POOL AND MICA-PERIDOTITE INTRUSIVES, GALLATIN COUNTY, ILLINOIS

BY

R. M. ENGLISH AND R. M. GROGAN

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OMAHA POOL AND MICA-PERIDOTITE INTRUSIVES, GALLATIN COUNTY, ILLINOIS[1]

R. M. ENGLISH[2] AND R. M. GROGAN[3]
Mattoon and Urbana, Illinois

ABSTRACT

The Omaha pool was discovered in November, 1940, by the Carter Oil Company's York No. 1, SE. ¼, SE. ¼, SW. ¼ of Sec. 33, T. 7 S., R. 8 E., Gallatin County, Illinois. The producing area is now defined and extends over 450 acres located generally southwest of the discovery well. Production is from the Palestine and Tar Springs formations of the Chester (Upper Mississippian) series.

The pool is on the crest of a large dome and is exceptional in that igneous rock is found in intrusive contact with the producing sands. Sills and dikes ranging from less than one foot to 50 feet in thickness, composed of mica-peridotite, occur at many levels in the Pennsylvanian and Chester series.

Contact effects indicate that some oil was in the sands before intrusion of the igneous material, suggesting a certain amount of prior uplift. The pronounced doming of the structure and the intrusion of dikes and sills may have accompanied intrusion of a hypothetical subjacent laccolithic or stock-like igneous body, probably in post-Pennsylvanian–pre-Cretaceous time. Minor folding occurred earlier at the close of the Mississippian period.

INTRODUCTION

The Omaha pool is located in northwestern Gallatin County which is in southeastern Illinois (Fig. 1). This field is one of the few localities in the state where igneous rock has been encountered while drilling for oil, and it is the only field where the producing sands are found in contact with igneous rock.

The first well drilled on the Omaha structure was the Kingwood's Robinson No. 1, NE. ¼, NW. ¼, NW. ¼ of Sec. 4, T. 8 S., R. 8 E., and was located in what is now the northwest corner of the field. This well, completed as a dry hole in February, 1940, found poorly developed Palestine and Tar Springs sands.

[1] Manuscript received, May 9, 1946.

The parts of this paper dealing with the stratigraphy and structure of the field, and with the general discussion of the producing area and of production statistics are the work of the senior writer. The junior writer studied the available cores of igneous rock and prepared the section dealing with their description. The writers collaborated in the discussion of time of accumulation and the reasons for the small size of productive area.

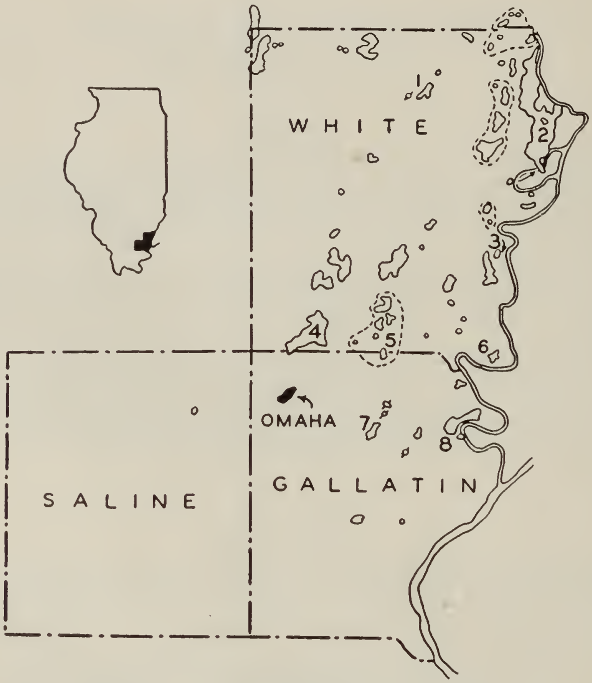
The maps showing oil wells represent development to October 1, 1945.

The writers gratefully acknowledge the advice and criticism given by M. D. Melvin and Allen Ehlers of the Carter Oil Company; by M. M. Leighton, A. H. Bell, L. E. Workman, O. W. Rees, P. W. Henline, J. E. Lamar, and R. E. Grim of the Illinois Geological Survey; and by Professor F. F. Grout of the University of Minnesota.

[2] Division geologist, Carter Oil Company.

[3] Associate geologist, Illinois State Geological Survey. Published by permission of the chief.

The discovery well of the pool, the Carter Oil Company's York No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 33, T. 7 S., R. 8 E., is located in the north part of the field. This well was completed in November, 1940, and produced at the rate of 186 barrels of oil and 40 barrels of water per day from the Palestine sand. Since that time 20 wells have been completed in the Omaha pool—14 in the Palestine



INDEX TO NUMBERED POOLS

1 CENTERVILLE EAST
2 NEW HARMONY CONSOL.
3 MAUNIE
4 ROLAND
5 HERALD
6 NEW HAVEN
7 INMAN WEST
8 INMAN EAST

Fig. 1.—Index map showing location of Omaha pool and of near-by pools producing from Chester formations.

sand, 3 in the Tar Springs sand, and 3 as dual completions in both sands. The producing area is now defined and extends over 450 acres.

The Omaha structure was mapped by the Illinois State Geological Survey in 1919.[4] Mapping was done on No. 5 coal from a few early test holes. Because of the poor records on these early borings and consequent lack of adequate information, the structure was shown as a faulted anticline centering in Sec. 32, T. 7 S., R. 8 E. A structure-contour map on No. 6 coal by the Illinois State

[4] G. H. Cady, "Coal Resources of District V," *Illinois Geol. Survey Coop. Min. Ser. Bull. 19* (1919).

Geological Survey, as of October, 1938,[5] showed a small dome in Sec. 32, T. 7 S., R. 8 E., instead of a faulted anticline.

The northern part of Gallatin County was core-drilled by the Carter Oil Company in the first half of 1938. Core-drill mapping on top of the Providence (Brereton) limestone located the crest of the Omaha dome in Sec. 4, T. 8 S., R. 8 E. Subsequent deeper drilling has necessitated little revision of the earlier location which was based on shallow drilling.

STRATIGRAPHY

The Omaha pool is located in an area of low relief, having a mean elevation of 365 feet above sea-level. A layer of glacial till approximately 100 feet thick covers the underlying Pennsylvanian rocks and conceals any topographic expression of the structure. Beneath the Pennsylvanian are rocks of the Upper Mississippian (Chester) and Lower Mississippian (Iowa) age. Formations of the Iowa series below the St. Louis have not been penetrated on the Omaha structure. Five miles northeast, the Kingwood's Martin No. 1, SW. ¼, NW. ¼, NE. ¼ of Sec. 13, T. 7 S., R. 8 E., was drilled to the total depth of 5,224 feet, ending in the Devonian, and encountered a Lower Mississippian section normal for the surrounding region.

Figure 2 is a generalized geologic section for the field showing the approximate depths of the formations penetrated.

LOWER MISSISSIPPIAN ROCKS

St. Louis.—The St. Louis, the oldest formation penetrated in the Omaha pool, is approximately 300 feet thick in this area. The deepest well in the pool was drilled 95 feet into the formation and encountered buff to brown, finely crystalline dolomitic limestone. The top of the St. Louis is marked by a translucent chert associated with brown dolomitic limestone and appears to be conformable with the overlying Ste. Genevieve formation.

Ste. Genevieve.—Subsurface studies of the Ste. Genevieve in the Illinois basin subdivide the formation in ascending order into three members—the Fredonia limestone, the Rosiclare sandstone, and the Levias (lower O'Hara) limestone.

The Ste. Genevieve formation is 170 feet thick. It is dominantly gray crystalline to oölitic limestone. Two thin sandy zones occur in the upper 70 feet of the formation. Porous oölitic limestone zones, the McClosky producing "sands," are not developed. There is little evidence for placing an unconformity between the Ste. Genevieve and the overlying Chester series in this locality, although it is generally accepted that one is present over much of the Illinois basin.

UPPER MISSISSIPPIAN ROCKS

The Upper Mississippian or Chester series is a succession of alternating sandstone and limestone-shale formations of variable thicknesses and lithologic char-

[5] G. H. Cady, "Structure Map of Herrin (No. 6) Coal Bed in Hamilton, White, and Parts of Gallatin and Saline Counties," *Illinois Geol. Survey Cir. 42* (1939).

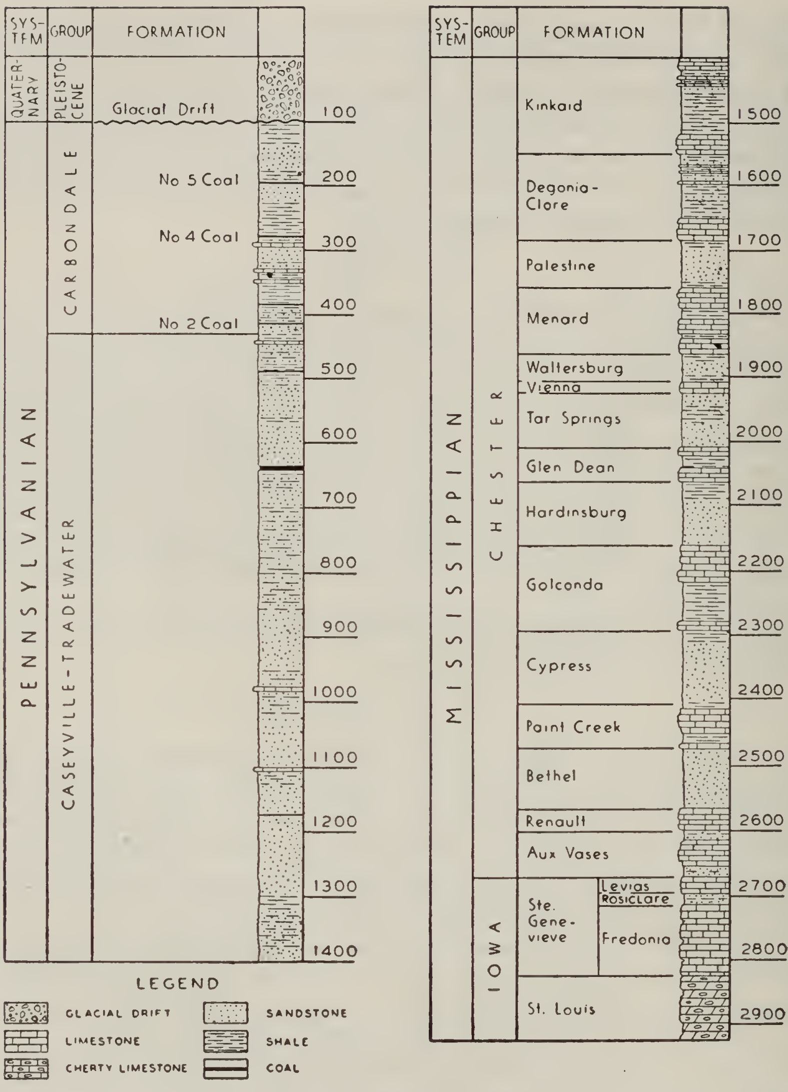


FIG. 2.—Geologic section.

acters. In its full development, the Chester series can be divided into eight cycles of alternating sandstone and limestone-shale formations. From the base upward, these are: (1) Aux Vases-Renault, (2) Bethel-Paint Creek, (3) Cypress-Golconda, (4) Hardinsburg-Glen Dean, (5) Tar Springs-Vienna, (6) Waltersburg-Menard, (7) Palestine-Clore, and (8) Degonia-Kinkaid. The Chester formations are all present in the Omaha pool and have a combined thickness of 1,275 feet.

Aux Vases.—There is some uncertainty about the correlation of the Aux Vases formation as recognized in subsurface studies with the Aux Vases as recognized in outcrop. The Aux Vases, the basal formation of the Chester series, closely resembles the Hoffner (topmost) member of the Ste. Genevieve formation as described from outcrop in Union County,[6] and may be its equivalent, at least in part.

In the Omaha field the Aux Vases formation is 80 feet thick and consists of a lower sandstone member, a middle limestone, and an upper shale member. The sandstone is 10–24 feet thick, fine-grained, white to greenish in color, and hard and shaly. Only very slight shows of oil have been found in the Aux Vases sand. In one well, The Texas Company's Edwards No. 1, SE. ¼, SE. ¼, NE. ¼ of Sec. 5, T. 8 S., R. 8 E., a thin streak of mica-peridotite was found in the base of this sandstone. This is the lowest horizon in the Omaha pool at which intrusives are known to occur.

The middle limestone member is gray, coarsely crystalline, somewhat oölitic, fossiliferous, with an average thickness of 40 feet. It contains some sandy and dolomitic beds in the lower half and locally some pink and green mottled sandy limestone.

The upper member of the Aux Vases, which is approximately 22 feet thick, consists of green and dark gray shale with thin beds of gray and brown limestone.

Renault.—The Renault formation overlying the Aux Vases is white to bluish gray crystalline to dense limestone, normally 25 to 30 feet thick in this area. In two of the three wells that penetrated the Renault in the Omaha field, the section has been thickened to 50 and 60 feet by intrusion of dark green and black finely crystalline mica-peridotite. The associated limestone beds have been altered very little by the intrusives.

Bethel.—The Bethel sandstone is exceptionally thick for this area. It has a normal thickness of 100–113 feet in the Omaha pool, but in one well, the Carter Oil Company's York No. 1, SE. ¼, SE. ¼, SW. ¼ of Sec. 33, T. 7 S., R. 8 E., a number of thin igneous bodies in the lower 50 feet of the sand have thickened the section to 130 feet. The Bethel sand is medium-grained, hard, and quartzitic; adjacent to igneous rock it is particularly hard and impermeable. The sand is lightly stained with oil in the more porous layers, but commercial quantities of oil are not present.

Paint Creek.—The Paint Creek formation consists of dark gray, green, red, and black shale, alternating with thin beds of brown and gray crystalline limestone. The base of the Paint Creek is marked by a dark gray mottled crinoidal limestone. The thickness of the formation varies from 34 to 46 feet. Igneous material was found in the Paint Creek in one well, The Texas Company's Edwards No. 1. Some alteration of associated limestone was noted in sample cuttings.

Cypress.—As generally described, the Cypress formation extends from the

[6] J. M. Weller, and A. H. Sutton, "Mississippian Border of Eastern Interior Basin," *Illinois Geol. Survey Rept. Inv. 62* (1940), p. 853.

top of the Paint Creek to the base of a thin but persistent limestone called the Barlow member of the Golconda formation. The Cypress varies from 103 to 109 feet in thickness and consists of a lower massive sandstone averaging 75 feet in thickness and an upper sandy shale and shaly sand section. The Cypress sand is white to gray and green in color. It is fine- to medium-grained, becoming coarser near the base of the formation.

Light oil stains are present from the top of the sand to within 25 feet of the base, but the sand is too tight to produce oil.

Golconda.—The Golconda formation is 135 feet thick. At its base is a thin gray fossiliferous limestone called the Barlow, which is one of the best structural markers in the Illinois basin. In the Omaha pool, this limestone is 8 feet thick. Above the Barlow is approximately 70 feet of gray and green shale. The upper part of the Golconda is composed chiefly of limestone with a few thin beds of green and red shale. The limestone is gray and brown, crystalline, and occasionally oölitic or dolomitic.

Hardinsburg.—The Hardinsburg formation ranges from 79 to 113 feet in thickness. A massive sandstone 25–57 feet thick occupies the base of the section directly overlying the Golconda limestone. It is probable that a minor unconformity separates these formations in the Omaha pool. The sand is fine-grained, white, fairly tight, with some very light oil staining. The shale present in the upper part of the formation is gray to green, sandy, with some thin stringers of limestone. Some intrusive rock was noted in the cuttings of the shale in one well, The Texas Company's Edwards No. 1.

Glen Dean.—The Glen Dean formation consists of two limestone beds separated by green shale. The limestone is gray and brown mottled, crystalline, in part fossiliferous and pyritic. The formation varies from 45 to 61 feet in thickness. A body of mica-peridotite in the Glen Dean limestone was encountered in the Carter Oil Company's L. Rister No. 2, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.

Tar Springs-Vienna-Waltersburg.—These formations comprise a section of similar lithology between the Glen Dean and Menard limestones. The Tar Springs formation consists of 70 feet of sand and shale, separated from the overlying Waltersburg sandy shale by a thin bed of Vienna limestone. The basal Tar Springs sand is 25 to 50 feet thick, fine-grained, and locally quartzitic, and is separated from the upper sand by green and gray shale. The upper sand is fine- to medium-grained, calcareous, and shaly. It grades into shale on the north flank of the productive area. However, sand is present on the north flank of the structure, and apparently shales out between the gas well in the SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NW. $\frac{1}{4}$ of Sec. 33, T. 7 S., R. 8 E., and the wells to the south.

The basal Tar Springs sand is productive of oil in six wells in the field. Intrusive mica-peridotite is found in contact with the oil sand in three of these wells. The sand showed little metamorphism in all wells except the Carter Oil Company's L. Rister No. 2, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E., which encountered an igneous body overlain by a quartzitic rubble breccia, showing the effects of more pronounced contact metamorphism.

Menard.—The Menard limestone has a thickness of 90–95 feet. The section from the base upward shows the following succession of strata: 10 feet of brown crystalline limestone; 5 feet of gray to green shale; 35 to 40 feet of fine crystalline gray and brown mottled limestone; 14 feet of green and red shale; and 26 feet of shaly dark gray and brown limestone.

Intrusive rock in the Menard limestone was encountered in two wells on the west side of the field, The Texas Company's G. Edwards No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 5, T. 8 S., R. 8 E., and the Carter Oil Company's Carnahan No. 2, NW. $\frac{1}{4}$, NW. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.

Palestine.—The Palestine is the chief producing formation in the Omaha pool. The sandstone is best developed in the northeast part of the pool, where it attains a maximum thickness of 50 feet. It is fine- to medium-grained, with carbonaceous silty partings. To the west and south the sand becomes shaly with interbedded dark gray and black sandy fissile shale (Fig. 8). Calcite veins are irregularly present.

Wells in the southwest part of the field encountered intrusive mica-peridotite in the base of the Palestine. The sand in these wells had some oil saturation but was too tight to produce in commercial quantities. In the Carter Oil Company's L. Rister No. 2, a core of Palestine sand carried only a black carbonaceous residue, indicating that volatile elements of the oil may have been driven off by heat of the intrusive.

Clore.—The Clore formation is variable in character. It ranges in thickness from 95 to 130 feet. The base and top of the formation are marked by thin discontinuous limestones. The basal limestones are crystalline, dolomitic, gray to brown in color. The upper limestones are dense, dark brown to gray and brown mottled. The bulk of the formation consists of dark gray to red and green shale with some beds of shaly sandstone. Several wells encountered thin bodies of mica-peridotite in the Clore formation.

Degonia.—The Degonia is chiefly sandy shale in the Omaha pool. It is 25 to 40 feet thick. Near the center of the pool a thin shaly sandstone is developed in the base of the formation.

Two wells encountered thin bodies of igneous rock in the Degonia.

Kinkaid.—An essentially complete section of Kinkaid, the topmost formation of the Chester series, appears to be present in the Omaha area although it is separated from the overlying Pennsylvanian rocks by an erosional unconformity which in some nearby areas has completely cut out the formation. The Kinkaid is 160 feet thick in the Omaha pool and may be divided into three zones—a massive basal limestone, a middle shale and limestone zone, and an upper massive limestone. The lower Kinkaid is a brown and gray mottled finely crystalline to dense siliceous limestone. The Kinkaid shales are bright green with some red and gray beds and are commonly sandy in the lower half. The upper

Kinkaid massive limestone is finely crystalline in texture and buff to brown and gray in color.

In the southwest part of the field, intrusive rock occurs in the middle of the Kinkaid formation. Intrusives are also present in the upper Kinkaid limestone in three wells in the pool.

PENNSYLVANIAN ROCKS

The Pennsylvanian system in the Omaha field consists of a variable series of sandstones and shales with minor amounts of limestone and coal, constituting a section nearly 1,300 feet thick. The Pennsylvanian in Illinois is divided into four groups, the Caseyville, Tradewater, Carbondale, and McLeansboro groups, in ascending order.[7] The McLeansboro has been entirely removed from the crest of the Omaha structure but is present around the flanks.

Caseyville and Tradewater.—In southeastern Illinois these groups include that part of the Pennsylvanian system lying below the base of the Sebree sandstone,[8] which lies a few feet below No. 2 (Murphysboro) coal. The lower 600 feet of the section is composed almost entirely of sandstone. In the upper 300 feet sandy shales are common. The sands are generally rounded, medium- to coarse-grained, and contain much mica and ferruginous carbonate. The shales are most commonly gray, sandy, and micaceous.

Thick bodies of mica-peridotite are present in these rocks in the southwestern part of the pool, occurring for the most part in the lower 350 feet of the section. Sandstones near the intrusions have become strongly indurated, apparently as a result of metamorphism.

Two bodies of sand in the Caseyville-Tradewater are oil saturated. The lower, called the "1,300-foot," sand is lenticular and limited in extent. This sand is best developed in the Carter Oil Company's York No. 1, where it has a thickness of 48 feet. The upper zone of oil saturation occurs at a depth varying from 520 to 580 feet in the top of a thick sand called the Curlew sandstone.

Carbondale.—The Carbondale group in southeastern Illinois is represented by strata between the base of the Sebree sandstone and the top of No. 6 (Herrin) coal. On the crest of the dome the No. 6 coal has been eroded away, but on the flanks the full section of Carbondale is present. In its full development the Carbondale is approximately 380 feet thick. The highest marker present over the crest of the dome is the No. 5 (Harrisburg) coal. It occurs approximately 280 feet above the Carbondale-Tradewater contact.

In addition to the coals and a few thin limestones, the Carbondale consists of gray and black shale and shaly micaceous sandstones.

[7] The Caseyville and Tradewater together are approximately equivalent to the former Pottsville. For a short discussion of the reason for the revision in terminology, see: H. B. Willman and J. M. Payne, "Geology and Mineral Resources of the Marseilles, Ottawa, and Streator Quadrangles," *Illinois Geol. Survey Bull. 66* (1942), pp. 85–87.

[8] H. R. Wanless, Chapter on Pennsylvanian stratigraphy in: David White, "Flora of the Lower Pennsylvanian in Illinois," *U. S. Geol. Survey*, unpublished manuscript.

PLEISTOCENE AND RECENT DEPOSITS

Between the eroded surface of the Pennsylvanian and the surface is approximately 100 feet of glacial till and alluvium.

MICA-PERIDOTITE INTRUSIVES

Location and nature of sample.—Igneous rock or rock from the adjacent sediments was obtained in the form of core-samples from six wells: Carter's R. Carnahan No. 1, SE. $\frac{1}{4}$, NW. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.; Carter's R. Carnahan No. 2, NW. $\frac{1}{4}$, NW. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.; Carter's D. M. Jones No. 1, NE. $\frac{1}{4}$, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.; Carter's L. Rister No. 2, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.; Sun's Patton No. 1, NW. $\frac{1}{4}$, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 4, T. 8 S., R. 8 E.; and Texas' G. Edwards No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 5, T. 8 S., R. 8 E.

The material from the Carter's Carnahan No. 1 well consists of core-samples, in downward sequence, of 7 feet of Palestine sandstone and shale, $11\frac{1}{2}$ feet of mica-peridotite, and $2\frac{1}{2}$ feet of shale and saturated sandstone, no contacts being preserved. From Carter's Carnahan No. 2 were obtained several short sections of core showing narrow peridotite dikelets in interfingering contact with oil-bearing Palestine sandstone. From the Carter's D. M. Jones No. 1 was obtained an almost continuous core consisting in downward order of approximately 13 feet of saturated Palestine sandstone and sandy shale, $4\frac{1}{3}$ feet of peridotite, and 5 feet of shale. The contact of the igneous rock with the overlying sandstone is preserved. The sample from Carter's L. Rister No. 2 is 2 feet of veined quartzitic breccia obtained from the Tar Springs formation 29 feet above an intrusive mass. The material from the Sun's Patton No. 1 consists of several small fragments of peridotite, Bethel sandstone, and their contact. The sample from the Texas' G. Edwards No. 1 is a short piece of core of intrusive breccia from the Menard formation. The core consists of fragments of shale and sandstone mostly less than an inch in diameter set in an igneous matrix.

Structural relations.—The peridotite contains numerous phenocrysts of dark mica which commonly show a fair degree of mutual orientation. Assuming that this orientation is substantially parallel with the walls of the igneous bodies and that the cores represent vertical sections, it is possible to estimate the probable dip of the bodies. Measurements on three cores suggest that the peridotite is in tabular bodies having dips of approximately 0°, 20°, and 60°; hence, it occurs as both sills and dikes. Many masses of peridotite occur at or near formational contacts or at intraformational changes in lithology where one would expect sills to be emplaced. Probably connecting sills and dikes alternate in step-wise sequences.

Petrography.—The dike rock is dark greenish gray and is composed of phenocrysts of dark mica, serpentine, magnetite, and occasional hypersthene enclosed in a fine-grained matrix. These essential features are the same in all the samples. The mica phenocrysts attain a length of at least 25 millimeters but are commonly 10 mm. or less. The serpentine is pseudomorphous after olivine and euhedral pyroxene, the largest grain observed being 10 mm. long, whereas grains 2 mm. or less are most common. Magnetite phenocrysts are mostly 3 mm. or less, and hypersthene commonly 7 to 12 mm. in length. The phenocrysts comprise approximately 10 per cent of the rock in the proportions of mica 4 per cent, serpentine 5 per cent, and magnetite and hypersthene 1 per cent.

As seen under the microscope, the primary minerals are mica (phlogopite?), magnetite (titaniferous), and olivine, with accessory apatite, perovskite, diopside, garnet (?), and hypersthene. Euhedral to subhedral pyroxene was an abundant primary mineral, both as phenocrysts and in the groundmass, but has all been altered to serpentine. The secondary minerals include serpentine, chlorite, calcite, leucoxene, magnetite, hematite, and at least one other, possibly a clay mineral or a chlorite, not identified. The groundmass is composed essentially of mica, chlorite, calcite, and a brownish, near-isotropic secondary mineral of undetermined composition.

Calcite, pyrrhotite, magnetite, apatite, diopside, and minor chalcopyrite have been introduced in and adjacent to veinlets ranging from the thickness of a pencil line to as much as 8 mm. in width. The texture is hiatal with respect to mica, seriate with respect to magnetite and serpentine, and subtrachytic.

Interesting features revealed by the microscope are the extensive development of calcite along the cleavage planes of mica, the presence of mica with abnormal pleochroism in and adjacent to calcite veinlets, and the presence of locally abundant anhedral crystals of a greenish yellow, isotropic mineral tentatively identified as primary garnet.

The extensive deuteric or hydrothermal alteration which the rock has undergone and the lack of recognizable feldspar or reliable indications of its former presence make naming the rock difficult. Material similar except in texture from the Flanary dike, Crittenden County, Kentucky, has been called mica-peridotite by Diller[9] and mica-olivinite or mica-peridotite by Johannsen.[10] Pending additional evidence, it is proposed to term the Omaha intrusives mica-peridotite.

Character of wall rock.—The dikes and sills are known to intrude limestone, sandstone, and shale. Only sandstones and shales are available for study in cores, and sandstones of the Bethel and Palestine formations are the only rocks whose actual contact with the igneous material is preserved, although some of the shale probably came from within 6 inches of the contact.

The Palestine sandstone is composed essentially of quartz grains with magnetite, muscovite (illite?), chlorite, leucoxene, titanite, zircon, and various feldspars as common accessory minerals. Secondary minerals include kaolinite and hematite. The cementing material is calcite and minor secondary quartz. The

[9] J. S. Diller, "Mica-Peridotite from Kentucky," *Amer. Jour. Sci.*, Vol. 44 (1892), pp. 286–89.

[10] Albert Johannsen, *A Descriptive Petrography of the Igneous Rocks*, Vol. 4, pp. 410–11, 424. University of Chicago Press (1938).

composition of the Bethel sandstone is similar with the exception that hornblende is an additional minor accessory.

Effects of intrusion.—The direct effect of the dikes and sills upon the host rocks was in most cases small, probably because of the relative thinness of many of the intrusives. A relatively low intrusion temperature may have been an additional factor. The most conspicuous of the contact effects is the presence at some contacts of a black carbonaceous residue probably derived from oil present in the sandstone before intrusion. Small veins which are probably genetically related to the intrusives extend several feet beyond the contacts, commonly mineralizing the host rock and in some places replacing it.

Some dikes or sills make sharp contact with the wall rock; others have a border zone of intrusive breccia or of interfingering dikelets and wall rock. At the contacts the mica-peridotite has been extensively altered. The mica and serpentine have been replaced by calcite, chlorite, secondary quartz, and tiny crystals of epidote. The titaniferous magnetite has been extensively replaced by leucoxene. The outlines of former phenocrysts still remain and show that their size was practically undiminished up to the contact. A considerable number of individual grains and clumps of grains of quartz derived from sandstone occur in the igneous rock to a distance of approximately one inch from some contacts. Aside from the carbonaceous material, mineralogic changes in the wall rock which are definitely attributable to contact action were observed in only one or perhaps two cores. The Bethel sandstone from the Sun's Patton well No. 1 exhibits a zone 1–2 mm. wide next to the contact which is essentially free of the calcite normally interstitial to the quartz grains, and which contains abundant greenish epidote in aggregates of anhedral grains and also in single or tufted acicular crystals. Minor amounts of chlorite, hematite, and pyrrhotite are also present. The underlying igneous material is known to be at least 5 feet thick.

The quartzitic breccia from the Carter's L. Rister well No. 2 shows mineralogic changes which may be due in part to contact action. No igneous material is present in the core, and the nearest known is 29 feet below; its thickness is not known. The changes possibly due to contact action are a minor recrystallization of the shale and sandstone fragments composing the breccia and the development of tiny euhedral crystals of rutile which are locally abundant, especially in the fragments which were formerly shale.

Both sandstone and shale adjacent to the dikes and sills are cut by veinlets mostly 2 mm. or less in width. The veinlets are mostly calcite with a minor amount of pyrrhotite, but those in the breccia from the Carter's L. Rister well No. 2 contain abundant apatite as well. Some of the veins are fissure fillings, whereas others appear to have replaced the host rock. Immediately adjacent to the veins, calcite and pyrrhotite, and in the one example, apatite, have been introduced into the host. Some sericite and chlorite in parts of the host rocks which were formerly clayey are probably also the result of hydrothermal action.

At the contacts of igneous rock and Palestine sandstone in the cores from the Carter's R. Carnahan No. 2 and Carter's D. M. Jones No. 1, a black carbonaceous coke-like substance lies as thin films along the contacts. Similar films occur in the igneous rock to a distance of 15 mm. from the contact and along probable lamination planes in the sandstone to a distance of at least 25 mm. from the contact. The carbonaceous material is hard enough to be preserved in the preparation of thin sections, is opaque, can be burned away in the flame of a Bunsen burner, and is insoluble in chloroform, ether, carbon tetrachloride, and carbon disulfide. Fragments of it were heated to a temperature of 260°C. on an electrically heated microscope stage, and up to that temperature they were not observed to soften or melt. This material is believed to be a carbonaceous residue derived from oil present in the sandstone under the influence of the heat of the intrusives.

It is of interest here to estimate the minimum temperature at which intrusion may have taken place. Under laboratory conditions, and if sufficient time is allowed, a temperature as low as 340°C. is sufficient to drive off the volatile fractions of petroleum and to decompose the remaining hydrocarbons so as to leave behind a carbonaceous residue.[11] For any given oil it is said that pressure has essentially no effect on the temperature of cracking. Following the method of Lovering[12] and using his thermal data for basalt and sandstone, it may be calculated that the theoretical maximum contact temperature of the sandstone containing the oil would have been in the neighborhood of 47 per cent of the intrusion temperature of the dikes and sills. By taking 340°C. as the temperature at which the carbonaceous material was formed and by assuming it to be 47 per cent of the intrusion temperature, the minimum temperature of the dikes and sills at the time of intrusion was estimated at approximately 725°C.

Recent experiments[13] have indicated a somewhat lower temperature of intrusion for a peridotite dike of similar composition where it crosses a coal seam in southwestern Pennsylvania. Measurements of the temperature at which masses of natural coke enclosed by the peridotite began to yield distillation products lead to the conclusion that the coke had been previously heated to a temperature of more than 480°C. but less than 550°C., and that the intrusion temperature could hardly have exceeded 600°C.

Igneous rocks of near-by areas.—Similar igneous material has been described in the fluorspar-producing area of Hardin and Pope counties, Illinois,[14] and the

[11] Roy Cross, "A Handbook of Petroleum, Asphalt and Natural Gas," *Kansas City Testing Laboratory Bull. 25* (1931 revision), p. 281.

[12] T. S. Lovering, "Heat Conduction in Dissimilar Rocks and the Use of Thermal Models," *Bull. Geol. Soc. America*, Vol. 47, No. 1 (1936), p. 96, Pl. 2.

[13] Robert B. Sosman, "Evidence on the Intrusion-temperature of Peridotites," *Amer. Jour. Sci.* (5), Vol. 35-A (1938), pp. 353–59.

[14] H. Foster Bain, "The Fluorspar Deposits of Southern Illinois," *U. S. Geol. Survey Bull. 255* (1905), pp. 27–30.
L. W. Currier, in Stuart Weller, "The Geology of Hardin County, Illinois," *Illinois Geol. Survey Bull. 41* (1920), pp. 237–44.

adjoining part of Kentucky and in several coal mines near Harrisburg, Saline County, Illinois.[15] The Pope-Hardin county occurrences are approximately 30 to 35 miles south of the Omaha field, and those in Saline County lie in a zone several miles wide and approximately 20 miles long extending southwest from the Omaha field.

The igneous rock from the Pope-Hardin area is said to be of two types, mica-peridotite and lamprophyre. That from Saline County is described as an olivine kersantite, a variety of lamprophyre. The petrographic similarity of the rocks from the three areas and their relatively close geographic association suggest that they came from the same parent magma.

The time of intrusion of the dikes in the fluorspar district is post-Lower Mississippian, and in the Harrisburg and Omaha localities at least as late as the lower Middle Pennsylvanian. It has been suggested elsewhere that the dikes are post-Paleozoic–pre-Cretaceous.[16]

STRUCTURE

Folding.—In contrast to the ordinary gentle elongate folds in southeastern Illinois, the Omaha structure is a symmetrical dome, dipping in all directions from the crest at the rate of 100 feet to the mile (Figs. 3, 4, and 5). This structure has a closure of 270 feet measured from the top of the dome to the base of the bordering synclines, whereas near-by producing fields, such as Roland 5 miles northeast, have a closure of the order of 30 to 40 feet. The magnitude and shape of the dome, together with the sills and dikes which intrude it, suggest that this structure may be dominantly the result of upward thrusting accompanying the rise of an igneous intrusion rather than of mainly horizontal orogenic forces. The symmetrical shape of the Omaha structure suggests that the postulated intrusion may have been a small laccolith or stock, of which the sills and dikes were offshoots.

The geological history of this field as revealed by thickness maps shows that there was very little folding during Chester time. However, there is evidence that this area underwent at least a slight uplift at the close of the Mississippian period. The isopach map of the interval from No. 5 coal to the upper Kinkaid limestone (Fig. 6) shows 20 feet of thinning of the Pennsylvanian section overlying the productive area. It is doubtful that the magnitude of folding at the end of Mississippian time was sufficient to form a trap in which more than a small amount of oil would have accumulated.

The injection of dikes and sills and the postulated doming of the Omaha structure were probably contemporaneous with the other igneous activity of

[15] G. H. Cady, "Coal Resources of District V," *Illinois Geol. Survey Coop. Min. Ser. Bull. 19* (1919), pp. 56–61. For location of dikes, see: G. H. Cady, "Structure Map of Herrin (No. 6) Coal Bed in Hamilton, White, and Parts of Gallatin and Saline Counties," *Illinois Geol. Survey Cir. 42* (1939).

[16] J. M. Weller, "Geology and Oil Possibilities of Extreme Southern Illinois," *Illinois Geol. Survey Rept. Inv. 71* (1940), p. 50.

southeastern Illinois and of northwestern Kentucky, which as mentioned earlier has been given as post-Paleozoic–pre-Cretaceous.

If it be true that the Omaha structure is the result of doming above a rising intrusive and that the intrusive was emplaced during the interval between Pennsylvanian and Cretaceous time, then the structure post-dates the main period of earth movements which produced the complex folding of the Illinois basin. The widespread unconformity at the top of the Chester, together with regional isopach maps, show that the basin emerged and that the rocks were

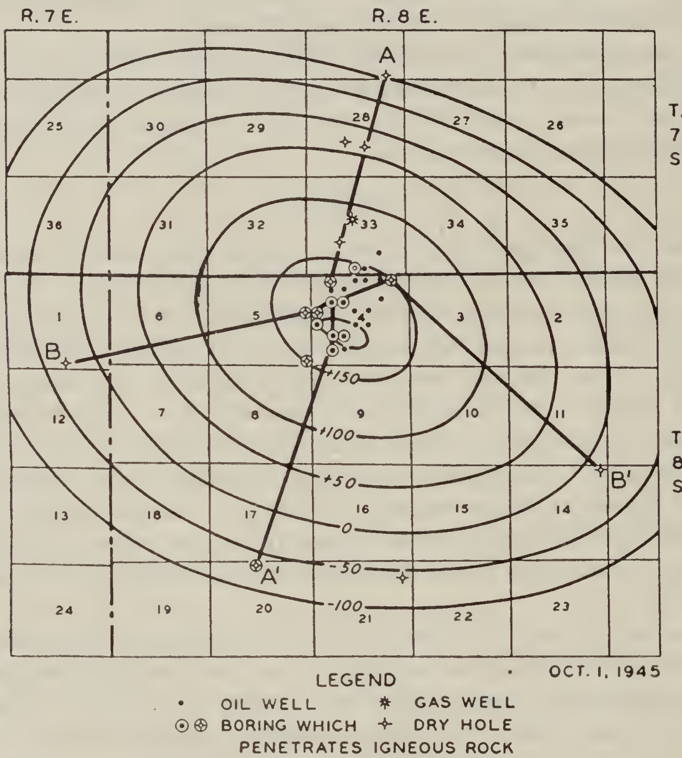


Fig. 3.—Omaha dome shown by contours on No. 5 coal. Datum sea-level. Contour interval 50 feet. (See figures 10 and 11 for cross sections *AA′* and *BB′*.)

folded at the end of Mississippian time. Later folding, Pennsylvanian to Cretaceous, for the most part followed the old lines of weakness and accentuated the older folds.

Faulting.—There is no evidence that faulting of any consequence occurred within the Omaha dome at the time when it was formed. No doubt minor faults or tension cracks resulted from so considerable an uplift, but no appreciable vertical displacement of the rocks by faulting is apparent.

Although major faulting did not accompany the formation of the Omaha dome, there is evidence that a fault is present 4 miles east of the field, extending north and south along the range line between R. 8 E. and R. 9 E. A well drilled by the Sinclair Oil Company in the NW. ¼, SW. ¼, NW. ¼ of Sec. 7, T. 8 S., R. 9 E., cut through this fault from the downthrown to the upthrown side,

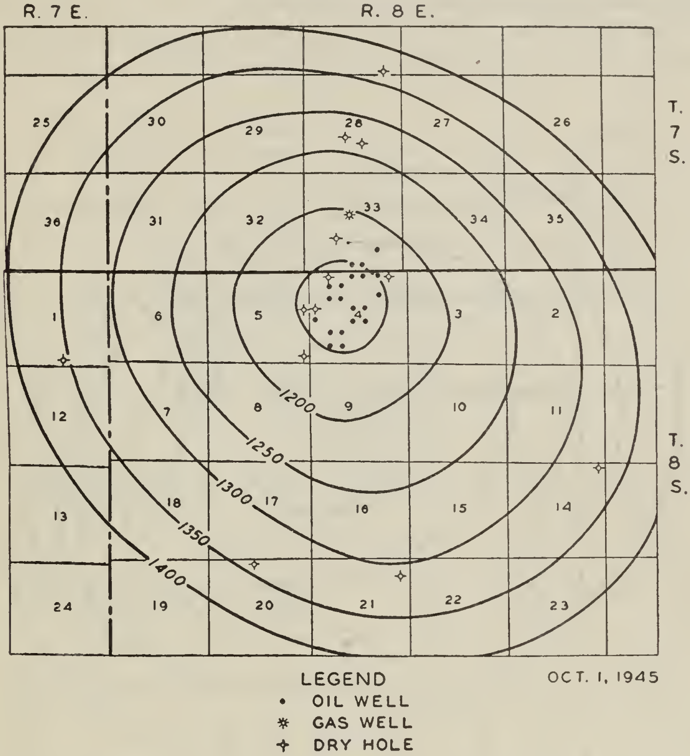


FIG. 4.—Omaha dome shown by contours on lower Kinkaid limestone. Datum sea-level. Contour interval 50 feet.

passing from the Hardinsburg sandstone directly into the Paint Creek shale. No igneous material was found in the fault. Measured in this well, the vertical displacement along the fault is approximately 240 feet.

TIME OF ACCUMULATION

Accumulation of oil in most pools in southeastern Illinois seems to have been controlled by post-Mississippian folding. However, folding of the Omaha structure at the end of Mississippian time is not believed to have been on a scale to effect more than a minor amount of oil accumulation (Fig. 6). The near-by Roland structure shows evidence of having been subjected to steeper folding than the Omaha field at the end of the Mississippian, but even so there has been very little oil accumulation in the Tar Springs and Palestine, even though these sands are well developed.

That oil accumulated in the Omaha structure before the sills and dikes cut the oil sands is shown by the presence of a carbonaceous coke-like material at the contact of the oil sands and the igneous rock in two cores and in sandstone some distance above the contact in a third core.

Two hypotheses are tentatively advanced to explain the conditions of oil accumulation. The first hypothesis considers that a small structure at the site of

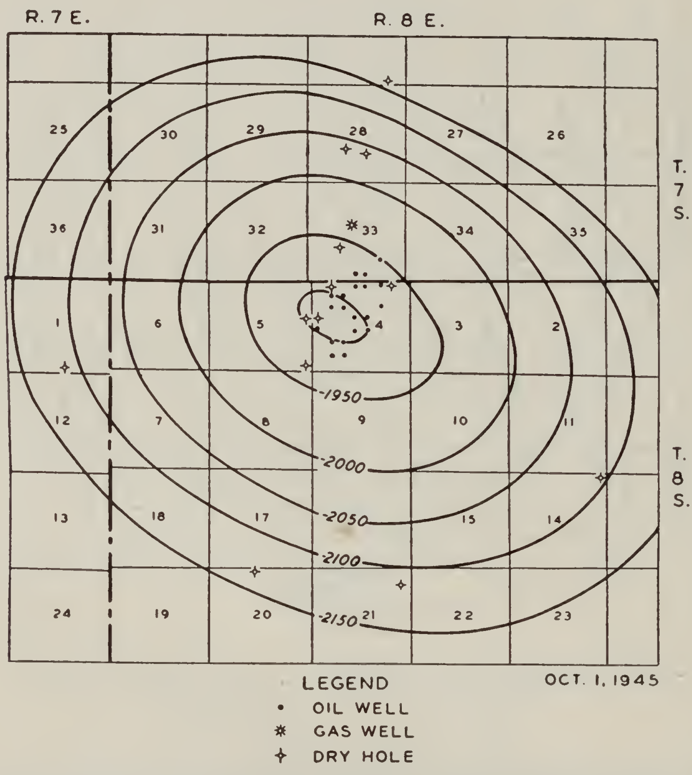


FIG. 5.—Omaha dome shown by contours on Cypress formation. Datum sea-level. Contour interval 50 feet.

the present dome was formed by folding at the close of Mississippian time, and that a minor amount of oil accumulated then and during succeeding Pennsylvanian time. In the interval between late Pennsylvanian and early Cretaceous times a small stock-like or laccolithic magma body was intruded below the pre-existing structure and caused pronounced doming. Contemporaneous satellitic dikes and sills heated the saturated sands with which they came in contact and drove off the volatile components of the oil to a greater or lesser degree. Succeeding migration of oil into the steep-sided dome thus formed by intrusion gave rise to further saturation of Chester and Pennsylvanian producing formations.

The second hypothesis suggests that oil accumulated in the Palestine and Tar Springs formations in the Omaha structure during or after the time the strata were being arched by the major underlying intrusion but prior to injection of the sills and dikes into the sands. Sometime later, as the result of increased

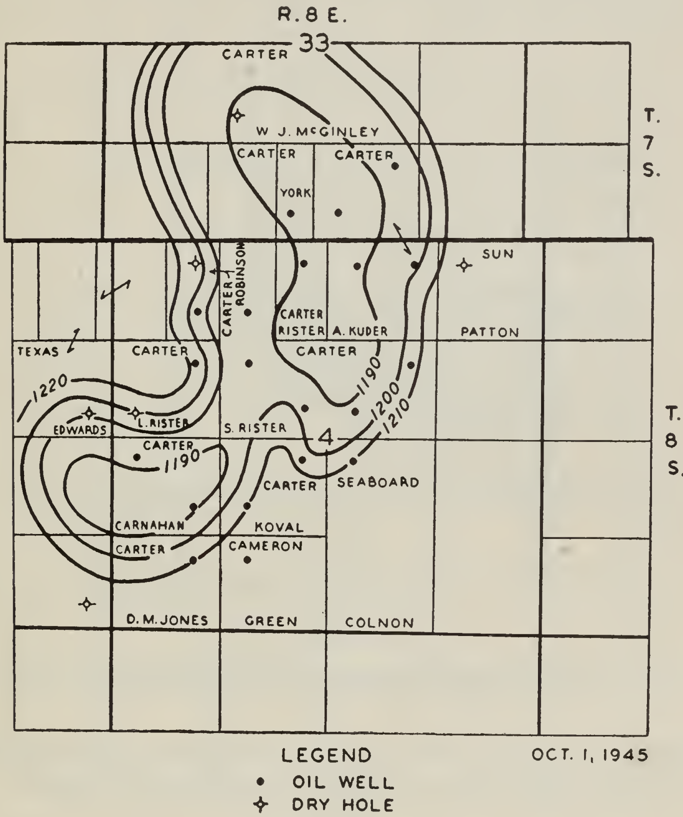


FIG. 6.—Isopach map of Omaha pool showing thickness of strata from No. 5 coal to upper Kinkaid limestone. Contour interval 10 feet.

pressure from below, some of the still partially liquid magma burst forth and penetrated overlying oil-bearing strata as dikes and sills, producing by contact action the carbonaceous residues already described.

Neither hypothesis is considered entirely satisfactory. The first explains the presence of coke at igneous contacts but does not provide for the heating of the bulk of the oil, which it supposes came in after the emplacement of the dikes and sills and presumably after they had cooled. The escape of the volatile components, which in the following section is suggested as a cause of the abnormally low A. P. I. gravity of the oil, would have had to occur slowly through minor fissures produced by the strong arching of the structure. The second hypothesis allows for intrusive heat to act on the greater part of the oil, but calls for either very rapid accumulation of oil or for a rather prolonged period of time between

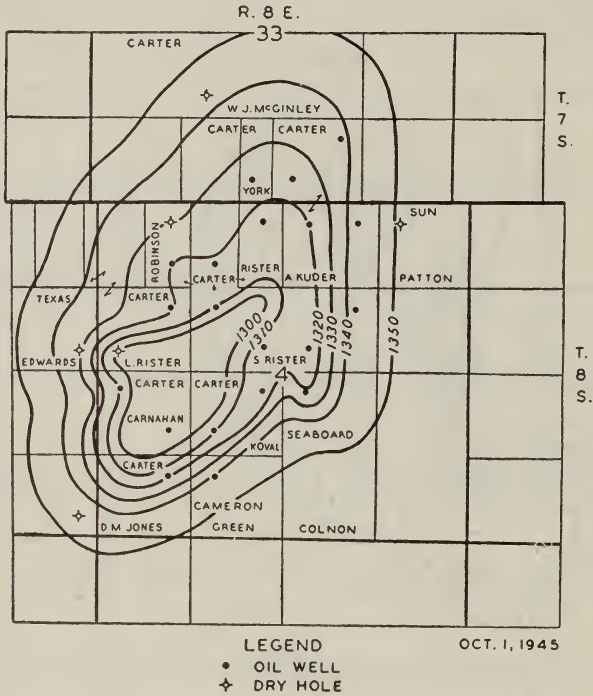


FIG. 7.—Omaha pool shown by contours on top of Palestine sand. Datum sea-level. Contour interval 10 feet.

emplacement of the main intrusive and the formation of the dikes and sills during which the magma body would have to remain partly liquid.

PRODUCTIVE AREA

The Omaha pool includes only 450 productive acres on the top of a structure covering approximately 15,000 acres. Some explanation for the small size of the producing area located on such a large structure has been sought ever since the limits of production have been known.

Areal limitations imposed by sand conditions and igneous intrusions may be part of the explanation. Detail structure maps on the Palestine and Tar Springs sands show that the center of the producing area is northeast of the highest point of the structure (Figs. 7 and 9). The Palestine, the principal producing sand in the pool, is best developed in the northeast part of the field and "shales out" southwest or is replaced by intrusions (Fig. 8). The Tar Springs sand is present in the southwest part of the pool only, and sills and dikes which intrude it may also have affected the productive extent of this sand.

The small size of the pool might be explained in another way by considering the time of accumulation of oil in Illinois fields. It has been pointed out that accumulation in most of the fields in southeastern Illinois was probably controlled by post-Mississippian folding. If the Omaha structure did not exist as a really effective trap until some time after the close of the Paleozoic era, and if

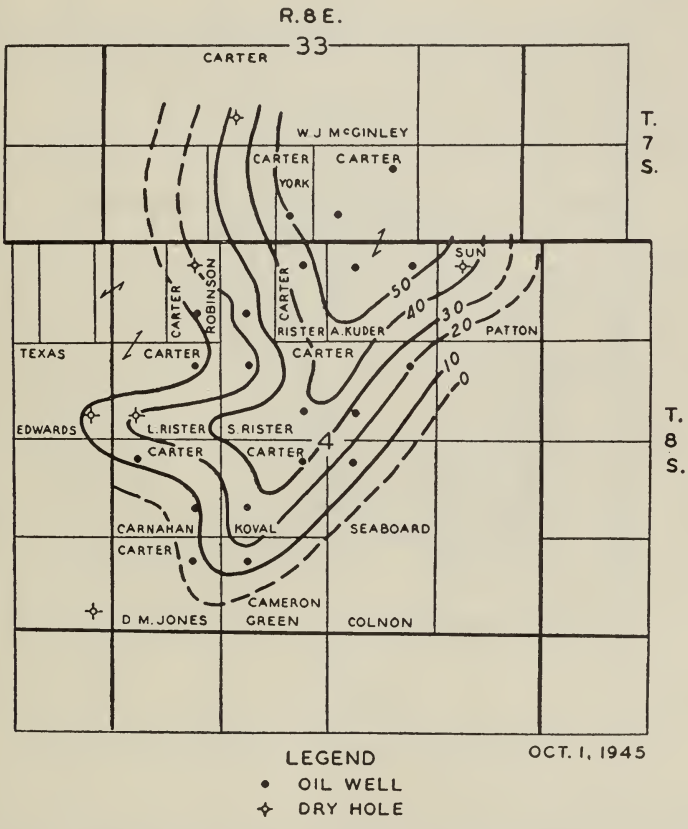


FIG. 8.—Isopach map of Omaha pool showing thickness of porous part of Palestine sandstone. Contour interval 10 feet.

the greater part of the oil originally available from Illinois source beds had been trapped before that time, then perhaps only a limited supply of oil would have been available for the Omaha pool. With the source beds largely depleted, there would have been little oil left for accumulation after uplift of the dome.

Dissipation of some of the oil to the surface along minor fissures would also help account for the small productive area of the field. Oil showings in Chester sands below the Palestine and Tar Springs indicate that oil may have accumulated in the lower sands in commercial quantities and later moved upward along fissures produced during or following arching of the dome. In this way the lower sands could have furnished the oil now present in the Palestine and Tar Springs formations. Accumulation in the lenticular sands in the Pennsylvanian strata could be explained in the same way.

If saturation were essentially complete before intrusion of the dikes and sills, it might be reasoned that heat from the intrusions would drive off some of

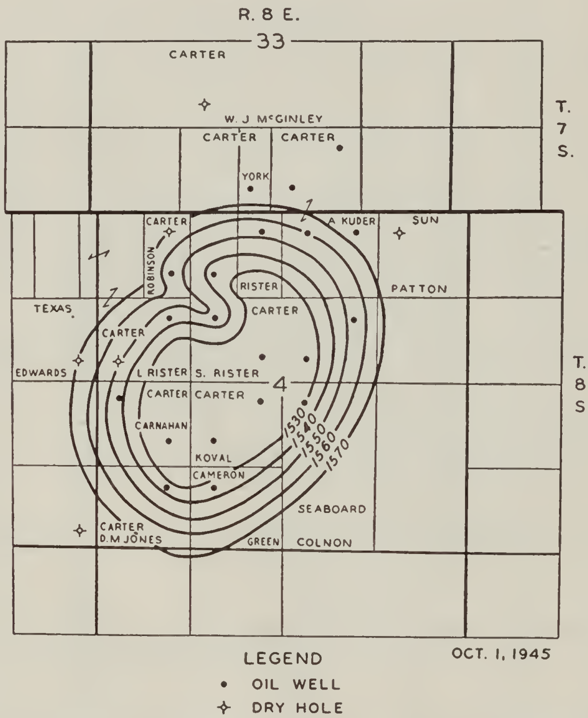


FIG. 9.—Omaha pool shown by contours on top of Tar Springs sand. Datum sea-level. Contour interval 10 feet.

the lighter constituents of the oil, producing a volume shrinkage of available oil and perhaps of productive area. The effect of thus heating a truly gas-tight system would be a decrease in oil volume and an increase in gas volume and possibly a certain amount of downdip migration of oil as a result. If the system were not gas-tight, the increased gas pressure would speed the upward diffusion and escape of the gas, leaving behind a diminished residue of oil of lower A. P. I. gravity and increased viscosity.

The Omaha structure probably was not gas-tight for it had no gas cap when drilled. Furthermore, oil from the Omaha pool has a gravity of 26° to 29°

A. P. I., 8°–10° lower than oil from the same formation in near-by pools (Fig. 1 and Table I). Although gas would be able to escape through a pervious caprock without the application of intrusive heat, the process would be greatly accelerated by the introduction of heat from molten intrusive rock.

By means of calculations based on a decrease in gravity from 36° A. P. I. (sp. gr. 0.845) to 26° A. P. I. (sp. gr. 0.898), Paul W. Henline[17] has estimated

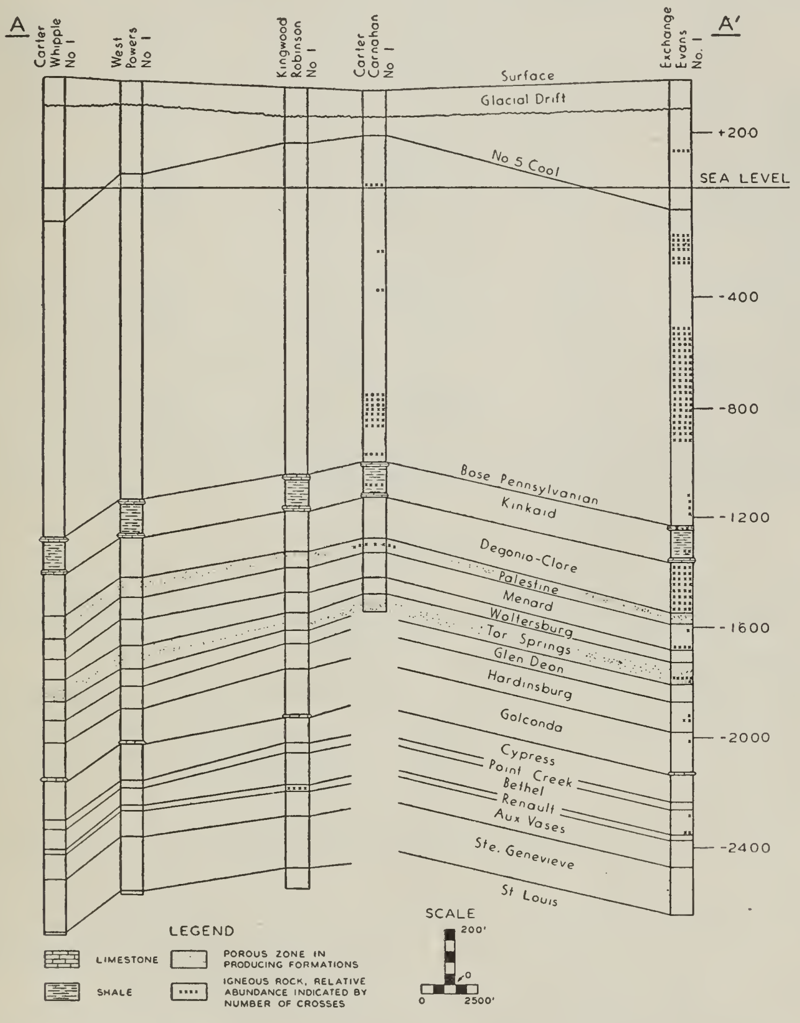


Fig. 10.—North-south section across Omaha dome. (See Figure 3 for line of cross section.)

[17] Associate chemical engineer, Illinois State Geological Survey, private communication.

that a liquid volume reduction of 35 to 40 per cent results from such a dissipation of light fractions. On this basis, the area of saturation might have been originally greater than it is now, occupying perhaps 615 to 667 acres instead of the present 450 acres.

TABLE I

GRAVITY AND VISCOSITY OF OIL FROM PALESTINE AND TAR SPRINGS FORMATIONS IN OMAHA AND NEAR-BY POOLS

Pool	*County*	*Oil-Producing Formations*	*A. P. I. Gravity*	*Specific Gravity*	*Saybolt Viscosity, 100°F.*
Omaha	Gallatin	Palestine	25.9	0.899	109
Omaha	Gallatin	Tar Springs	27.0	0.893	102
Roland	Gallatin	Tar Springs	31.7	0.867	52
Inman, West	Gallatin	Tar Springs	38.4	0.833	41
Inman, East	Gallatin	Tar Springs	34.6	0.852	46
New Harmony Consolidated	White	Tar Springs	36.0	0.845	41
Herald	White	Tar Springs	37.2	0.839	44
New Haven	White	Tar Springs	36.4	0.843	42
Centerville, East	White	Tar Springs	37.2	0.839	40
Maunie	White	Palestine	33.8	0.856	47
Average excluding					
Omaha		Palestine	33.8	0.856	47
Omaha		Tar Springs	35.9	0.845	44

O. W. Rees, P. W. Henline, and A. H. Bell, "Chemical Characteristics of Illinois Crude Oils with a Discussion of Their Geologic Occurrence," *Illinois Geol. Survey Rept. Inv. 88* (1943).

PRODUCTION

The Omaha pool on October 1, 1945, had produced 1,056,444 barrels of oil. It is estimated that the ultimate recovery will be 5,482 barrels per acre, or 2,467,000 barrels for the 450 productive acres.

The Palestine sand is expected to yield at least 90 per cent of the oil produced. The Tar Springs sand is of limited extent, covering a small area in the southwest part of the pool, and its low permeability and lenticular nature indicate that the recovery from this sand will be low.

A small gas reservoir is present on the north flank of the structure as shown by the Carter's Duckworth No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NW. $\frac{1}{4}$ of Sec. 33, T. 7 S., R. 8 E., which made 2,000,000 cubic feet of gas on an open-flow gauge from the Tar Springs. The gas is present in a Tar Springs sand body which shales out to the south toward the pool. The well has been shut down since its completion on January 5, 1943, because there is no ready gas market in the area.

Twenty wells have been drilled in the Omaha pool, or an average of one well to 18 productive acres. The spacing program followed in developing the field is known as the "Schuler" pattern. In this spacing, two wells are drilled to 40 acres, but each well is located on a regular 10-acre location (Figs. 7 and 9). Two wells on the east side of the pool were not drilled on this pattern.

Initial potentials in the pool ranged from 25 to 330 barrels, averaging 125 barrels per well. At the peak of production in April, 1941, the field produced 1,275 barrels of oil per day. In September, 1945, the daily average production

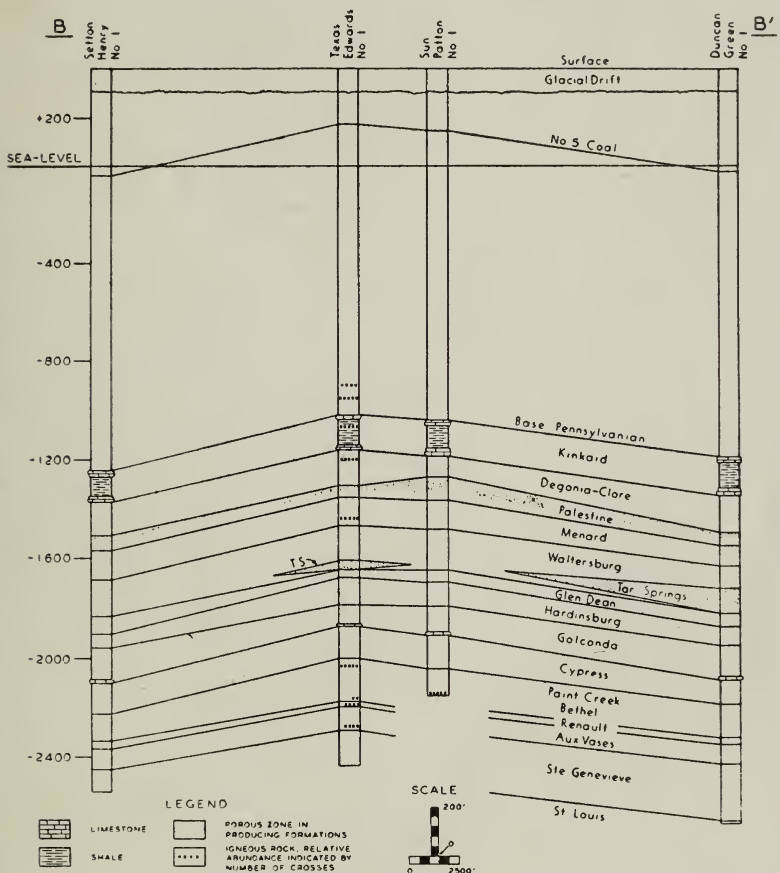


FIG. 11.—West-east cross section, Omaha dome. (See Figure 3 for line of cross section.)

was 392 barrels. The pool has never been subjected to proration but has been produced to capacity since discovery.

The estimated original bottom-hole pressure of Palestine wells was 750 pounds. In September, 1941, the average bottom-hole pressure had declined to 428 pounds and on June 1, 1945, it was 300 pounds. The average gas-oil ratio for the field is 300 cubic feet per barrel.

Two lenticular sands in the Pennsylvanian series may ultimately produce a limited amount of oil. The upper, or "570-foot sand," produced water in the Carter Oil Company's York No. 1 but may produce oil higher on structure in the southwest part of the field. The lower, or "1,300-foot sand," was found in only two wells in the pool—Carter's York No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 33, T. 7 S., R. 8 E., and Carter's Kuder No. 1, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 33, T. 7 S., R. 8 E. The productive extent of this sand is not expected to exceed 30 acres.