PETROLEUM AND NATURAL GAS.

GEOLOGY AND OIL PROSPECTS OF THE RENO REGION, NEVADA.

By Robert Anderson.

INTRODUCTION.

During the last few years much interest has been aroused in Nevada over the question whether petroleum may be obtained from any of the geologic formations of the State. Up to the present time no paying quantity of oil has been found here, but prospecting is going on at a number of different localities in regions of diverse geologic character.

In November, 1908, the writer made an examination of the area around Reno, in western Nevada, where a well had been for some months in process of drilling. The present paper discusses the geology of the region, especially the supposed oil-bearing beds, and outlines the conclusions reached regarding the possibility of the occurrence of petroleum.

The examination of the Truckee formation in the region discussed in this paper has resulted in the conclusion that it contains no paying quantity of petroleum, if any at all. Reasons for this conclusion will be found at the end of the paper.

SITUATION AND TOPOGRAPHY.

The Reno region is situated at the western edge of Nevada and of the Great Basin, near the eastern part of the Sierra Nevada, where Truckee River flows from the mountains into the open plain of the Truckee Meadows. The territory examined lies in the foothills within a few miles of the city of Reno, along the boundary line between the Reno and Carson quadrangles, as mapped by the United States Geological Survey.

The level floor of the Truckee Meadows extends to the east and southeast of Reno, and is bounded within a few miles on all sides by hills and mountains, except at the narrow canyon that gives outlet to Truckee River through the Virginia Range on the east. The elevation of the meadows is 4,500 feet above the sea. To the west the plain narrows in the vicinity of Reno, and is continued upward toward the base of the Sierra Nevada by the valley of the Truckee. This valley is bordered on the north and south by several interrupted terraces at different levels and by foothill ridges that slope with gentle incline up to the foot of the steep, rough faces of the mountain blocks that form high spurs of the Sierra Nevada. This summit slope of the hills is itself an old terrace, being the highest and most widespread one. It begins at an elevation between 300 and 400 feet above the river, and its upper limit is in some places as much as 800 feet above the valley. The mountains rise several thousand feet higher, the Peavine Mountain block to the north and the Carson Range block to the south of Truckee River.

GEOLOGY.

GENERAL OUTLINE.

The geologic column of the Reno region is noteworthy for its incompleteness, most of the periods of past time being unrepresented in the rocks. Portions of the Tertiary and Quaternary alone are recorded in unaltered sedimentary beds, and even these do not afford, so far as yet found, evidence of their exact age.

The main topographic divisions of the region correspond to areas of diverse geology. The mountains present the oldest rocks, which are igneous and metamorphic. The terraced foothill belt, with the exception of a thin surface coating of gravel, is formed of upturned middle Tertiary sedimentary beds, the abrupt transition between the gentle ridges and the steep mountains being approximately coincident with the contact between these beds and the older rocks. The valley and lower hill slopes are covered by horizontal sedimentary deposits of much more recent age. In the present connection the middle Tertiary beds are of prime importance.

For a more general account of the geology of this portion of Nevada the reader should consult the reports of the Fortieth Parallel Survey,[a] in which some of the features of the region are discussed, and a recent paper by G. D. Louderback,[b] which is devoted to this region in particular.

THE BED-ROCK COMPLEX.

The oldest rocks in the Reno region are those forming the mass of Peavine Mountain and the axis of the Carson Range. They are described by Louderback in the paper above cited under the designa-

[a] Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 849; vol. 1, 1878, pp. 412 et seq.

[b] General geological features of the Truckee region east of the Sierra Nevada: Bull. Geol. Soc. America, vol. 18, 1907, pp. 662-669.

tion "Bed-rock complex" as consisting "chiefly of granitic rocks, largely granites (in part granodiorites), with residual masses of more or less metamorphosed sedimentary and igneous rocks into which they were intruded." This complex was classed as Archean by the geologists of the Fortieth Parallel Survey, but is more probably of much later origin, as is stated by Louderback, the metamorphic rocks being Paleozoic or Mesozoic, or both, and the intruding granitic rocks of the same age as those of the Sierra Nevada. There is reason to believe that the complex corresponds to the "Bed-rock series" described by various geologists in the Sierra Nevada. Good exposures of the fresh granite appear in the rocky hills bordering the river valley 5 miles west of Reno.

TERTIARY VOLCANIC ROCKS.

The rocks overlying the bed-rock complex are lavas and mingled products of volcanic eruptions. They were probably formed during the Tertiary period after a long interval during which the older rocks had formed a land surface in this region. As a consequence of the granite intrusions, the deformation of the older rocks, and the long period of erosion, the volcanic rocks rest upon the bed-rock complex unconformably.

The lava is andesite, varying in mineralogical character from place to place. It is intermingled with locally indurated agglomerate formed of tuff and angular and rounded fragments of lava of all sizes up to huge bowlders. These rocks are well exposed near the head of Alum Creek, about 4 miles southwest of Reno, and form the entire face of the Carson block to the northwest and to the south from that point. Basalt of late Tertiary or Pleistocene age, dating from a period after that in which the Truckee formation, next to be described, was deposited, occurs about 8 miles up the river west of Reno, but not within the immediate area here described.

TRUCKEE FORMATION.

Occurrence and correlation.—The single terrane of unaltered sedimentary beds in the Reno region that is known certainly to be older than the Quaternary comprises 2,100 feet or more of diatomaceous earth, sand, original and reworked tuff, clay, gravel, and minor lignitic beds. These strata occur in a monocline dipping at medium angle away from the mountains toward the Truckee Meadows. They make up an apparently continuous, conformable succession, which, though it is divided into several zones characterized by a somewhat different grouping of various sediments, may be regarded as one formation. The formation lies upon the andesite, and was built up during the period succeeding that in which the major portion of the andesitic eruptions took place.

The Truckee formation is continuous, though only here and there exposed, over an area of 15 to 20 square miles just west of Reno. It is coextensive with the foothill area for 5 miles west of Reno, for about 2½ miles north and 1 to 2½ miles south of the river. It is continuous in the hills on the west side of the Truckee Meadows south of Reno, and is to be found also in the hills bordering the river valley around Verdi, 10 miles west of Reno; in Spanish Spring Valley, Lemmon Valley, and other basins to the north of the Truckee Meadows; and, according to Louderback, in the summit region of the Virginia Range south of the point where that range is cut by Truckee River.

These beds were correlated by Clarence King [a] with similar deposits that are widely scattered over the western portion of the Great Basin and were classed together by him under the name Truckee group. He concluded that the beds of this "group" were formed in Miocene time in a vast fresh-water lake which he named Pah Ute Lake. He considered them to be contemporaneous, if not continuous, with the beds of the John Day Valley in Oregon. He described a typical occurrence of them at the north end of the Kawsoh Mountains and the south end of the Montezuma Range, to the west of the Carson and Humboldt Sink, about 50 miles northeast of Reno, where they measured 2,300 feet in thickness. As a whole, he considered the beds to be not less than 4,000 feet thick. Evidence of their age is scanty as yet. They may belong to the late Eocene, the Oligocene, or the Miocene. Similar beds occur in isolated areas in many portions of western Nevada, being exposed chiefly along the margins of the basins. Lindgren [b] has described beds in the mountains across the California line to the west of Reno, which probably belong to the same formation, and which he considers to have been formed as lake deposits. They occupy small areas in the branch valleys of Truckee River, are slightly tilted, and consist of tuff, yellowish sand and clay, thin seams of impure lignite, and brilliant white deposits containing diatoms, but considered by him to be volcanic ash. The description suggests that these beds are very similar to the diatomaceous earth and other sediments of the Truckee formation near Reno. Turner [c] has described a very thick terrane in Esmeralda County, in southwestern Nevada, under the name Esmeralda formation, which the meager evidence obtainable places in the middle Tertiary. He ascribes a lake origin to the formation and suggests that it may be a continuation of the Truckee. Spurr,[d] in

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[a] Rept. U. S. Geol. Expl. 40th Par., vol. 1, 1878, p. 412 et seq.

[b] Lindgren, Waldemar, Truckee folio (No. 39), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

[c] Turner, H. W., The Esmeralda formation: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 191-208.

[d] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. U. S. Geol. Survey No. 208, 1903.

giving a general map of the formations of southern and central Nevada, follows this suggested correlation.

Structure.—The Truckee formation dips away from the mountains at an average angle of at least 20°. The dip varies locally, without any system of variation that has been discovered, from 35° to 12°, but these extremes are rare, the usual dip being between 20° and 27°. Southwest of Reno the beds dip to the northeast, but northwest of the town they dip more to the east or southeast, thus forming a broad syncline or downward warp in the general monocline, with its axis along the valley of Truckee River. West of the mouth of Hunters Creek, however, which is about 4 miles upstream from Reno, the valley appears to diverge to the northwest from the course of this axis. In the region of Verdi, a few miles farther west, the beds dip in the opposite direction—southwestward or westward—so far as observed, and it is therefore probable that they formerly extended in an anticlinal fold over the region between. The anticline is believed to have resulted from a combination of folding and faulting.

Throughout the Reno region the Truckee formation is traversed by an intricate system of small faults with throws of only a few inches or feet. Almost every exposure of the beds displays a number of such faults forming a network of small displacements. The faulting is almost invariably of the normal type, and the hade is usually between 45° and the vertical. Though these faults traverse the strata in all directions and the beds are thrown down variously, it is believed that in most of the faults the hade is in a general westward direction and that there is a considerable resultant downthrow to the west. In consequence, much duplication of the beds is brought about and the thickness of the strata composing the monocline is exaggerated in appearance.

Lithology and thickness.—The best exposures of the Truckee formation in the Reno region are obtainable along the two flumes that follow different contours in the hills south of the river. By means of these and other exposures in the vicinity, a section was obtained from the base of the formation on Hunters Creek to the highest beds exposed, about 2 miles southwest of Reno and one-half mile east of the Washoe Oil and Development Company's well. The different zones appearing in the formation in this section may be described as follows, from the base upward:

Zone A (100+ feet). The pre-Truckee andesite is overlain by a zone of tuff and agglomerate, in which no well-marked stratification or certain indication of its relation to the overlying beds has been found. It is believed to have been deposited subaerially. It may or may not be properly considered as a portion of the Truckee formation.

Zone B (600+ feet). Within 100 or 200 feet above the andesite, definite stratification begins in alternating, fairly thin beds of tuffaceous sand and grit, gravel and clay. Several thin layers of white, impure diatomaceous clay appear. The beds are of many different varieties and are locally variable, and in some of them many ingredients are intermingled. Fine material predominates, but in several there are scattered pebbles reaching a diameter of several inches. The sand is composed chiefly of somewhat rounded crystals of feldspar and ferromagnesian minerals. Some of it has the bluish color common in tuffaceous beds, but the predominating color of this zone is a whitish gray. The color varies, however, with the individual beds and the sand assumes a yellowish cast, especially toward the top. In general, the bedding is well defined, but the banding within the beds is irregular. The sand and pebble layers are in many places cross-bedded. Here and there many impressions of plants, like reeds or rushes, appear in the fine-grained beds.

Zone C (500+ feet). Zone B grades upward into a zone not markedly differentiated from it. The chief difference is that diatomaceous and argillaceous beds increase in quantity and alternate in thin zones with sand. Most of the fine-grained beds are whitish diatomaceous earth like that occurring in zone D but for the most part not so pure. This material occurs here in thin, rather irregular laminæ and is soft and flaky, though fairly compact. It contains numerous elongated flat impressions grouped together thickly and overlying one another which are, with little doubt, marks of reeds or rushes. Locally, there may be found traces of leaves, black carbonaceous specks, and brown lignitic discolorations. A few delicate fragments resembling bones were found in the sand, but they are not certainly bones. The fine-grained layers increase in number toward the top of the zone. Sand, grit, and pebble beds similar to those in the zone below occur, but the brownish-yellow sand predominates and is, in fact, the most abundant type of sand in the formation as a whole. It is a very porous, friable, usually fine sand, with even, subangular grains of differently colored crystals. The pebble beds occur sparingly and the pebbles are not coarse. A few beds of sand are somewhat indurated.

Zone D (500+ feet). Zone C is succeeded by a fairly distinct zone composed almost entirely of white diatomaceous earth or shale, of which the diatom skeletons form the principal constituents. A few thin seams of fine yellow sand, usually hardened by an abundance of iron oxide, appear as mere partings, but the quantity is almost negligible. The diatomaceous earth varies in color from cream to pure white and is dazzlingly bright in strong sunlight. It occurs in pure massive and homogeneous deposits, through which continuous lamination planes are not traceable; in thick beds that are roughly laminated; and in thin beds with sharp partings. The material of the massive beds splits conchoidally in all directions, whereas the more laminated varieties have a somewhat shaly fracture. The earth is compact and coherent, yet porous and soft enough to be easily crushed or cut into any shape. It is so light that it floats on water. The powder that rubs off the surface is smooth and fine like flour, and leaves a similar white dust on the hands. The purest of the material contains no grit whatever, but in much of it a slight amount of the very finest grit may be detected between the teeth. Impressions of marsh plants occur as described in the lower zones, the organic matter being entirely removed or else left only in the shape of a brown stain or thin film of carbonaceous matter. Remains of leaves of deciduous trees have been found sparingly. The cracks and lamination planes in these beds are in places followed by layers of iron oxide.

This diatomaceous earth is almost exactly like the softer varieties of the well-known Monterey shale and the diatomaceous beds of other formations in California. It differs chiefly in the fresh-water instead of marine character of the diatom species that compose it. None of the porcelaneous or flinty beds characteristic of the Monterey and other formations of California have been found here, but some of the beds are sufficiently compact and distinctly bedded to be termed shale.

These beds described as diatomaceous earth no doubt contain considerable fine silt, and some beds include minor quantities of volcanic ash, but as a whole they are unusually pure. Continuous exposures of several hundred feet of the pure-white beds of this zone are afforded by the railroad cut north of Truckee River, about 4 miles west of Reno. There some layers of gritty grayish-white volcanic ash composed of angular needles are interbedded with the white earth and grade into it. The exposures of zone D are excellent on the line of the section along the flume for half a mile or more west of the Washoe Oil and Development Company's well, its contact with the zone above being exposed just north of the well.

Zone E (75+ feet). The beds of zone D are sharply but conformably overlain by a zone composed almost exclusively of coarse and fine yellowish sand, like that of zone C. One bed of coarse sand, about a foot thick, is stained brownish black by iron and manganese oxide, making it look like oil-stained sand. The beds vary from mere laminæ to layers several feet thick and are sharply marked off from one another by banding due to changes in material and texture. There are some clay seams and a few layers of impure diatomaceous earth. In places the sand is roughly aggregated and contains lenses of gravel. A thin layer of impure lignitic cross-bedded material was observed.

Zone F (275+ feet). Zone F is a continuation of beds like those of the zone below, but contains a greater proportion of clay and diatomaceous earth. In general aspect the outcrops present a white or yellowish-gray color, but the individual beds exhibit a variety of shade, texture, and character. The fine-grained beds show all gradations between sand, micaceous gritty and earthy clay, and diatomaceous earth, different varieties being interlaminated. At the base of this zone and at points higher up in it there are minor zones, several feet in thickness, of white diatomaceous earth, usually somewhat gritty and impure.

Zone G (50+ feet). Above zone F the beds cease to be well exposed and the dip is uncertain. Sand like that below is exposed for several hundred feet with an appearance of a low dip, until finally entirely covered up by a thin capping of Quaternary gravel. The highest beds of the Truckee formation exposed in this section are at a point from 1 to 2 miles east of the Washoe Oil and Development Company's well.

The total thickness of the zones described above is 2,100+ feet. The direction along which the section was measured is east-northeast, whereas one taken directly across the strike would trend considerably more to the northeast. It is believed that more duplication of the beds occurs along this line than there would along a line normal to the strike, for the reason that they are probably thrown down more and more toward the west by small faults as the axis of the downfold before mentioned is approached. But it is thought that in any case considerable allowance for such reduplication would have to be made in the estimates of thickness. The apparent thickness of the beds traversed in the section was 3,600 feet. This has been reduced in the above description to 2,100 feet. The amount of reduction proper under such conditions, however, is not measurable, and therefore the thicknesses of the zones as here given are to be considered as only rough estimates of the actual thickness of the beds. They are thought to be conservative. Moreover, there may be a considerable thickness of beds above the highest that were found exposed, which were at the brow of the hills between 200 and 300 feet above and over a mile from the plain of the Truckee Meadows, toward which the beds dip.

The beds of the Truckee formation are by nature variable and in other portions of the Reno region they do not conform exactly to the character displayed in the section described. The basal portion, especially, is variable. The lower part of the formation, 5 miles west of Reno, for instance, where it overlies the granite is composed of roughly aggregated granite and tuffaceous sand, gravel, and breccia, with some layers of fine sand and clay. In the region of the above-described section no granite materials were observed. At the head of the east fork of Alum Creek, about 4 miles southwest of Reno, and in the hills extending from that place toward Reno, the lower portion of the formation contains a larger proportion of diatomaceous earth than was seen in the section described. To take the formation as a whole in the Reno region, it may be said that between one-third and one-half of the total thickness is made up of beds composed largely of diatom remains.

Fossils.—The Truckee formation is poor in fossils by means of which its age may be determined. Impressions of reeds or rushes, a few leaves of deciduous trees, and diatoms are the only remains found at all well preserved in the Reno region. The impressions supposed to be reeds or rushes are very abundant but usually fragmentary and faint. They occur in all parts of the formation in the section above described, especially in the diatomaceous earth, and also in the lignite and diatomaceous beds near Verdi, in Spanish Spring Valley, and elsewhere, being everywhere characteristic of the Truckee. A leaf resembling that of the maple was found in the diatomaceous earth of zone D along the flume about half a mile west of the Washoe Oil and Development Company's well, and other leaf fragments were obtained elsewhere. A small cone resembling a fir cone was brought up in the above-mentioned well from the carbonaceous matter at a depth of 1,540 feet. There are numerous specimens of plant remains in the collection at Stanford University, as was learned through the kindness of Prof. J. P. Smith, which came from tuffaceous beds in the vicinity of Truckee River somewhere "near Reno," the locality not being more definitely specified on the label. The beds are probably part of the Truckee formation. The leaves resemble in a general way those of the birch, service berry (*Amelanchier*), manzanita, and willow. The collection contains one pine-cone impression. According to Professor Smith, the leaves are like the Miocene types of the Sierra Nevada and Pacific coast province, and would favor a middle rather than an early Tertiary age for the beds.

The diatom fauna of the Truckee formation is a rich one and many of the specimens are very well preserved. In the Reno region layers and zones of diatomaceous earth occur throughout the formation, and in its center there is a zone many hundred feet thick composed in large part of the siliceous shells of diatoms. Under the microscope this white earth appears as an almost pure mass of diatom remains. Many different species are recognizable in it, all of freshwater types. Similar enormous deposits of diatomaceous earth are characteristic of the Truckee formation elsewhere.

According to Clarence King, in his description above cited, 46 distinct species of diatoms were found by Dr. C. E. Ehrenberg in specimens of similar diatomaceous earth from Nevada. King reported the finding of fresh-water mollusks in a limestone bed in the middle of the Truckee at the type locality west of the Carson desert. A rhinoceros tooth and leaves were found there also. Fish remains are reported by Louderback from beds of this formation east of the Virginia Range.

Origin.—The Truckee formation was assumed by Clarence King to indicate that a fresh-water sea spread over western Nevada, and even far beyond its limits to the north and south, during middle Tertiary time. A simpler explanation, however, that is believed to be more in accordance with the evidence that has been found may be proposed to account for the presence of these beds in the portion of Nevada around Reno. The abundance of remains of grasslike plants characteristic of a marshy habitat and the occurrence of lignitic layers at different horizons indicate that much of the sediment was laid down on marshy ground where reeds and rushes grew. The broad leaves and the stems of these plants, mingling with the fine sediments that were washed in and with the remains of the diatoms that lived in the water, were preserved in the layers of ooze thus formed, and even helped to build up the deposits. At times these plants accumulated in especial abundance to form peat. The abundance of the diatoms is in accord with this theory of the origin of the deposits, for these organisms are known to be notably prevalent in sheets of shallow fresh water and over marshy tracts. At the present day their skeletons may be found accumulating in such places and forming deposits. The features that have been described, coupled with the local variability and irregularity of stratification of many of the beds, indicate that the greater portion of the terrane was deposited over the surface of a watery plain that may at times have been inundated to form a lake and at other times have been dry.

That the beds were not chiefly formed in a lake is indicated further by the usual lack of the remains of animal organisms such as inhabit lakes, by the absence of changes in the character of the sediments such as would be expected in lake deposits at different distances from the shore, and in general by the shallow-water or surficial rather than deep-water nature of the beds. The character of the materials proves the proximity of the source of supply, and the accumulations of leaves of deciduous trees and other tree remains indicates nearness of the dry land. The manganese and iron oxides permeating many of the sands suggest a bog origin. The cross-bedding and rough intermingling of sediments common in the coarser material give evidence of deposition by streams. Louderback, in his paper before cited, says that the basal beds near Reno "show several alternations of distinct lake sediment and alluvial material or wash each a few feet or yards thick," and concludes that the lake in which he considers the beds to have been deposited fluctuated in areal extent and probably occupied "an interior basin without outlet (at least part of the time) similar to the Quaternary Bonneville or Lahontan."

The principal materials making up the Truckee formation are the innumerable diatom tests and other plant remains, little-worn crystalline grains derived from the erosion of not far distant lava and tuff, grains derived by erosion from the various older rocks, and tuff from the eruption of volcanoes in action at the time the beds were formed. These materials were accumulated through the direct deposition of the organic remains, by means of streams that spread widely over the plain, and by the wind.

It is hard to believe that such a thick series of beds could have been formed continuously over the vast territory of the hypothetical Pah-Ute Lake. It would seem that the difficulties of explaining the subsidence of this area so as to accommodate a series so great, the position of a source of supply for sediments such as those of the Truckee formation, the development of the later physical features, and the whereabouts of the enormous quantities of material that would have had to be removed to leave only the present small patches of these beds, not to speak of other questions involved, would preclude the possibility of such a hypothesis. It is more probable that during the general Truckee period conditions more or less similar prevailed in several or many different basins within this broad region, these basins and their bounding ranges being developed in some degree as they are to-day, and that basin deposits were formed in each as they are forming now. The conditions of sedimentation differed chiefly from those of the present in that the moister climate of middle Tertiary time favored the presence of fens and marshes, streams, and temporary lakes. The basins probably underwent a process of gradual subsidence with respect to relatively rising mountain blocks that hemmed them in.

LATER GRAVELS.

The foothills, river terraces, and valley in the Reno region are covered almost everywhere with a mantle of gravel that has been deposited since the tilting and partial removal by erosion of the Truckee formation. They lie nearly if not quite horizontal and represent a relatively recent geologic period, being for the most part Quaternary. No evidence has been obtained, however, bearing on the age of all of these deposits, and late Tertiary beds may be present beneath the valley floor as well as in places at the surface. It is believed that these gravels accumulated during long periods of time through the agency of streams over former valley floors and as alluvial deposits, and that they do not necessarily indicate that lakes occupied the region during certain periods, though it is not improbable that bodies of water existed at times.

Approximately horizontal, stratified gravel deposits having a thickness of at least 50 feet occur at various places in the valley of Truckee River and around the edge of the Truckee Meadows. An excellent exposure occurs on the north side of the valley between 1 and 2 miles west of Reno, where the beds are cut by a normal fault having a throw to the west of 20 to 30 feet.[a] These beds may be either late Tertiary or Pleistocene in age.

The terraced surfaces of the foothills in the Reno region are covered with a variable deposit, only a few feet in thickness, of coarse and roughly aggregated gravel with rounded and angular fragments, sand, and some clay. The gravel is full of bowlders of all shapes which range in diameter up to several feet and which weather out and strew the surface. In places the deposit is very thin, and allows the underlying Truckee formation to appear; elsewhere it has a thickness of 15 feet or more. In the higher hills a surface talus of angular blocks appears here and there.

The lower terraces are capped by irregular gravel deposits of more recent age than the main portion of the deposits already described. In some places the surface is literally one mass of huge loose bowlders.

ECONOMIC DEVELOPMENTS.

The opinion has spread among various persons interested in the Reno region that petroleum will be obtained from the strata in this vicinity. Accordingly, a number of claims have been taken up and companies have been formed with a view to prospecting for the oil. One of these, the Washoe Oil and Development Company, started drilling a well in August, 1907. In November, 1908, when the well was visited by the writer, it had reached a depth of 1,890 feet, but drilling had been suspended, temporarily at least, at that time. The well is situated on the brow of one of the ridges of the foothills, a little over 2 miles southwest of Reno, a mile south of Truckee River, and at an elevation of about 300 feet above it, in the SE. ¼ sec. 21, T. 19 N., R. 19 E. (Mount Diablo base line and meridian). The following is the log of the well, as furnished by the company:

[a] See photograph and description of interesting features in the paper by G. D. Louderback (Bull. Geol. Soc. America, vol. 18, 1907, pp. 662-669).

Log of well No. 1, Washoe Oil and Development Company.

	Feet.
Conglomerate	10
Sand	105
Blue chalky shale	140
Chalky shale	205
Blue chalky shale (water at 225 feet)	230
Blue shale	280
Caving blue shale	340
Shale	370
Blue shale	540
Sticky blue shale	570
Blue shale	660
Blue shale, a little lighter	730
Blue shale	790
Blue shale, lighter	810
Blue shale	830
Hard shale	840
Blue shale	945
Light-blue shale	970
Caving blue shale	980
Blue shale	1,135
Brown shale	1,173
Sand and hot water (water rises within 200 feet of surface)	1,200
Sticky brown shale	1,208
Brown shale	1,230
Blue shale and a little sand, with water	1,250
Blue shale, showing a little oil	1,270
Water sand	1,300
Brown sand and shale	1,325
Shale and conglomerate, some very hard	1,350
Sticky blue shale	1,365
Brown shale, with a little sand	1,370
Brown shale, with hard layers	1,375
Blue shale	1,385
Brown shale	1,407
Blue shale	1,410
Brown shale, with a little sticky blue shale	1,447
Blue shale	1,460
Dry sand	1,470
Blue shale	1,475
Brown shale	1,515
Sand, with water	1,520
Blue shale	1,530
Brown shale	1,540
Streaks of coal	1,545
Brown shale, with streaks of sand and blue shale, caving and running	1,600
Brown shale	1,695
Blue shale and a little sand, with water and a little oil	1,710
Blue shale	1,890

The well is very near the contact between zones D and E in the geologic section before described. For the first 10 feet or so the well was drilled through the Quaternary gravel at the surface; the next 95 feet mentioned in the log are thought to be the basal beds of zone E, and the "shale" beds below that are the diatomaceous earth of zone D. The well probably does not penetrate any beds lower than zone C, and considering the supposed duplication of the strata by faulting, it might doubtless go much farther down without reaching the base of the formation. Of the oil stated in the log to have been discovered in the drilling, the present writer has no personal knowledge. No gas is struck in the well, except possibly some hydrogen sulphide. A sample of the mud from the bottom of the well was brought up by the bailer at the time of the writer's visit. It was a fine-grained dark-gray gritty clay, full of mica particles. Though the bailer was brought up through cold water, its contents were still steaming and heated to over 90° F., indicating that the temperature at the bottom was considerably greater.

The operations connected with the drilling were for the most part not difficult. The strata were penetrated easily and only an occasional very thin hard layer was encountered. The 12½-inch and 10-inch casing was inserted at once after drilling, no underreaming being necessary. Some difficulty was experienced with caving sand and mud and in shutting off the water. An average of 25 to 30 feet was drilled through each twenty-four hours.

CONCLUSIONS AS TO THE OCCURRENCE OR NON-OCCURRENCE OF PETROLEUM.

The question whether or not oil will be found in the Reno region may be limited to the Truckee formation, for that formation alone affords strata in which oil might be reasonably sought in appreciable quantity. From the character of these strata such search is not entirely without reason. The fact that the beds are so rich in diatom remains suggests the possibility that oil might have originated in them as it is believed to have done in some of the diatomaceous beds of California, the diatoms being the supposed source, at least in part. There is, however, no ground for the popular misconceptions that the beds in Nevada are the same as the oil-bearing strata in California and that a continuous petroliferous belt is traceable from the Bakersfield region northward through Nevada. As a matter of fact, no such belt and no close relationship between the formations exists. The beds in Nevada were deposited in fresh water and upon the land, whereas the oil-bearing strata in California were laid down in the sea. The questions as to oil occurrence must be treated independently in the two provinces. Furthermore, the beds in different parts of Nevada are of different age and origin and each locality requires to be treated on its own merits. The conclusions presented below apply to the Reno region only. They are not claimed to be more than the individual opinion of an unbiased observer.

It is believed that the Truckee formation does not contain petroleum in paying quantities, if at all. The following are the principal reasons for this conclusion:

(*a*) No indication of the presence of oil has been discovered in the beds at the surface, although they are tilted and the succession is exposed as a whole in such a way that some of the oil could hardly fail to escape to the surface and leave a trace, if any were present. Moreover, the completely permeating system of small faults would furnish further avenues of escape. The supposed indications of oil that have been reported by previous observers are iron, manganese, and vegetable stains in certain strata and on the surface of standing pools of water in the vicinity.

(*b*) The structure of the beds is that of a monocline of considerable dip, at the base of which the oldest beds of the formation are exposed overlying andesite and older rocks of the mountains. A large amount of the formation that was originally deposited and upheaved has been removed by erosion, including the upward fold of the beds that probably once arched over toward the west into the southwestward-dipping strata of the Verdi region. That fold, even if imperfect, would most probably have contained the greatest concentration of the oil if any had been present.

(*c*) The monoclinal structure, the truncated and intricately faulted condition of the strata, and their general softness and porosity would favor diffusion and escape of the oil rather than its accumulation in large quantities if any were present.

No definite reasons can be given for the failure of the diatomaceous beds of the Truckee formation to produce petroleum, while the diatom content of the original petroliferous formations in California is thought to have been the source of much of the oil there. Some persons have expressed the opinion that oil is never produced in fresh-water beds. The reason for its absence in this region is probably not to be sought, however, in the inability of fresh-water organisms to produce oil, but rather in the manner in which the beds were laid down and the conditions to which they were subjected after their deposition. The diatomaceous beds of the Truckee are thought to have been formed in marshes and shallow bodies of water, the nearness of the sediments to the surface causing them to be exposed to conditions favoring decomposition and escape of the organic matter they contained. The manner of deposition of the marine beds in California, on the other hand, must have been very different, owing to the depth of burial of the organisms, the possibly greater rapidity of burial, and the chemical constitution of the sea water. Moreover, the partial alteration of the beds in California through pressure, heat, and other causes may have furthered the process of distillation of the oil, whereas the soft beds of the Truckee formation have suffered little change.

TWO AREAS OF OIL PROSPECTING IN LYON COUNTY, WESTERN NEVADA.

By Robert Anderson.

INTRODUCTION.

One well is being drilled and considerable prospecting for oil is going on in Lyon County, western Nevada, in the valleys adjacent to Walker River. In November, 1908, two days were spent by the writer in examining the portions of this county in which interest centers, namely, the region east of Wabuska near the great northerly bend of Walker River and the region of Smiths Valley north of Wellington. These regions are included in the Wabuska and Wellington quadrangles as mapped by the United States Geological Survey. The purpose of this paper is to outline their physical features [a] and give some details and conclusions regarding the oil prospects.

REGION EAST OF WABUSKA.

The examination was confined chiefly to the basin-like valley in which the Yerington Oil and Gas Company is drilling a well, 7 to 10 miles east of Wabuska and north of the bend of Walker River. This valley is fairly typical of a number of similar basins that form elbows in the valley of the river. The basin is surrounded by mountains formed of andesite and volcanic agglomerate, fringed with a superficial deposit of incoherent lake sediments along an old terrace level of Lake Lahontan. The basin has a fairly level floor with a surface covering of fine sand and clay. Along the river there are exposures of 20 feet or more of horizontally stratified fine light sand and sandy clay, some of which is cross-bedded. The age of this material is probably Quaternary. These unconsolidated deposits, mingled with coarser fragmentary matter, form the floor of the valley. The fact

[a] Some features of the geology of this portion of Nevada have been touched upon in the following publications:

Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: Mon. U. S. Geol. Survey, vol. 11, 1885.

Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: Bull. U. S. Geol. Survey No. 208, 1903.

Smith, D. T., The geology of the upper region of the main Walker River, Nevada: Bull. Dept. Geology Univ. California, vol. 4, No. 1, 1904, pp. 1-32.

that knolls of the lava which forms the foundation of the valley protrude above the floor of the basin, in places very near the river, points to the conclusion that the sediments filling the basin nowhere exceed a few hundred feet in depth. Such being the geologic character of the region, it doubtless contains nothing to warrant the expenditure of money in the search for petroleum, there being no strata that might be expected to yield an appreciable quantity of oil.

Those interested in the drilling operations in this region state that they obtain oil by the chloroform test from the dirt and from the "shale." The lava in the hillocks that rise above the surface of the basin, as above mentioned, has in places a marked platy cleavage and has been taken to be shale. The following log of the well which is being drilled in the center of the basin was furnished November 12, 1908, by the Yerington Oil and Gas Company:

Log of Yerington Oil and Gas Company's well east of Wabuska, Nev.

	Feet.
Sand and water	40
Blue clay	60
Sand	65
Sand and clay	130
White sand and water	140
Clay	150
Caving sand	240
"Porphyry white" (?)	248
Black rock	262

The hard dark rock at the bottom through which the drill had already penetrated 14 feet, is a porphyritic igneous rock which there is every reason to believe is in place.

SMITHS VALLEY.

Smiths Valley, which is situated in the southeastern arm of Lyon County on the border of Douglas County, is typical of the intermontane basins of Nevada. It is a deep, elongated valley several miles wide between two north and south mountain ranges, the Pine Nut Range on the west and the Singatse[a] Range on the east. The latter swings around the north end of the valley at the mining camp named Buckskin and converges with the Pine Nut Range, narrowing the valley to a defile that leads up to a low pass at its head. The valley opens out somewhat on the southeast toward Wellington, where it is crossed by Walker River, which comes out of a deep canyon at the south end of the Pine Nut Range and flows through a gap in the Singatse Range on the east.

[a] According to Dwight T. Smith, in the paper above cited, this has been found to be the Indian name of the range. In the bulletin by Spurr it was referred to as the "Smith Valley Range."

The Pine Nut Range presents an abrupt escarpment toward Smiths Valley all along its straight eastern flank. The range is with little doubt a fault block uplifted along this scarp. No foothills intervene between mountain and plain, but the sharp angle between them is softened by fairly steep slopes of talus and alluvial fan deposits. The range is high and massive. It is composed chiefly of granitic and porphyritic igneous rocks, to judge from the débris deposits at the base.

The Singatse Range, on the east side of the valley, is of very different character. It is comparatively low, slopes more gently from the valley, and has an irregularly broken topography and in places pinnacled summits. It is formed chiefly of much-altered limestone intruded by granite and rhyolite and capped with andesite.

The valley floor is remarkably level except where it is encroached upon at the sides by alluvial wash from the mountains and low bluffs of horizontal sedimentary beds. The northern portion of the valley is an inclosed basin, separated by a low rise of ground from the southern portion, which is traversed by Walker River. The drainage of this northern part collects in its center and the lowest portion of the floor is usually somewhat marshy and at times covered with a shallow sheet of water.

On the west side of this basin, at the very foot of the Pine Nut Range, there is a large spring of hot water called Hinds Hot Springs. The water is very pure and leaves no deposit where it issues from the coarse granitic débris at the mountain base. Small streams flow out from it over the meadow. Within a few hundred feet south of the spring cool sulphur water issues from the base of the range and other springs occur elsewhere along the foot. These springs give additional evidence that the east face of the range is a zone of fracturing and faulting.

At numerous places in the valley springs appear near the outer extremities of the alluvial fans. Well-defined stream courses entering the valley are rare and the drainage from the mountains reaches the plain through or under the fans. These springs are apt to be marked by small mounds, probably the result of accumulating vegetation and the retention of wind-blown material at these points.

The deposits that are forming on the surface of the floor are mostly fine grained. At several places exposures of Quaternary sand deposits reveal a considerable admixture of manganese oxide, which probably indicates that the valley was marshy in parts when they were formed, as it is to-day. These black deposits have been mistaken by some person for asphalt. A constant stream of gas issues from the center of the valley floor at one point. The gas burns readily and has been taken as another indication of the presence of oil, but it is probably only a variety of marsh gas.

On the east side of the Smiths Valley basin low bluffs rise above the floor at the edge of a wide terrace or plateau that occupies this side of the valley. The terrace is formed of apparently horizontal strata of light-colored unconsolidated sand and clay, of which a thickness of at least 40 feet is exposed in the bluffs. These beds doubtless underlie the valley floor, having originated as a basin filling in late Tertiary or early Quaternary time. A lake may or may not have occupied the valley at the time of their deposition. It is probable that part of the beds at least represent deposits over the valley floor when it was marshy, similar to deposits that are forming now. According to Russell, Lake Lahontan did not extend into Smiths Valley.

The material of these beds is mostly of fine grain and the stratification massive. Fine sandy clay of light straw color predominates. It contains a great abundance of well-preserved diatom remains and also many small impressions and filaments of vegetable origin. There are also a few remains like those of marsh grasses. Fragments of fossil bones and teeth of large land mammals occur in the sand at the surface of the terrace, having probably weathered out of the beds, but nothing identifiable was found.

It is not known what depth is reached by the sedimentary beds just described. That they have, together with the surface deposits, a thickness in this basin of several hundred feet is very probable. According to Dwight T. Smith in the paper above cited, a thickness of a few hundred feet of these beds is exposed where Walker River cuts across Smiths Valley. The evidences of comparatively recent movements in this region favor the conclusion that the configuration of the basin was determined at no very distant period, geologically speaking, and that the volcanic rocks or older bed-rock series of the original floor underlie the deposits of the basin filling at a depth of not many hundred feet.

The physical features and geologic character of the region are not such as to favor its selection as a possible petroleum producer, and no indications have been found to lend color to the view that oil is present.

ANALYSES OF CRUDE PETROLEUM FROM OKLAHOMA AND KANSAS.

By D. T. Day.

As part of a systematic examination by the same methods of analysis for all varieties of petroleum in the United States, a study has been made of the petroleums of Oklahoma and Kansas, and the preliminary results are given in the tables below.

These samples were collected in March and April, 1908, by J. P. Dunlop. For this purpose Mr. Dunlop was provided with cans which were soldered immediately so as to prevent all chance of evaporation. One gallon was uniformly taken when the sample was collected at the well, and 5-gallon samples were taken from the pipe lines in order to get a large representative sample from each distinct field. The samples were expressed to the Washington laboratory, where the analyses were made.

A set of very delicate specific-gravity spindles was made especially for this investigation, by C. Tagliabue & Sons. The samples were brought to a temperature of 60° in a cylinder cooled in a water bath. The specific gravity was then taken, and the tables show also the conversion of this figure into degrees Baumé. The samples were then distilled by Engler's method as modified by Ubbelohde. Thus 100 cubic centimeters of the crude oil, measured at 60°, were delivered by a pipette into a distilling bulb holding about 125 cubic centimeters. The dimensions of this bulb are those prescribed by Engler. The thermometer used was a nitrogen thermometer reading to 550° C., which had been carefully standardized by the Bureau of Standards. The condenser tube, as prescribed by Engler, was 75 cubic centimeters long and had an inclination of 75°. The point of initial boiling was taken when the first drop of oil fell from the condenser tube into the receiving flask. To avoid loss by evaporation the condenser tube fitted into the graduated receiving flask, which was provided with a stopcock to draw off the oil at 150° and again at 300°. Note was also taken of the proportions boiling within each range of 25°, but these details are not published in the tables given herewith. The fraction between the initial boiling point and 150°, constituting the gasoline fraction, and the fraction between 150° and 300°, constituting the kerosene fraction, were examined as to specific gravity with a picnometer. The residuum was weighed as soon as cool; then its specific gravity was taken in the usual way and the volume calculated. As will be noted, the total thus obtained for the different fractions includes the sum of all variations in the determinations. This total for many samples slightly exceeds 100 per cent, but for a greater number is considerably below that amount, owing to the presence of water—in fact, the percentage of water is thus rather clearly indicated.

The method of Kramer and Bottcher was used for determining the unsaturated hydrocarbons present in the crude oil and in the distillate between 150° and 300°. The amount of gasoline was in many samples too small for systematic determination of the percentage of unsaturated hydrocarbons in it. The method consists in shaking 25 cubic centimeters of the crude petroleum with 25 cubic centimeters of sulphuric acid of specific gravity 1.83, corresponding to ordinary pure sulphuric acid, about the equivalent of that used in petroleum refining. The acid and oil are shaken in a small flask with a long neck, the neck holding 25 cubic centimeters. The flask is then filled with strong sulphuric acid until the oil which remains uncombined with the acid can be measured in the neck of the flask. The loss in volume between the original 25 cubic centimeters and the oil which remains undissolved by sulphuric acid is taken to represent the unsaturated hydrocarbons.

Paraffin wax was determined by the Engler-Holde method, two parts of absolute alcohol and one part of absolute ether being used as the solvent, from which the paraffin wax is precipitated on cooling to −20° C. The asphalt was determined by Holde's method, by weighing off 1 gram of residuum and shaking this with 40 cubic centimeters of gasoline which was free from unsaturated hydrocarbons and which boiled between 65° and 95° C. After shaking this is allowed to stand for forty-eight hours and the precipitated asphalt is dissolved in benzol, dried at 105°, and weighed.

Without any detailed discussion of the results, which are given clearly enough in the following tables, it is hoped that these analyses will be of considerable use to the producers and the geologic students of the individual pools. They will be supplemented later by determinations of viscosity of the crude oils and of percentage of sulphur and a detailed examination of the distillates, including further study of the nature of the unsaturated hydrocarbons. The main purpose of the examination, however, is to afford a comparison of the oils of this region with the oils from other parts of the United States.

Analyses of crude

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Tulsa County.
35	Well	Mar. 27	80	1	J. I. Yorgee lease, Robt. Galbreath, Tulsa.	3	638	Red Fork pool
36	do	do	80	1	do	5	601	do
37	Leader pipe	do	80	1	Van Yorgee lease, Robt. Galbreath, Tulsa.	1-7	1,240	do
38	Well	do	80	1	Missouri Lincoln Trust Co. lease, L. E. Mallory & Son, Tulsa.	1	1,200	do
39	Pipe line	do	80	5	Pump station at Red Fork, Prairie Oil and Gas Co., Independence, Kans.			do
								Creek County.
49	Pipe line	Mar. 28	60		Prairie Oil and Gas Co., Tulsa, Bird Creek district.			Bird Creek and Skiatook pools.
50	Well	Apr. 1	55	1	N. Chisholm lease, Creek and Indiana Investment Co., Sperry.	1	1,420	do
51	do	do	55	1	do	4	1,200	do
52	do	do	55	1	Smith lease, Shawnee Oil Co., Sperry.	1	1,408	Skiatook pool
53	do	do	55	1	do	4	1,412	do
54	do	do	55	1	Chisholm lease, Shawnee Oil Co., Sperry.	2	1,466	do
40	do	Mar. 28	60	1	Grace Berryhill lease, Oklahoma State Oil Co., Kiefer.	9-13	1,500	Glenn pool
41	do	do	50	1	Pittman farm, sec. 7 T. 17 N., R. 12, Argue & Compton, Tulsa.	11	1,500	do
42	Pipe line	do	50	5	Pump station, Prairie Oil and Gas Co., Kiefer.			do
43	Well	do	60	1	Thos. Berryhill lease, Indiana Oil and Gas Co., Kiefer.	7	1,518	do
44	do	do	60	1	Wm. Berryhill lease, Indiana Oil and Gas Co., Kiefer.	15	1,529	do
45	do	do	60	1	W. B. Self lease, Prairie Oil and Gas Co., Tulsa.	23	1,523	do
46	do	do	60	1	do	7	1,553	do
48	do	do	60	1	Corndoffer lease, sec. 18, T. 16, R. 12, Swasey Oil Co., Fort Worth, Tex.	1	2,340	Mounds pool
								Okmulgee County.
55	Settling tank	Apr. 2	50	5	Prairie Oil and Gas Co., Morris.			Morris pool
56	Well	do	50	1	Meridian lease, Brown Oil and Gas Co., Morris.	1	1,600	do
57	do	do	50	1	do	4	1,600	do
58	do	do	55	1	Buchanan lease, Burns & Caton, Morris.	1	1,680	Bald Hill pool
59	do	do	55	1	J. W. Buchanan lease, J. Harmon, Morris.	1	1,703	do
								Muskogee County.
60	Well	Apr. 3	55	1	Evans lease, Julia Oil Co., Muskogee.	1	1,553	Muskogee pool, new field.
61	do	do	55	1	do	3	1,473	do
62	do	do	55	1	K. Stevens lease, Success Oil and Gas Co., Muskogee.	2	1,558	do
63	do	do	55	1	J. W. Siebold lease, Success Oil and Gas Co., Muskogee.	1	1,574	do
64	do	do	65	1	Fort Worth Development Co. lease, of Richmond Development Co., Muskogee.	1	1,702	do
65	do	do	65	1	G. W. Sadler lease, Huckleberry & Co., Muskogee.	3	1,735	do
69	Pipe-line tank.	Apr. 4	70	5	Prairie Oil and Gas Co., Muskogee.			do

petroleum from Oklahoma.

Physical properties: Gravity at 60° F.: Specific.	Physical properties: Gravity at 60° F.: Degrees Baumé.	Physical properties: Color.	Distillation by Engler's method: Begins to boil at (°C.).	By volume: To 150° C.: Cubic centimeters.	By volume: To 150° C.: Specific gravity.	By volume: 150° to 300° C.: Cubic centimeters.	By volume: 150° to 300° C.: Specific gravity.	By volume: Residuum: Cubic centimeters.	By volume: Residuum: Specific gravity.	By volume: Total (cubic centimeters).	Unsaturated hydrocarbons: Crude (per cent).	Unsaturated hydrocarbons: 150° to 300° (per cent).	Paraffin (per cent).	Asphalt (per cent).
0.8368	37.3	Green.......	88	15.0	0.7195	36.0	0.7945	48.5	0.9073	99.5	22.4	....	2.60	0.0
.8323	38.2	Dark green..	93	9.0	.7220	40.5	.7814	48.5	.9038	98.0	17.6	1	4.39	.0
.8413	36.4	.....do.......	90	14.0	.7352	37.0	.7992	48.9	.8855	99.9	22.4	2	6.37	.05
.8358	37.5	Black.......	97	8.0	.7268	44.5	.7882	47.0	.9021	99.5	14.4	3	3.92	.35
.8594	32.9	.....do.......	110	4.0	.7430	38.0	.7948	55.8	.9103	97.8	18.4	1	4.88	.15
.8626	32.3	Dark green..	120	2.0	....	37.5	.8070	60.6	.9003	100.1	29.2	6	7.30	.28
.8495	34.8	.....do.......	100	7.0	.7380	38.5	.8018	52.8	.9021	98.3	29.2	9	2.87	.62
.8563	33.5	.....do.......	122	Trace.	....	40.5	.8030	57.0	.9021	97.5	14.0	11	8.41	.42
.8480	35.1	.....do.......	95	6.0	.7348	37.0	.7898	54.9	.9032	97.9	14.8	7	7.35	.23
.8439	35.9	.....do.......	98	5.0	.7440	36.0	.7858	58.8	.8997	99.8	12.8	10	9.74	.50
.8328	38.1	.....do.......	68	11.0	.7142	32.5	.7968	51.8	.8974	93.3	13.2	10	6.65	.14
.8459	35.5	Black.......	112	7.5	.7464	42.0	.7980	50.0	.9061	99.5	21.2	6	5.41	.11
.8459	35.5	.....do.......	105	8.5	.7566	42.0	.8001	49.9	.9032	100.4	22.8	7	6.98	.45
.8464	35.4	.....do.......	100	4.5	....	46.0	.7942	49.9	.9032	100.4	27.6	9	5.99	.24
.8439	35.9	.....do.......	105	8.0	.7508	44.5	.8008	48.0	.9091	100.5	20.8	6	7.53	.90
.8333	38.0	.....do.......	80	11.5	.7260	43.5	.7964	45.3	.9079	100.3	21.6	4	11.46	.35
.8373	37.2	.....do.......	94	10.0	.7328	41.0	.7968	47.6	.9021	98.6	16.8	5	3.12	.21
.8424	36.2	.....do.......	98	10.0	.7402	42.5	.7990	47.6	.9079	100.1	26.4	6	9.70	.51
.8631	32.2	Bright green.	175	....	....	38.5	.8126	59.9	.8992	98.4	12.4	4	8.44	.62
.8459	35.5	Light green..	112	3.0	....	34.0	.7924	62.1	.8866	99.1	10.0	1	11.90	.0
.8383	37.0	Dark green..	82	10.0	.7260	30.0	.7988	57.1	.8861	97.1	13.6	3	9.46	.0
.8403	36.6	Green.......	75	13.0	.7338	31.0	.8008	56.4	.8895	100.4	13.2	8	6.75	.10
.8531	34.1	Dark green..	110	5.5	.7515	36.0	.8018	58.0	.9003	99.5	20.0	8	3.43	.15
.8578	33.2	.....do.......	131	1.5	....	35.5	.8096	62.4	.8992	99.4	16.4	3	5.70	.76
.8328	38.1	Green.......	97	11.0	.7332	36.0	.7960	52.8	.8866	99.8	15.2	4	7.64	.0
.8264	39.4	.....do.......	83	11.0	.7218	36.0	.7976	51.4	.8855	98.4	16.8	5	6.03	.0
.8314	38.4	.....do.......	93	12.0	.7298	38.0	.7984	50.3	.8861	100.3	15.2	3	2.24	.0
.8343	37.8	.....do.......	90	7.0	.7316	40.0	.7876	52.4	.8861	99.4	16.8	2	1.24	.0
.8333	38.0	.....do.......	90	11.0	.7090	37.0	.7986	51.2	.8861	99.2	16.4	8	1.52	.0
.8348	37.7	.....do.......	98	5.0	.7410	40.0	.7828	54.6	.8855	99.6	16.0	4	6.96	.0
.8358	37.5	Olive green..	99	3.5	.7415	41.0	.7816	55.5	.8838	100.0	17.6	2	12.45	.0

Analyses of crude petroleum

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Muskogee County—Continued.
66	Well	Apr. 4	70	1	Pioneer Oil and Gas Co., Muskogee.	1,2,3	1,000	Muskogee pool, old field.
67	...do	...do	70	1	Connolly well, P. Connolly, Muskogee.	......	1,000	...do
68	...do	...do	70	1	Reeves well, P. Connolly, Muskogee.	......	1,000	...do
								Seminole County.
70	Well	Apr. 6	65	5	Wewoka Realty and Trust Co., Wewoka.	1	1,625	Wewoka pool
								Kiowa County.
71	Well	Apr. 7	65	1	Ricketts lease, Whitewater Oil and Gas Co., Gotebo.	2	365	Gotebo pool
72	Tank	...do	65	2	Seney lease, Deering Oil and Gas Co., Gotebo.	2	443	...do
								Pawnee County.
73	Tank	Apr. 10	60	5	Prairie Oil and Gas Co., Cleveland station.	......	......	Cleveland pool
74	Well	...do	60	1	Laterette lease Test Oil Co., Cleveland.	16	......	Cleveland pool in city limits.
75	...do	...do	60	1	...do	17	......	...do
76	...do	...do	60	1	...do	15	......	...do
77	...do	...do	60	1	Ohio and Indiana Oil Co., Cleveland.	8-9	......	...do
78	...do	...do	60	1	Cory lease, F. M. Martin, Cleveland.	1	1,157	Cleveland Pool Jordan Valley Township.
79	...do	...do	60	1	L. L. Cory lease, J. E. Martin, Cleveland.	1	1,174	...do
80	...do	...do	60	1	Berger lease, Prarie Oil and Gas Co., Independence, Kans.	7	1,800	...do
81	...do	...do	60	1	...do	4	1,750	...do
82	...do	...do	60	1	Lowery lease, Louisiana Purchase Oil Co., Cleveland.	2	1,620	...do
83	...do	...do	60	1	...do	6	1,600	...do
								Osage County.
84	Pipe line	Apr. 11	60	5	Prairie Oil and Gas Co., Bartlesville.	......	......	Bartlesville pool
86	Well	...do	65	1	Lease 31, Colliver Consolidated Oil Co., Markham & Ball, Bartlesville.	5	1,487	...do
87	...do	...do	65	1	...do	6	1,480	...do
88	...do	...do	65	1	Lot 32, Illuminating Oil Co., Bartlesville.	20	1,500	...do
95	...do	Apr. 8	70	1	T. 26 N., Skelton-Moore Oil Co., Bartlesville.	14	1,088	Shallow Sand pool
								Washington County.
85	Pipe line	Apr. 11	60	5	Prairie Oil and Gas Co., Bartlesville.	......	......	Bartlesville pool
89	Well	Apr. 12	70	1	T. 27, Williams lease, Stubbs & Lowe, Dewey.	4	1,200	Dewey and north of Dewey.
90	...do	Apr. 13	70	1	Berger lease, Woodward & Roll, Dewey.	1	525	...do
91	...do	...do	70	1	McEwen lease, Stubbs & Lowe, Dewey.	5	500	...do
92	...do	...do	70	1	Shaler lease, Bartles Oil Co., Dewey.	7	1,250	Webber pool
93	...do	...do	70	1	Stubbs & Lowe, Dewey	2	1,200	...do
94	...do	...do	70	1	(R. C. A.) Adams Oil and Gas Co., Washington, D. C.	1	1,300	...do

from Oklahoma—Continued.

Physical properties.			Distillation by Engler's method.									Unsaturated hydrocarbons.		Paraffin (per cent).	Asphalt (per cent).
Gravity at 60° F.		Color.	Begins to boil at (°C.).	By volume.											
				To 150° C.		150° to 300° C.		Residuum.		Total (cubic centimeters).					
Specific.	Degrees Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.		Crude (per cent).	150° to 300° (per cent).		
0.8216	40.4	Light olive green.	110	5.5	0.7415	46.0	0.7812	43.7	0.8745	95.2	12.0	4	3.88	0.0
.8279	39.1	.....do.......	115	4.0	.7520	48.0	.7856	48.4	.8750	100.4	11.2	2	2.15	.0
.8328	38.1	.....do.......	140	Trace.	....	46.0	.7810	53.2	.8745	99.2	12.4	2	4.91	.0
.8844	28.3	Black........	128	1.5	....	30.0	.8266	67.3	.9067	98.8	30.0	3	6.28	.90
.8480	35.1	Black.......	115	3.5	.7399	46.5	.7828	51.5	.9097	101.5	29.6	15	5.56	1.30
.8552	33.7	.....do.......	128	2.0	....	40.0	.7884	56.9	.9186	98.9	57.2	3	5.01	.31
.8485	35.0	Black.......	97	10.0	.7428	37.5	.8074	53.2	.8980	100.7	34.8	5	6.06	.20
.8516	34.4	Dark green..	100	9.5	.7794	35.0	.8166	55.4	.8980	99.9	38.4	3	7.75	.03
.8542	33.9	.....do.......	115	2.5	.7705	40.0	.8060	55.4	.8992	97.9	35.2	2	6.63	.15
.8516	34.4	.....do.......	103	7.0	.7586	36.0	.8124	56.4	.8980	99.4	39.2	2	7.86	.81
.8516	34.4	.....do.......	117	4.5	.7670	39.0	.8060	55.9	.8980	99.4	34.8	2	6.62	.30
.8464	35.4	.....do.......	110	5.0	.7530	44.0	.7992	48.8	.8974	97.8	32.4	3	5.55	.05
.8403	36.6	.....do.......	108	7.5	.7398	44.5	.7882	48.5	.8974	100.5	33.2	5	5.59	1.18
.8383	36.9	.....do......	80	10.0	.7200	43.5	.7978	47.4	.9056	100.9	38.8	7	5.42	1.12
.8605	32.7	.....do.......	120	1.0	.7603	41.0	.8030	56.9	.8969	98.9	20.4	12	5.68	.92
8459	35.5	.....do.......	85	15.5	.7452	36.0	.8119	49.4	.9032	100.9	26.4	....	4.38	.82
.8669	31.5	.....do.......	140	Trace.	....	39.5	.8139	60.7	.9038	100.2	25.2	4	7.26	.63
.8584	33.1	Dark green..	130	3.0	.7625	39.0	.8116	58.7	.8980	100.7	25.2	2	5.27	.18
.8521	34.3	Black.......	115	3.0	....	43.5	.7818	54.0	.8992	100.5	20.4	9	2.73	1.00
.8505	34.6	.....do.......	105	3.5	.7499	42.0	.7808	51.5	.9044	97.0	30.8	12	2.61	1.34
.8547	33.8	Dark green..	113	3.5	.7574	44.0	.7868	52.4	.9009	99.9	21.0	0	7.90	1.12
.8398	36.7	Black.......	76	11.5	.7101	35.0	.7869	51.9	.9050	98.4	21.2	8	......	1.26
.8521	34.3	Dark green..	103	8.0	.7378	37.0	.8090	54.5	.9038	99.5	24.4	4	3.75	.23
.8605	32.7	.....do.......	103	3.0	....	42.0	.8008	55.7	.9103	100.7	18.8	1	6.07	.47
.8772	29.6	Black.......	128	1.0	.8549	32.0	.7972	63.3	.9024	96.3	38.0	2	3.50	1.43
.8605	32.7	.....do.......	80	9.5	.7299	28.0	.7968	58.5	.9241	97.0	34.8	....	3.68	1.26
.8368	37.3	Dark green..	70	13.0	.7214	32.0	.8008	51.9	.9067	97.9	20.8	4	3.01	.94
.8485	35.0	.....do.......	98	6.0	.7339	40.0	.7928	53.9	.9079	99.9	20.5	11	6.81	.99
.8547	33.8	.....do.......	95	7.5	.7559	39.0	.8128	53.1	.8906	99.6	30.8	14	2.26	.85

Analyses of crude petroleum

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Rogers County.
96	Well	Apr. 14	60	1	T. 24, R. 17, Horace M. Adams, Chelsea.	12	400	Alluwe pool
97	do	do	60	1	do	11	400	do
98	do	do	60	1	Sec. 16, T. 24, R. 16, Steuben lease, H. M. Adams, Chelsea.	38	500	Chelsea pool
99	do	do	60	1	Sec. 14, T. 24, R. 16, Bennett lease, H. M. Adams, Chelsea.	1	498	do
								Nowata County.
100	Well	Apr. 14	60	1	Sec. 35, T. 27, R. 16, Susan Connor lease, New York and Pennsylvania Oil Co., Nowata.	1	735	Childers pool
101	do	Apr. 15	65	1	Sec. 8, T. 26, R. 16, Jane Claggett lease, F. D. Bailey, Nowata.	3	750	do
102	do	do	70	1	Sec. 31, T. 27, R. 16, Wolf lease, Davis & Berrian, Nowata.	1	812	Delaware pool
103	do	do	70	1	Sec. 33, T. 27, R. 16, Edgar Bean lease, Van Vleck & Graham Oil Co., Nowata.	4	830	do
105	Pipe-line tank	do	75	5	Prairie Oil and Gas Co., Station 40, Nowata.			Delaware and Childers pools.
								Nowata and Rogers counties.
104	Pipe line	Apr. 15	75	5	Prairie Oil and Gas Co., Station 38, Nowata.			Shallow Sand pool.

Analyses of crude

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Montgomery County.
106	Well	Apr. 16	60	1	Gilroy lease, Brown Brokerage Co., Coffeyville.	1-15	600	Coffeyville pool
107	Settling tank	do	60	2	M. Davis lease, Dunkley & Odell, Coffeyville.	1-40	625	do
113	Well	Apr. 18	70	1	J. Hall lease, Lynch & McSweeney, Wayside.	1-2	800	Wayside pool
114	Settling tank	do	70	2	do			do
115	Well	do	70	1	G. L. Bank lease, Miller Rider & Co., Independence.	4	1,180	Bolton pool
116	Pipe-line tank	do	70	5	Prairie Oil and Gas Co., station 5, Independence.			do
								Chautauqua County.
108	Pipe line	Apr. 17	60	5	Prairie Oil and Gas Co., Peru station, Independence.			Peru pool
109	Well	do	60	1	F. G. Hill's lease, Interstate Oil and Gas Co., Peru.	1-2	1,070	do
110	Settling tank	do	60	1	Hill's lease, Central Pool Oil Co., Peru.	1-12	1,100	do
111	Well	do	60	1	Interstate lease, Pittsburg Oil and Gas Co., Peru.	1	1,100	do
112	do	do	65		do	6	1,100	
								Elk County.
117	Well	Apr. 18	65	1	Allen County Investment Co., Longton.	2	585	Longton pool
118	Settling tank	do	65	2	do			do

from Oklahoma—Continued.

Physical properties. Gravity at 60° F. Specific.	Physical properties. Gravity at 60° F. Degrees Baumé.	Physical properties. Color.	Distillation by Engler's method. Begins to boil at (°C.).	By volume. To 150° C. Cubic centimeters.	By volume. To 150° C. Specific gravity.	By volume. 150° to 300° C. Cubic centimeters.	By volume. 150° to 300° C. Specific gravity.	By volume. Residuum. Cubic centimeters.	By volume. Residuum. Specific gravity.	Total (cubic centimeters).	Unsaturated hydrocarbons. Crude (per cent).	Unsaturated hydrocarbons. 150° to 300° (per cent).	Paraffin (per cent).	Asphalt (per cent).
0.8413	36.4	Dark green..	67	10.0	0.7134	33.0	0.7910	54.2	0.9091	97.2	21.2	9	6.14	0.55
.8413	36.4	Greenish blk	65	15.0	.7245	32.0	.7995	50.1	.9168	97.1	23.2	9	2.89	4.01
.8511	34.5	.....do.......	80	13.5	.7148	31.0	.8035	54.8	.9168	99.3	26.0	8	9.10	1.26
.8516	34.4	Dark brown.	97	6.0	.7206	35.0	.7924	54.6	.9272	95.6	26.4	13	4.16	2.19
.8449	35.7	Dark green..	80	14.0	.7415	33.0	.8035	51.2	.9090	98.2	38.4	10	4.51	.75
.8439	35.9	.....do.......	78	11.0	.7270	36.0	.8024	51.1	.9091	98.1	22.0	7.5	4.59	.93
.8493	34.8	Light green..	65	16.5	.7435	35.0	.8195	47.4	.9156	98.9	18.4	8	4.18	1.69
.8424	36.2	Dark green..	81	9.0	.7182	38.5	.7966	51.6	.9138	99.1	12.8	10	8.23	1.74
.8500	34.7	Dark brown.	107	3.0	....	42.0	.7918	49.8	.9103	94.8	24.0	3	4.45	.26
.8537	34.0	Black.......	100	7.0	.7380	39.0	.8034	53.8	.9103	99.8	24.4	3	3.04	.12

petroleum from Kansas.

0.8822	28.7	Dark green..	173	......	....	31.0	0.8082	66.2	0.9138	97.2	22.0	....	5.31	0.17
.8717	30.6	Black.......	100	6.0	0.7289	33.0	.8030	58.3	.9241	97.3	24.4	....		
.8696	31.0	.....do.......	75	9.5	.7100	28.0	.8080	58.9	.9396	97.4	35.6	....	4.66	.61
.8838	28.4	.....do.......	81	5.0	.7315	28.0	.7962	66.0	.9290	99.0	50.0	8		
.8424	36.2	.....do.......	72	14.7	.7273	31.0	.8095	49.2	.9365	94.9	20.0	....	(a)	(a)
.8495	34.8	.....do.......	109	7.0	.7358	36.5	.7982	55.6	.9126	99.1	24.0	6	6.31	.55
.8526	34.2	Black........	87	7.0	.7244	32.5	.7934	58.7	.9150	98.2	27.6	5	3.81	.35
.8557	33.6	Dark green..	110	7.0	.7310	37.0	.7975	63.2	.9150	97.2	24.8	....	5.79	1.53
.8521	34.3	.....do.......	80	12.0	.7160	30.0	.7945	55.5	.9138	97.5	24.8	3	5.24	.20
.8454	35.6	Black........	77	11.0	.7218	30.0	.7988	55.3	.9162	96.3	12.4	6	4.54	.42
.8500	34.7	.....do.......	66	13.0	.7177	31.5	.8015	52.5	.9174	97.1	......	3	5.41	.34
.8637	32.1	Black........	98	12.0	.7202	27.5	.7920	59.3	.9229	98.8	29.6	5	7.19	.89
.8631	32.2	.....do.......	96	6.0	.7360	31.0	.7890	59.6	.9198	96.6	30.8	....	4.30	1.56

[a] With No. 119.

Analyses of crude petroleum

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Wilson County.
119	Well	Apr. 20	70	1	D. Johnson lease, Dolly Johnson Oil and Gas Co., Neodesha.	13	800	Neodesha pool
120	do	do	70	1	T. Johnson lease, Prairie Oil and Gas Co., Neodesha.	3	820	do
121	Settling tank	do	70	5	Dolly Johnson Oil and Gas Co., Neodesha.			do
								Allen County.
122	Settling tank	Apr. 20	75	5	McKinley Crude Oil Co., Humboldt.			Humboldt pool
123	Well	do	75	1	McKinley Crude Oil Co., Humboldt, Logan Township.	11	851	do
124	do	do	75	1	Fussman lease, Logan Township, Frank Fussman, Humboldt.	1	850	do
125	do	do	75	1	do	3	850	do
126	do	Apr. 21	75	1	Hedrich lease, I. N. Knapp, Chanute.	6	700	Chanute pool
127	do	do	75	1	Beach lease, Rex Oil and Gas Co., Chanute.	16	751	do
128	do	do	75	1	do	12	737	do
129	Tank	do	75	5	Kansas Cooperative Refining Co., Chanute.			do
130	Pipe line	do	75	5	Chanute Refining Co., Chanute.			do
133	Well	Apr. 22	65	1	Carroll lease, Eastern Kansas Oil Co., Moran.	4	735	Moran pool
134	do	do	75	1	Smith lease, Eastern Kansas Oil Co., Moran.	2	735	do
136	do	do	70	1	Newton lease, E. F. Holman, Moran.	5	735	do
135	Pipe line	do	75	5	Eastern Kansas Oil Co., Moran.			Moran & Bronson pool.
								Neosho County.
131	Tank	Apr. 21	75	5	Webb lease, Northland Oil and Gas Co., Erie.			Erie pool
132	Well	do	75	1	Barger lease, Buckeye Oil and Gas Co., Erie.	2	520	do
								Miami County.
137	Well	Apr. 23	70	1	C. J. Hafey, Paola	4	360	Paola pool
								Franklin County.
138	Well	Apr. 23	65	1	Springer lease, Hardison & Streeter, Rantoul.	1-4	350	Rantoul pool
139	do	do	70	1	Tullows lease, Hardison & Streeter, Rantoul.	6	350	do
140	Tank	do	70	5	Prairie Oil and Gas Co., Pump station, Rantoul.			do

from Kansas—Continued.

Physical properties.			Distillation by Engler's method.								Unsaturated hydrocarbons.		Paraffin (per cent).	Asphalt (per cent).
Gravity at 60° F.		Color.	Begins to boil at (°C.).	By volume.										
				To 150° C.		150° to 300° C.		Residuum.		Total (cubic centimeters).	Crude (per cent).	150° to 300° (per cent).		
Specific.	Degrees Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.					
0.8373	37.2	Dark green..	80	17.0	0.7172	30.0	0.8005	48.6	0.9079	95.6	18.0	....	3.40 (a)	0.08 (a)
.8368	37.3	Black........	88	16.0	.7158	36.0	.7925	47.7	.9091	99.7	20.0	....		
.8568	33.4	Dark green..	135	1.0	....	40.5	.7994	57.0	.9109	98.5	30.0	3	5.79	.10
.8878	27.7	Dark green..	123	1.0	....	29.0	.8152	68.9	.9247	98.9	32.8	2	3.93	2.33
.8895	27.4	Black........	110	3.0	....	29.0	.8142	67.0	.9284	99.0	23.6	6	1.92	2.68
.8822	28.7	.....do.......	108	5.0	.7460	26.5	.8205	67.4	.9272	98.9	29.6	....	2.10	1.03
.8850	28.2	.....do.......	85	3.5	.7515	27.0	.8160	67.2	.9284	97.7	41.2	8	7.92	.39
.8706	30.8	Dark green..	125	3.0	.7500	37.5	.8029	59.3	.9229	99.8	26.0	1	3.78	.89
.8647	31.9	.....do......	109	5.0	.7350	36.0	.7993	57.8	.9223	98.8	24.0	1	4.25	1.23
.8647	31.9	.....do.......	110	6.0	.7375	36.0	.7992	56.6	.9204	98.6	22.4	....	4.71	1.45
.8615	32.5	Black.......	90	7.5	.7156	33.0	.8022	58.7	.9192	99.2	24.0	8	1.45	1.50
.8637	32.1	Dark brown.	113	4.5	.7405	35.0	.7927	57.2	.9174	96.7	24.4	8	4.32	1.15
.8794	29.2	Black.......	95	8.0	.7275	29.0	.8137	61.0	.9358	98.0	19.6	3	1.21	2.63
.8799	29.1	.....do.......	78	10.0	.7105	25.5	.8125	64.8	.9180	100.3	29.2	....	3.48	1.66
.8712	30.7	.....do.......	75	7.5	.7190	25.0	.8135	60.3	.9409	92.8	28.0	....	3.94	2.67
.8589	33.0	.....do.......	106	3.0	.7330	37.0	.7822	59.5	.9192	99.5	27.6	6	4.61	2.32
.8739	30.2	Black.......	135	1.0	....	34.0	.8000	64.1	.9115	99.1	27.2	7	4.78	3.20
.8658	31.7	.....do.......	110	3.0	....	35.0	.7960	61.8	.9162	99.8	23.6	2	1.22	.88
.8511	34.5	Black.......	80	10.0	.7202	33.0	.7964	55.8	.9223	98.8	19.6	8	7.44	2.94
.8557	33.6	Black.......	76	11.5	.7116	29.5	.7950	54.9	.9272	95.9	34.0	....	3.45	2.29
.8750	30.0	.....do.......	136	1.0	....	39.5	.7892	60.1	.9358	100.6	26.0	2	3.98	2.80
.8578	33.2	.....do.......	103	5.5	.7220	33.5	.7850	59.7	.9217	98.7	26.4	6	4.34	1.93

[a] Also No. 115.

THE MADILL OIL POOL, OKLAHOMA.

By J. A. TAFF and W. J. REED.

INTRODUCTION.

LOCATION.

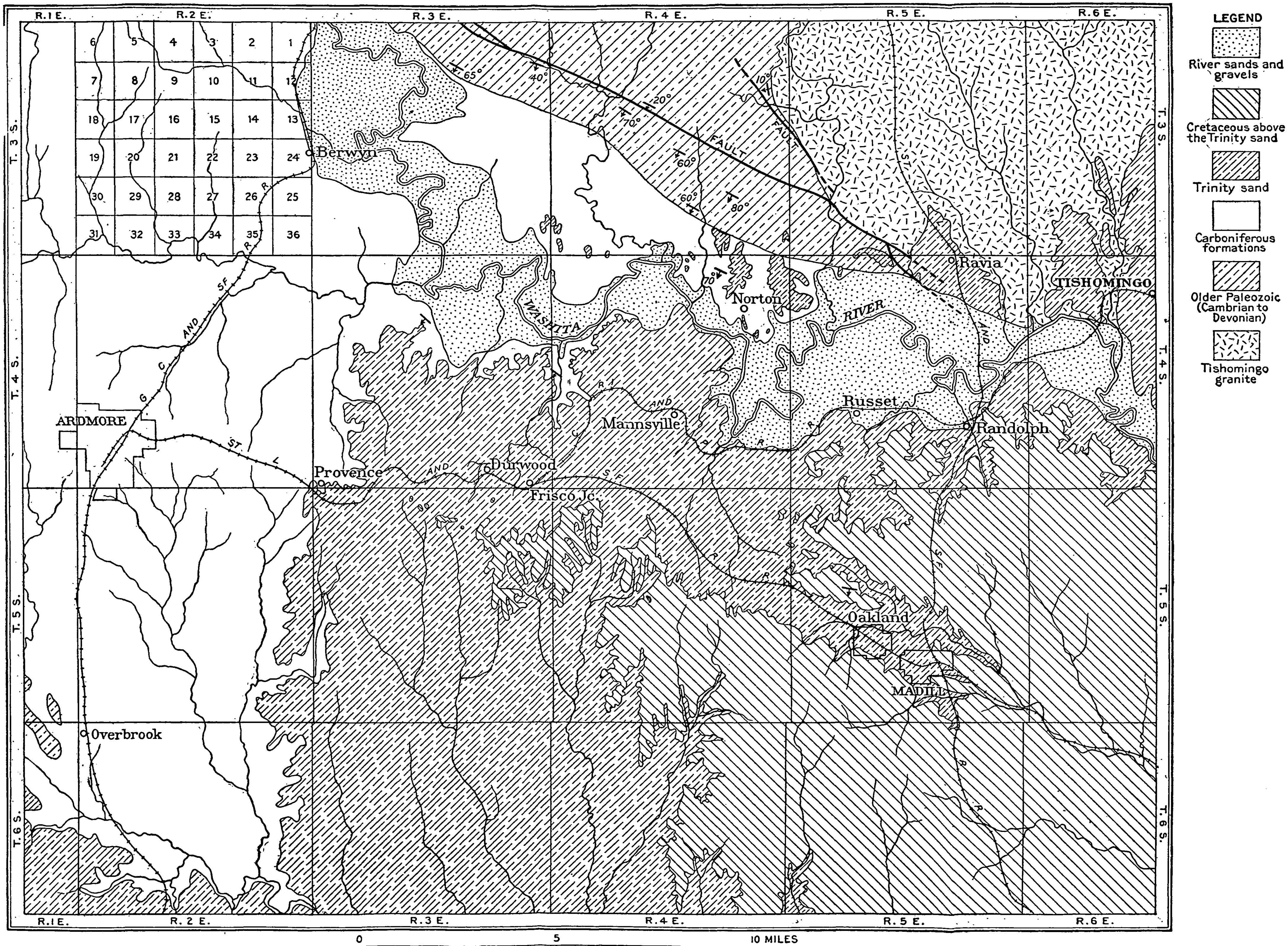
The Madill oil pool, so far as development has proved its extent, is located in the southeastern part of T. 5 S., R. 5 E., Oklahoma, being 1½ miles southeast of the town of Madill and about 12 miles a little west of south of Tishomingo, the former capital of the Chickasaw Nation, Indian Territory. It is within 12 miles of Red River and near the middle of the State from east to west. Madill is at the junction of two lines of the St. Louis and San Francisco Railroad. One is a north-south line through Tulsa and Denison. The other is an east-west road from Ardmore, Okla., to Hope, Ark. (See Pl. I.)

SOURCES OF INFORMATION.

The Madill oil pool lies in the central-southern part of the Tishomingo quadrangle, an area bounded by meridians of longitude 96° 30′ and 97° and parallels of latitude 34° and 34° 30′. The Tishomingo quadrangle was surveyed geologically in 1900 and the Tishomingo folio,[a] a part of the Geologic Atlas of the United States, was published in 1903. The results of the surveys in this region as published in the Tishomingo folio portray almost precisely the geologic conditions proved by the drill in the development of the Madill oil pool.

The presence of oil seeps and the occurrence of bitumen saturating certain sands have from time to time attracted the attention of those interested in oil development in the region of Madill, but it was not until March, 1909, after continued efforts on the part of the Mal-Millan Oil Company, that the productiveness of an area 1½ miles southeast of Madill was sufficiently proved to induce an influx of operators and cause leasing to be taken up in earnest. On account of this activity a trip of short duration was made to the field about the middle of April, 1909, and that portion of this report pertaining to quality and development of the oil is based in part on the information obtained in the field at that time.

[a] Geol. Atlas U. S., folio 98, U. S. Geol. Survey, 1903.



GEOLOGIC MAP OF VICINITY OF THE MADILL OIL POOL, OKLAHOMA.

By J. A. Taff and W. J. Reed.

CHARACTER OF THE COUNTRY.

The district surrounding Madill is an undulating plain that slopes gently toward the southeast. Washita River, with its broad, shallow valley, lies a few miles to the north and Red River a like distance to the south. The topography has been developed upon comparatively soft limestones, marls, and sands during a long period and under conditions essentially the same as those existing at the present time.

Immediately north of the Washita River valley is the region of the Arbuckle Mountains or Arbuckle uplift. The term "mountains" has been applied, not because high elevations are attained but because of the roughness of the surface and the hardness of the rocks, in distinction to the softer strata and more gentle undulations of the surrounding, slightly lower, and smoother country. The general surface of the Arbuckle uplift is essentially the same as that in the region of Madill; that is, it is an undulating plain, tilted slightly toward the southeast, from which the Cretaceous rocks of the Madill region have been removed in comparatively recent geologic time.

STRATIGRAPHY.

GENERAL OUTLINE.

There are two classes of rocks in the region of Madill, distinguished from each other by great difference in age and by their distinct structure or the attitude of the beds composing the formations. These distinguishing characters have a definite bearing on the occurrence of the oil and deserve more particular mention. The geology of the region has been described in detail in the Tishomingo folio, and will be discussed here only so far as it seems to have a bearing on the petroleum problem.

The older of the two great groups of rocks mentioned is the Paleozoic, which comprises the tilted and folded hard strata that lie north of Washita River and the similarly disturbed softer rocks that lie along both sides of the Washita River valley from the vicinity of Norton westward to Berwyn and thence southward to the vicinity of Overbrook. It includes representatives of the Cambrian, Ordovician, Silurian, and Carboniferous systems, which rest upon pre-Cambrian granite. A small area of the same older Paleozoic rocks is exposed in a small uplift southwest of Overbrook. The second group, the Mesozoic, includes the flat and slightly tilted rocks which lie chiefly south of Washita River and east of Ardmore. The rocks belong to a single system, the Cretaceous. The rock formations are here grouped in a manner suited to their discussion in respect to the presence or absence of petroleum and are so represented on the accompanying map (Pl. XXIII).

TISHOMINGO GRANITE.

The Tishomingo granite is a coarsely crystalline rock which contains a few dikes or intrusions of finely crystalline diabase. It antedates in age the oldest Paleozoic strata in the region, which are probably middle Cambrian. A large area of this granite is exposed north of Washita River and is most probably only a small part of that which is concealed east of Tishomingo by an overlapping formation of sand that has been described as the Trinity sand. The granite extends toward the southeast as a floor beneath the Trinity sand, with a slope of about 40 feet to the mile. It can not be considered in any sense as oil bearing, and any oil that may be found in the overlying Trinity sand has its source elsewhere and has attained its position by migrating laterally in the sand.

OLDER PALEOZOIC ROCKS.

There are six formations of the older Paleozoic rocks that lie in succession, one above another, and that were originally deposited over the granite. They are, in ascending order, the Reagan sandstone (Cambrian); the Arbuckle limestone (Cambro-Ordovician); the Simpson formation and Viola limestone (Ordovician); the Sylvan shale (Ordovician-Silurian); the Hunton limestone (Silurian); and the Woodford chert (Devonian). These formations as now exposed occur south and west of the granite area and are tilted steeply toward the southwest. They are grouped together as shown upon the map. With the exception of three thin formations, one of sandstone, one of shale or clay, and a third of chert, and certain sandy and shaly beds in a fourth formation, the whole section of 7,000 to 8,000 feet of these older Paleozoic rocks is composed of hard dolomites and limestones with some interbedded chert and shale.

The eastern limit of this group of hard rocks is marked by the western boundary of the granite and its southern limit by a definite line of chert hills or ridges produced by the Devonian chert. These chert hills also define the southern boundary of the more elevated Arbuckle Mountainous area.

LATER PALEOZOIC ROCKS.

Overlying the Devonian chert is a great thickness of carboniferous black and blue shale with beds of sandstone. Associated with these rocks are also beds of limestone and limestone conglomerates, and at one locality a bed of coal. Certain sandstone beds in these Carboniferous strata are highly impregnated with semiliquid bitumen, a residue of petroleum. These rock formations have been crumpled into folds and then worn down until the beds which were once deeply buried are now found with their edges projecting at the surface. In the vicinity of Ardmore and Woodford the tarry bitumen exudes from the exposed edges of some of the sandstone beds which have been quarried as bituminous rocks and from which bitumen has been extracted for commercial purposes. Many of the shale beds, especially those near the base of the Carboniferous section, contain disseminated petroleum in places.

CRETACEOUS ROCKS.

The Cretaceous strata lap across the Paleozoic rocks from the granite over the Ordovician and Silurian limestones, the Devonian chert, and the Carboniferous shale, sandstone, etc.

TRINITY SAND.

The lowest and thickest Cretaceous formation is the Trinity sand. It is a compact but unconsolidated, moderately fine sand with a smaller amount of clay and probably local bands or beds of sandy clay. At and near its base the Trinity sand becomes coarser and locally changes to conglomerate. In the vicinity of Ravia and farther east the basal coarse sand of the Trinity is composed largely of granitic material derived from the underlying granite. West of Ravia and probably to the south under cover the basal conglomerate is composed of pebbles and rounded limestone bowlders that had their origin in the hard limestones of the Arbuckle region, immediately to the north. This porous conglomerate and the sand at the base of the Trinity form the receptacle which holds the oil that is being exploited at Madill. The Trinity sand was deposited on a gently undulating or nearly flat surface that had been worn down upon the granite and the various classes of both hard and soft rocks of Paleozoic age above described.

As now situated the edge of the Trinity formation is spread out over a wide extent of country. The drainage of the land is toward the southeast, in the direction of the dip of the Cretaceous rocks, and for this reason large areas of Trinity sand are exposed along the valley of Glasses Creek. Streams south of the railroad between Ardmore and Madill have uncovered a large area of Trinity sand, leaving remnants of the overlying limestone along their divides.

The Trinity sand is approximately 400 feet thick. Because of the slightly uneven floor of the Paleozoic rocks on which it is laid down, the thickness may vary within comparatively short distances, either above or below 400 feet.

GOODLAND LIMESTONE.

In the district shown on the map there are several comparatively thin formations of limestone, clay, and marl that occur in orderly succession, one above another, overlying the Trinity sand. The first of these formations, lying directly on the Trinity, has been described as the Goodland limestone. It is a partly crystalline cream colored to white and moderately hard limestone, and has a thickness of about 25 feet. Its presence is easily recognized because it occurs just above the sand. It is almost continuously exposed along its edge and usually makes barren low bluffs or terraces. Many considerable areas are exposed, and in such areas the Goodland limestone makes a table-land with thin rocky soil. The outcrop of this limestone is of service in that it marks the top of the Trinity sand, near the base of which the oil has been found in the Madill pool. Knowing the approximate thickness of the Trinity sand, the operator can, when the level of his well is referred to the elevation of the Goodland limestone in the vicinity, determine the depth to which he may expect to drill in order to reach the oil horizon.

OTHER CRETACEOUS FORMATIONS.

Resting on the Goodland limestone is a formation of blue clay marl with a few beds of oyster shells. It has been described in the Tishomingo folio as the Kiamichi formation and is about 50 feet thick. This formation makes smooth, rolling black lands.

The Kiamichi marl is succeeded by a formation of limy clay and yellow to white limestone that together have a thickness of about 150 feet. This formation has been described as the Caddo limestone. Some of the limestone beds in this formation are suggestive of the Goodland limestone, but comparison shows that they differ in hardness and that each formation contains fossil shells that distinguish it from the other. Moreover, the limestone beds of this formation are 100 feet or more above the Trinity sand.

Resting on the Caddo limestone is a formation of red and bluish clays with thin beds of shell limestone that weather out to reddish hues. Local beds of sandstone also occur near the top of the formation. This formation has been named the Bokchito and is about 140 feet thick. It occupies but a small area in the district represented by the map and makes the hilly country on the divide south of Little Glasses Creek.

These formations above the Trinity sand are referred to here as an aid to prospective drillers for oil. A knowledge of their occurrence and thickness will assist the operator to determine the depth to the oil sand.

RIVER SAND AND GRAVEL.

Washita River has constructed a wide, flat valley in which it has deposited silt, sand, and gravel. This river alluvium is spread over a width of 1 to 4 miles, in which the river meanders, here and there touching the sides of the valley but not anywhere cutting through to the bottom. Opposite Tishomingo, near the edge of the mapped area, the river deposits are spread over the granite on the north side of the valley and the Trinity sand on the south side. In the vicinity of Norton the river sediment passes upon Carboniferous strata and so continues northwestward beyond the northern boundary of the area mapped. The greatest thickness of the river deposits is not known, but there is reason to believe that it is not more than a very few hundred feet at most.

STRUCTURE.

There are two dominant structural features in the region of Madill that may have a bearing on the occurrence of petroleum. These are the Arbuckle uplift and the Cretaceous monocline. The Arbuckle uplift involves the granite, the older Paleozoic rocks, and the later Paleozoic represented by the Carboniferous formations. Each of these classes of rocks is distinguished on the map. All these formations have been folded up together in a general uplift and the several kinds of rocks are steeply inclined at various angles, in great contrast to the Trinity sand and later Cretaceous rocks, which lie almost flat and incline gently in one direction, thus forming, structurally, a monocline.

ARBUCKLE UPLIFT.

The Tishomingo granite is in the central or axial part of the Arbuckle uplift. This granite mass has doubtless been deformed, but the trend of the folds can not be determined except as indicated by the structure of the older Paleozoic rocks that rest upon it. The Tishomingo granite was not intruded into the sedimentary rocks, but was formed before they were laid down. The older Paleozoic rocks have been warped into a number of folds and are faulted in certain places, but the general inclination of the strata is toward the southwest, away from the granite. Near the granite the rocks dip 10° to 20° SW. Farther to the southwest, near the Carboniferous boundary, the dips are 60° to 80° in the same direction.

The Carboniferous rocks have been thrown into many steep folds that trend in a northwest-southeast direction, with the general uplift of the Arbuckle Mountains. In the vicinity of the Washita River valley west of Norton, on both the north and south sides, the Carboniferous shales and sandstones are tilted steeply toward the southwest. Higher beds in the Carboniferous section occur in many steep folds between Berwyn and Overbrook. The trend of these folded rocks have the same northwest-southeast bearing and the rocks extend beneath the Trinity sand in the direction of Madill.

FAULTS.

Certain faults have developed in the older Paleozoic rocks west of the granite area. These faults or fractures of the strata trend in a northwest-southeast direction, the direction of the Arbuckle uplift. The rocks on the southwest side of each fault indicated on the map have been thrown or have moved downward with respect to the rocks on the opposite or northeast side. The fault that separates the Paleozoic rocks from the granite passes under cover of the Trinity sand 1 mile west of Ravia, bearing in an almost due southeast direction. It is probable that the Carboniferous rocks farther south and also west of Madill may have been faulted in a like manner.

The Carboniferous formations are very similar one to another, being composed chiefly of shales and sandstone, and faults in them are not easily detected. Besides, the Carboniferous rocks in the region of Berwyn and Ardmore have not been surveyed in detail, and faults that extend with the strike of the folds may have escaped recognition. All the disturbances, including the faulting of the Paleozoic rocks, occurred before the Trinity sand was laid down.

CRETACEOUS MONOCLINE.

The structure of the Trinity sand and succeeding formations is extremely simple. These rocks have now probably the same attitude that they had when they were deposited—that is, they lie almost flat and but slightly tilted toward the south. Very slight warpings of the Cretaceous strata have been noted, but no folds have been developed sufficiently to be characterized as anticlines or synclines nor, it is believed, to control or influence the accumulation of oil.

PETROLEUM.

PHYSICAL PROPERTIES.

A fresh sample of crude petroleum was obtained from a well 1½ miles southeast of Madill and shipped to Washington in a gas and oil tight receptacle and analyzed in the laboratory of the United States Geological Survey by David T. Day.

The crude Madill oil is very liquid. Its color in reflected light is dark olive and in transmitted light a dark wine. The specific gravity at 60° F. was 0.7887; the Baumé gravity 47.5°. On distillation by Engler's method 100 cubic centimeters of crude oil began to boil at 65° C. While heating from 65° C. to 150° C. 22 cubic centimeters of gasoline were given off, the specific gravity of which was 0.7118. From 150° C. to 300° C. 38 cubic centimeters of kerosene were given off, with a specific gravity of 0.7788. After heating to this temperature 36.8 cubic centimeters remained as a residuum, of which the specific gravity was 0.8669. In this residuum 7.41 cubic centimeters were determined as paraffin, no trace of asphalt being found. Eight per cent of the crude sample and 1 per cent of the kerosene proved to be made up of unsaturated hydrocarbons.

The gravity of this oil, 47.5° Baumé, is approximately 7° higher than that of the best oil produced at Muskogee, or 13° higher than that of the average Mid-Continent crude oil. On distillation the crude petroleum gave 60 per cent of lighter oil (gasoline and kerosene), about 7 per cent of paraffin, and little or no asphalt. The 6 per cent of lighter oil yielded approximately 22 per cent of gasoline and 30 per cent of kerosene. The average crude oil from the Mid-Continent field, when distilled, produces hardly 50 per cent of lighter oils, with a ratio of about 1 to 4, kerosene predominating.

OCCURRENCE.

The principal oil-bearing rock in this region and the only one which has produced oil in any considerable quantity is at or near the base of the Trinity sand, a little more than 400 feet below the surface at Madill. The oil-bearing rock is a deposit of compact sand and gravel, but the particles and pebbles are not cemented together. Although the oil seems to be almost wholly confined to this horizon, gas has accumulated in other positions in the Trinity sand besides the one in which the oil is found, and this would seem to indicate that oil might be found at similar horizons farther south, where they lie at lower levels and at greater depths from the surface.

The oil sands have been reported to have a thickness of 40 feet, but it appears that the exact thickness of the pay sand may not be over 25 or 30 feet.

DEVELOPMENT.

Up to April 20, 1909, eight wells had been drilled to a depth of more than 400 feet in the vicinity of Madill, and of this number four had been producers, although when the field was visited all were shut in. (See fig. 13.) All the four producers are located on the Jeff Arbuckle farm, in the SW. ¼ sec. 25, T. 5 S., R. 5 E., which is being developed by the Mal-Millan Oil Company, of Madill. A well at the cotton gin on the Madill town site encountered gas at a depth of 180 feet, which, when ignited, produced a large flame that was allowed to burn for a day, after which the gas was cut off in order that the drilling might progress unimpeded.

The well producing the largest volume of oil was completed on March 22, 1909. It was at first reported that the initial production of this well amounted to more than 1,000 barrels, but persons who were present at the well during its early existence and who have had considerable experience in gaging wells flowing into earthen storage tanks place the production at 14 to 16 barrels an hour, or barely 400 barrels a day. The fact should be taken into account, however, in this connection that the wells were drilled with a rotary drill and that the hole in the sand is not more than 3 inches in diameter. As it is not possible to shoot this well, it is not fair to compare its production with that of other wells which have been shot and which have an initial hole with much larger diameter, and as a result give the oil a much greater opportunity for escape. If the Mal-Millan well had been drilled in the ordinary way in which wells are drilled in the Mid-Continent

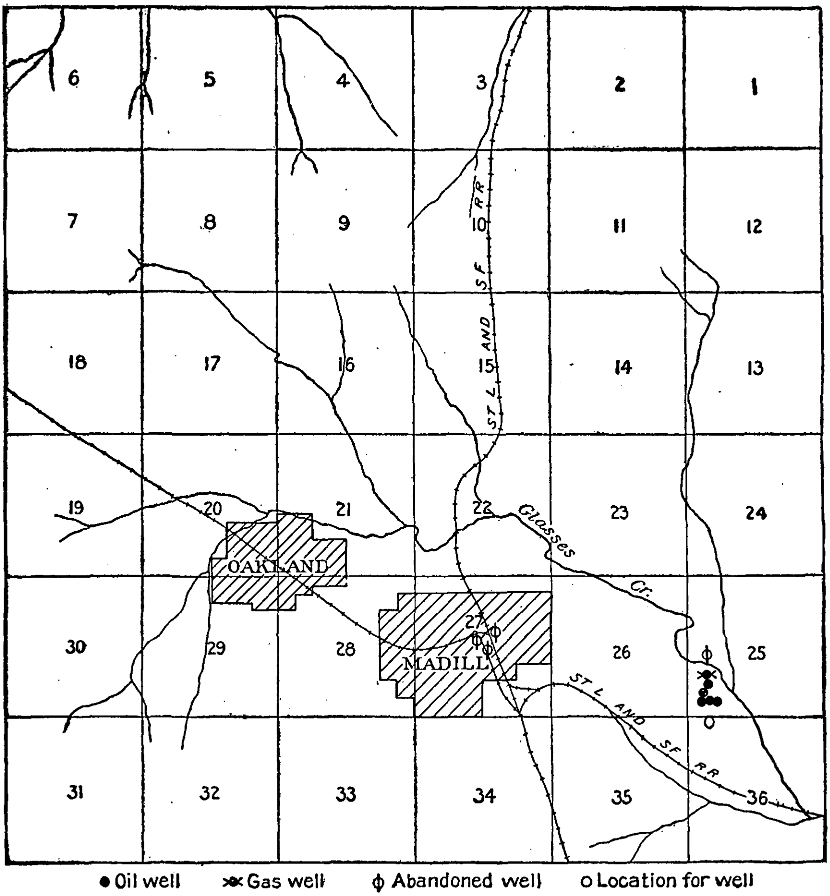


FIGURE 13.—Map of T. 5 S., R. 5 E., showing location of wells drilled in vicinity of Madill, Okla.

field, that is, with a churn drill of large diameter, it is only a matter of conjecture what the initial production might have been.

One of the producing wells on this farm is developing a considerable quantity of gas, which has been piped to the Arbuckle house and used for domestic purposes. This well also produced some oil, which makes it necessary to open the stop cock at frequent intervals and allow the oil to come to the surface in order that the gas may be given free passage in the casing.

PROBABLE SOURCE OF OIL.

The Trinity sand is known to contain petroleum or bitumen, a residue of crude petroleum, at various localities in southwestern Arkansas, southern Oklahoma, and Texas. At all the localities where this crude petroleum or its residue have been found the Trinity sand is several hundred feet thick. This sand is a beach or shallow-water deposit of siliceous sand with local comparatively thin beds of clay. It contains exceedingly scanty remains of organic life, either vegetable or animal. Here and there thin shell limestone layers occur in the central part of the formation, and at widely separated localities silicified wood has been found, but nowhere is there sufficient evidence of the occurrence of organic matter to warrant the assumption that the oil originated in the formation that contains it.

In southwestern Arkansas and in northern Texas, as well as in southern Oklahoma, thick deposits of Carboniferous rocks that contain oil residues underlie the Trinity sand. Furthermore, the Carboniferous beds are tilted in such a manner that their edges project against the base of the Trinity sand. Any oil in the Carboniferous strata beneath the Trinity would in the course of time be conveyed upward and would either lodge in that sand or find an exit through it to the surface. There seems at present no other reasonable explanation than that the oil of the Madill pool had its source in the underlying Paleozoic strata.

Whether the oil in its present position near the base of the Trinity sand is contiguous to the original oil-bearing strata of the subjacent rocks, or whether it has migrated laterally, may possibly be determined by the drill. Should original oil-bearing strata beneath the Trinity sand be tapped by the drill, the inference is that such oil-bearing rocks would be found to trend in a northwest-southeast direction, with the strike of the rocks in the Arbuckle uplift as exposed in the district to the north and west of Madill.

DEVELOPMENT IN THE BOULDER OIL FIELD, COLORADO.

By Chester W. Washburne.

The Boulder oil field was described by N. M. Fenneman in 1905;[a] since that time there has been considerable development of the field which will be briefly mentioned in this paper. The writer spent only one day in the field, January, 7, 1909, under the guidance of Mr. S. F. Rathvon, secretary of the Inland Oil Company.

The most important recent development is the striking on December 29, 1908, of the first gusher or flowing well of the region. This well, No. 13, of the Inland Oil Company, is located in the center of sec. 33, T. 2 N., R. 70 W., on the plunging end of a rather sharp anticline which has been mapped by Fenneman.[b] It had an initial production of about 250 barrels per day, which had decreased to 160 barrels at the time of the writer's visit.

The location of the well at this place was based on the structure of the rocks as shown by the outcrop of the Hygiene sandstone member of the Pierre shale on Fenneman's map. The success of the well corroborates Fenneman's conclusion as to the structure of the locality and makes it seem probable that the productive territory may extend 3 or 4 miles northward along the same anticline toward Lykins Gulch.

Since 1905 the Inland Oil Company has drilled 12 other wells from one-half to 1 mile south of No. 13. Of these wells 8 pumped from 5 to 170 barrels a day, 2 encountered a trace of oil, and 2 were entirely dry. They derive their oil from a sandstone in the Pierre shale 2,000 to 2,500 feet deep. All the productive wells are located on an anticline. Those at the top of the anticline produce gas and light oil which varies in gravity from 42.2° Baumé in well No. 8 to 42.9° Baumé in well No. 3. The wells farther down the limbs of the anticline produce heavier oil mixed with water. The gravity of the oil in these wells ranges from 40.1° Baumé in well No. 7 to 40.7° Baumé in well No. 1. As the oil occurs in sandstone it is probable that this difference in gravity is not due to absorptive

[a] Geology of the Boulder district, Colorado: Bull. U. S. Geol. Survey No. 265, 1905.

[b] Op. cit., Pl. II.

fractionation in the rock similar to that observed by David T. Day.[a] The case is similar to those observed by Ralph Arnold in the California oil fields, where the oil associated with water is heavier than that which flows into the wells free from water. A possible explanation is found in polymerization of the oil, by the catalytic action of water, after the manner suggested by Höfer for Trinidad asphalt; or there may be some separation of the oil due to the greater ease with which heavy oil mixes with water. The crude oil is a limpid, yellow, transparent to translucent fluid.

The separation of paraffin from the oil in the wells clogs them rapidly. The difficulty is only partly removed by cleaning the wells. Attempts to warm the wells by steam have failed on account of the high steam pressure required. Some practicable method of warming, therefore, will have to be devised before maximum production can be obtained. The paraffin does not clog the pipe lines, all of which are laid on the surface of the ground, but separates in yellow crystals, which are readily carried in suspension by the oil. In this respect the paraffin is remarkably different from that in the Florence oil, described on page 58.

Besides the wells mentioned above, about six other successful wells have been drilled by other companies since 1905, but the shortness of the writer's visit prevented him from obtaining information concerning them or a small new refinery which they supply.

At the time of the publication of Fenneman's report, the oil of the Boulder field was all shipped to Florence, Colo., where it was refined by the United Oil Company. The selling price of the crude oil was $1.10 per barrel f. o. b. at Boulder. In 1907 the Inland Oil Company completed a modern refinery at Boulder having two stills, each of 400 barrels capacity. At the present time one of the stills charged once a day handles all of the company's oil. The results of the distillation are:

Distillation at refinery of Inland Oil Company, Boulder, Colo.

	Per cent.
Gasolene	20 -22
Water-white oil	38 -40
Gas oil	12½-15
Wax oil	15
Residuum	6- 7
Loss	1- 2

Considerable hydrogen sulphide escapes in the latter part of the distillation. The gasolene has a gravity of 65° to 66° Baumé. The water-white oil, or kerosene, has a gravity of 42.8° to 43.8° Baumé. It has the legal flash test of over 101°, 108°, or 110° F.,

[a] Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. U. S. Geol. Survey No. 365, 1908.

according to whether it is prepared for the States of Colorado, Wyoming, or Utah, respectively. The heavier "gas oil" is used in enriching illuminating gas. The wax oil consists principally of a high grade of crystalline paraffin with a high melting point, adapted to any of the principal commercial uses of paraffin. The remainder of the wax oil is mostly light lubricating oil. By-products of considerable value are lost on account of the lack of machinery to separate the paraffin wax and the lubricating oils. In the Florence field a similar oil is almost as valuable for these by-products as it is for other constituents. At the present time the wax oil and residuum of the Boulder field are mixed and sold as fuel oil, but on account of the small local demand, the fuel oil accumulates until it has to be burned merely to get rid of it. The fuel oil has been tested on the wagon roads for laying dust, but the tests are said to have been unsatisfactory on account of the light body of the oil.

The total production of the field was reported to be about 350 barrels a day in April, 1909.

THE FLORENCE OIL FIELD, COLORADO.

By Chester W. Washburne.

INTRODUCTION.

The Florence oil field is located in south-central Colorado. It includes the town of Florence, Fremont County, and extends 4 miles south of that place. It has an east-west extension of 3 miles and a productive area of about 14 square miles.

Reports on the field were made in 1886 by M. C. Ihlseng;[a] in 1888 by J. S. Newberry;[b] in 1891 by G. H. Eldridge;[c] in 1896 by R. C. Hills;[d] from 1901 to 1903 by Arthur Lakes;[e] and in 1904 by N. M. Fenneman,[f] thus covering the history of the field almost from the beginning and preserving data that would otherwise have been lost. The geology of the region has been recently described by N. H. Darton.[g]

The present study was undertaken in the fall of 1908 for the purpose of discovering how the oil occurs. The results of the study will be fully set forth in a later publication and are only partly summarized in this paper.

GENERAL GEOLOGY.

The oil field lies in a synclinal reentrant of the front of the Rocky Mountains, between two en échelon folds made by the Front Range on the northeast and the Wet Mountains on the west. This reentrant is commonly referred to in geologic literature as the "Canon City embayment." (See fig. 14.)

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a Report on oil fields of Fremont County: Report of field work and analyses, Colorado School of Mines, 1886, pp. 67-80.

b The new oil field of Colorado and its bearing on the question of the genesis of petroleum: Trans. New York Acad. Sci., vol. 8, 1889, pp. 25-28.

c The Florence oil field, Colorado: Proc. Am. Inst. Min. Eng., vol. 20, 1892, pp. 442-462, map and cross sections.

d The Florence oil field, Fremont County, Colorado; private report for the United Oil Company, 29 pp., maps of wells, topography, and structure.

e Prospecting for oil in Colorado: Mines and Minerals, vol. 21, 1901, pp. 481-483, 4 figs.; Petroleum in western North America: Mines and Minerals, vol. 22, 1901, pp. 78-80; The geology of the oil fields of Colorado: Bull. Colorado School of Mines, vol. 1, 1901, pp. 221-226; The geological occurrence of oil in Colorado (abstract): Sci. Am. Suppl., vol. 52, 1901, p. 21505; Oil in Colorado, the geology of the deposits, and the various horizons in which signs of oil have been found: Mines and Minerals, vol. 22, 1902, pp. 256-257; The present oil situation in Colorado, a review of the histories of the several regions, and the discoveries which have been made: Mines and Minerals, vol. 23, 1903, pp. 399-401, 2 figs.

f The Florence, Colo., oil field: Bull. U. S. Geol. Survey No. 260, 1905, pp. 436-440.

g Geology and underground waters of the Arkansas Valley in eastern Colorado: Prof. Paper U. S. Geol. Survey No. 52, 1906.

STRATIGRAPHY.

The youngest rocks exposed in the Canon City embayment are a coarse conglomerate, 500 feet thick, overlain by a remnant of volcanic tuff. These are regarded as belonging to the Shoshone group. Unconformably beneath the Shoshone strata are 800 feet of fresh-water shales and sandstones containing the coal of the Canon City coal field, and thought to be equivalent to the Laramie formation of the Denver Basin, although the lower part may possibly be of Montana age.

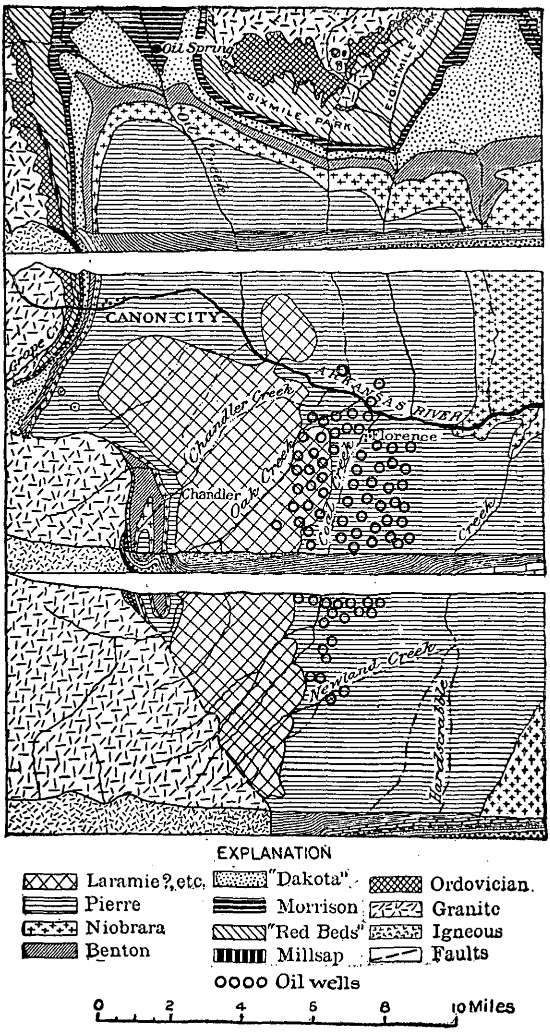

FIGURE 14.—Geologic sketch map of the Canon City embayment. After N. H. Darton.

The Montana group of marine strata conformably below these fresh-water beds is subdivided in this report into the Trinidad (?) sandstone and Pierre shale. The former is often referred to as "Fox Hills." The latter is here important because it contains the oil of the Florence field.

The Trinidad (?) sandstone, 100 feet thick, lying at the top of the Pierre shale, is a conspicuous feature of the western part of the field, where it forms an irregular line of low bluffs. It is the uppermost marine stratum, with the exception of the yellow sandstone about 75 feet thick which lies in the coal-bearing formation about 300 feet above the lowest coal bed, and, although not traced through, is believed by Doctor Stanton to be equivalent to the Trinidad sandstone of the Walsenburg, Spanish Peaks, and Elmoro quadrangles.

The upper part of the Pierre shale is sandy, containing many thin beds of sandstone within 300 feet of the top. Below this the shale is nearly a pure clay shale. Marine fossils are locally abundant at various horizons from top to bottom of the shale and fragmental plant remains are common in the upper 700 feet. The total thickness of the Pierre is estimated to be 4,500 feet. Exact measurements are impossible on account of the low dip of the shale and lack of continuous exposure. The Niobrara strata were probably reached at a depth of 2,900 feet in well No. 2b of the Florence Oil and Refining Company. The top of this well is about 1,600 feet below the top of the Pierre. Well No. 349 of the United Oil Company penetrated the shale for 3,750 feet without reaching the underlying Niobrara. The top of this well is about 200 feet below the top of the Pierre.

The Pierre shale is a remarkably uniform body of rock. It is soft and dark gray to greenish black at the surface. Underground the rock is firm, readily fissile along the bedding planes, as shown by the flat platy character of the drillings, and considerable bodies of it are almost white, although dark-gray to bluish-black colors prevail. It is treacherous material to drill through, caving badly into the wells. Numerous hard concretions also interfere with drilling by deflecting the drill and making the holes crooked. The shale consists almost wholly of argillaceous material with no limestone layers or notably calcareous layers except near the base, below the oil-bearing zone, and with no true sandstone except in the upper part, far above the oil zone. Some slightly arenaceous beds contain enough fine sand to feel gritty between the fingers. The grains of quartz in these beds are exceedingly minute, and they are completely embedded in the argillaceous matrix. The rock is too impervious to act as an oil sand in the ordinary way.

Beneath the Pierre shale is the Niobrara group, which in this region has been subdivided into an upper formation, the Apishapa, consisting of light-colored calcareous shale, and a lower formation, the Timpas limestone. Fish scales are abundant in the Apishapa, and both formations everywhere contain much solid bitumen scattered through the pores and smaller joints, but none in the larger fissures. The Apishapa shale is about 450 feet thick and the Timpas limestone about 100 feet thick, including a strong 50-foot limestone at its base, which makes a conspicuous ridge at the foot of the "Dakota" hogback.

The Benton group, underlying the Niobrara, consists of three formations, in descending order the Carlile shale, the Greenhorn limestone, and the Graneros shale. The Carlile shale consists of about 200 feet of very dark gray or black shale, overlain by 8 to 20 feet of coarse-grained calcareous sandstone, charged with very alkaline water. Oil in small quantities is reported from the black shale in a well drilled by A. J. Green 6 miles northeast of Canon City. The Greenhorn limestone consists of about 30 feet of dark-gray calcareous shales and eight to twenty intercalated beds of limestone 4 to 12 inches thick. The Graneros shale includes about 300 feet of dark-gray shale.

The "Dakota" sandstone underlies the Benton group and forms the base of the marine Cretaceous of this region. It consists of two sandstones, each about 100 feet thick, separated by 10 to 15 feet of clay shale. The formation contains artesian water, but in connection with the oil it is interesting principally on account of the solid black bitumen found in it near Canon City.

Beneath the "Dakota" is the Morrison formation, best known in this region for the dinosaur bones which it contains in Garden Park, and most important in the present study because petroleum escapes from it in a few localities. The formation consists of about 400 feet of sandstone and varicolored shales and local thin fresh-water limestones. At the head of the sharp canyon leading out from Garden Park, about 7 miles northeast of Canon City, is an oil spring which has long been known. The oil escapes with water from Pleistocene gravel, locally cemented by bitumen, on the east bank of Oil Creek. It has doubtless entered the gravel from fissures in the underlying Morrison beds. It is a very heavy, black viscous oil, of about 15° Baumé gravity. The quantity now escaping does not exceed 20 gallons a day. One other oil spring is reported on Oil Creek, and one on Hardscrabble Creek about 20 miles farther southeast, both in the Morrison beds. In the same formation a trace of heavy black oil was encountered in the Weaver artesian well about 8 miles southeast of Florence.

Below the Morrison are the following formations: the Fountain formation ("Red Beds"), about 1,000 feet thick; the Millsap limestone (Mississippian), about 200 feet thick; Ordovician strata comprising the Fremont limestone, Harding sandstone, and Manitou limestone, with a combined thickness of about 400 feet; and about 40 feet of upper Cambrian sandstone, which rests upon Archean granite and schist. In the Canon City embayment no signs of oil have been found in these lower formations.

STRUCTURE.

The structure of the Florence oil field has generally been regarded as synclinal, but in the present state of knowledge of the distribution of the oil it would be better to call the field a monocline. The dips in the productive area are low, 3° to 6° W. Just east of the oil field the dips are from 25° to 45° W. West of the known productive territory dips of 2° to 4° prevail for 2½ miles, to the axis of the syncline, where there is a sharp upturning of the beds. The western limb of the syncline is very narrow in comparison with the eastern limb on account of its high dips, 45° E. to 90°, or by overturn, 45° W. to 90°.

The smaller features of the structure, small anticlinal and synclinal cross swells, are too faint to produce changes in dip, but they cause slight irregularities in the general north-south strike. These broad swells have no relation to the distribution of the oil.

Small, sharp anticlines follow the beds of many of the small creeks. These are purely superficial phenomena of recent origin, due probably to the expansion of the rocks when they weather and to the consequent thrusting of the superficial layers into the little gulches. Structures of this type also have no relation to the occurrence of the oil.

Small monoclinal folds passing into faults with a general east-west trend and a throw of less than 50 feet have been noted at several places. These monoclinal folds and faults probably indicate the existence of fissures below them in the oil-bearing zone. It is known definitely that the oil occurs in fissures having the same direction as these monoclinal flexures, and it must therefore be concluded that the presence of east-west fissures and flexures at the surface is a favorable indication of the oil-productive character of the locality. A small monoclinal fold and fault of this type run eastward from a point near the "Blazing Rag" or Bluff Springs mine through the excellent oil territory which lies along the line between Tps. 19 and 20 S. It is quite probable that there are many similar parallel fissures underground in that part of the field.

THE OIL.

MODE OF OCCURRENCE.

GEOLOGIC CONDITIONS.

As previously mentioned, the oil of this field occurs in the Pierre shale, in a zone about 2,500 feet in vertical thickness. It has a stratigraphic range in the shale of more than 3,000 feet, but the productive beds are limited to about 2,400 feet. The upper surface of the productive zone is in places roughly parallel to the dip of the beds, but the upper surface of the zone in which traces and unprofitable amounts of oil and gas are found is in general nearly horizontal, lying from 750 to 1,000 feet deep. The highest traces of oil and gas are reported at about this depth for the entire distance across the field, notwithstanding the fact that the Pierre shale descends 1,600 feet in that distance.

The oil does not follow any bed or series of beds in the shale. As shown by the outcrop, the oil zone does not contain any sandstones or other porous beds capable of acting as reservoirs. The oil lies in joints and fissures. This statement is made without reservation, because the writer believes that it is fully justified by considerations which can not be presented fully in this brief paper. The evidence consists (*a*) of observations on the correspondence in direction of the major joints observable in the rocks at the surface with the alignment of wells which have interfered with each other; (*b*) of the fact that many wells have been drilled within a few feet of each other without encountering oil at the same depth; (*c*) of the fact that gas struck in a shallow well often immediately ruins an adjacent well several hundred feet deeper by tapping the source of pressure; (*d*) of the fact that many wells drain adjacent wells that are very much shallower; (*e*) of the indication of vertical connection between the oil bodies shown by the marked increase in maximum pressure with depth; and (*f*) of the dissimilar pressures in adjacent wells of the same depth.

Corroborative evidence is furnished by the drillers, who report "crevices" in most of the wells, many of which are probably only large concretions in the shale that have been struck on one side, causing deflection of the drill and a crooked hole. In numerous other cases, however, large quantities of water have been poured into a well without moistening the shale sufficiently to enable drilling to proceed, and the conclusion of the drillers that the water has been used up in filling a crevice is probably correct. Less certain are some other observations, such as the reported dropping of the tools as much as 20 feet beyond the distance drilled. This appearance may have resulted from an error in counting depth by the unreliable method of tying strings to the cable. In this connection the following report on the United Oil Company's well No. 402 is interesting: "Bad crevices were found at 2,300 feet, and the bailer was lost in one of these large crevices, but it did not interfere with the drilling, as the crevice was large enough to allow the bailer to be driven into it, without interfering with the work."

It is apparent that a well must strike an open fissure in order to obtain productive oil. It is probable that this fissure is much larger than—in fact, of an entirely different order of magnitude from—the surrounding oil-bearing fissures and pores, which are almost certainly of capillary size. This conclusion is based on the fact that when the oil is struck there is often a sudden rise to heights of 300 to 1,500 feet in wells that immediately afterwards produce only 3 to 5 barrels a day. In one exceptional well the initial rise of oil amounted to 2,500 feet. The high initial rise of oil means that the oil is under high pressure (100 to 800 pounds to the square inch) and that enough of it is in large openings for the dissolved gas to expand quickly and fill the well with oil to the height of the initial rise. As the high rock pressure must decrease slowly in the spaces distant from the well, it must be concluded that the small flow of oil, lasting in some wells for over twenty years, comes from capillary openings. Conclusive evidence that the general pressure in the rock pores remains high is found in the fact that initial rises of oil amounting to more than 400 feet (pressure over 150 pounds) have been observed in wells drilled within 100 feet of small (2 to 5 barrel) producers that had flowing pressures of less than 5 pounds. The difference in pressure here shown between long-drained fissures and freshly struck fissures can be explained only by supposing that the fissures struck by these wells have no connection except through the exceedingly minute pores and joints of the shale. During the long time, possibly measured by geologic periods, that the oil has been in the rock, equilibrium between the pressure in the fissures and in the pores must have been established. In other words, the pressure in the pores must be of the same order as that indicated by the maximum initial rise of the oil. If the smaller oil-bearing pores have a pressure of 400 to 800 pounds to the square inch, they must be of capillary size, because they offer such enormous resistance to the flow of the oil that it reaches the wells with a flowing pressure of less than 5 pounds to the square inch. It is impossible to escape the conclusion that the oil of the initial rise comes from open fissures and that the oil which flows into the well later is collected from very minute capillary fissures and pores that are tributary to the larger passages. Further support to this idea is furnished by the slight increase in the specific gravity of its oil as a well grows old (see p. 530), because David T. Day[a] has shown that natural fractionation of crude oil is indicative of migration in the capillaries of shale.

INFLUENCE OF WATER.

The concentration of the oil has probably been brought about by water, which is able to shove the oil before it on account of its greater capillary pressure, due to greater surface tension. Partial exploration indicates that the lower part of the syncline is barren of oil, a condition readily accounted for by supposing that the rock pores in that part of the syncline are filled with water. There is some evidence supporting this view. Likewise the east margin of the field lies less than one-fourth of a mile from a line of sharply increasing dip, or monoclinal flexure, along which water could doubtless penetrate the shale more readily than in the gently dipping rocks of the productive territory. Several wells in this belt encountered deep salt water. On the north and south the limits of the field, and hence the relation to water, are not yet known.

[a] Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. U. S. Geol. Survey No. 365, 1908. See also Proc. Am. Philos. Soc., vol. 36, No. 154, 1897, and Trans. Petroleum Congress (Paris), 1900.

In the vertical distribution of water and oil the relations are much more definite. The oil is hemmed in above by the ground water and below by artesian water in the Timpas limestone and subjacent sandstone of the Carlile. The ground water supersaturates the shale for a distance of 300 to 500 feet from the surface. Above these depths fresh or slightly alkaline water is reported in most of the wells. This water, like the oil 500 feet beneath it, is in open fissures over nearly all the field, except on the west side, where it occurs mostly in the sandy shales and "Fox Hills" sandstone and partly in fissures in the clay shale immediately below these porous beds.

It seems probable that the pores in the shale are saturated or nearly saturated with water down to the upper limit of the traces of oil and gas, which is a roughly horizontal line, 750 to 1,000 feet deep. In parts of the field the vertical sinuosities of the upper limit of traces of oil and gas are similar in position and kind to the sinuosities of the lower limit of reported veins of water. This approach to parallelism between the upper limit of oil and the lower limit of water furnishes an unexpected but convincing argument that water is an important factor in the distribution of oil. The argument is especially strong because both these limits traverse over 1,000 feet of strata in passing from the east to the west side of the productive territory.

Water has rarely been found below 500 feet and only in one or two wells below 1,200 and above 2,500 feet. Wells along the eastern margin of the field commonly strike salt water when they reach the Niobrara formation. In well No. 2b of the Florence Oil and Refining Company salt water encountered in the Niobrara at a depth of 2,910 feet rose to the top of the well. In a few localities evidence has recently been found that some ground water has entered the zone of productive oil through wells that were not tightly plugged when they were abandoned.

The theory that water influences the distribution of oil rests on a deduction concerning the relation of a fluid in capillary pores to the same fluid in supercapillary space that has little observational basis at the present time. The writer believes that water penetrates beyond the lower limits at which it can be detected by flowage into the wells. In this deeper zone the pores of the shale are probably saturated or partly saturated with water, which is held in them by capillary force, leaving no excess to fill the larger fissures. The drillers could observe only the latter, free-flowing, excess water, and probably only in amounts of a barrel or more. It is the invisible capillary water that compresses the oil and tends to drive it through the rock. This invisible, pore-filling water is thought to extend downward through a zone about 500 feet thick which is roughly parallel to the lower limit of the observed ground water. The zone is exceptionally thick where fissures are exceptionally strong or cut through unusual distances. In some places it may touch a similar zone that lies below all the oil horizons and, by crowding the oil aside, make the locality unproductive.

The fissures in the Timpas limestone and the pores in the coarse sandstone at the base of the limestone are filled with water under high pressure, as mentioned above. A score or more of wells in this region, drilled mostly to reach the "Dakota" artesian horizon, have demonstrated that the limestone and sandstone are charged with very salty water. Several deep oil wells in the eastern part of the field have encountered salt water in light-colored shale, presumably the Apishapa shale, above the Timpas limestone. A notable instance is well No. 2b of the Florence Oil and Refining Company, mentioned above. The water in the Apishapa is probably for the most part in open joints and fissures, although the drillers report that in the well just mentioned the water came from "thin black sandstone."

Above the stratigraphic zone of water described in the last paragraph there is probably a thick zone in which water fills the pores of the Pierre shale but not the open fissures. This corresponds with the zone above the oil described on page 524. It hems in the oil below just as the homologous upper zone seals the oil above.

Eldridge[a] thought that the nearly horizontal upper limit of the oil might be due to approximately uniform evaporation. However, it seems impossible for evaporation to be effective through about 1,000 feet of fine shale, the upper 300 to 500 feet of which is known to be full of water. Moreover, evaporation should leave abundant tarry residues, which have not been found. The few traces of unusually heavy oil reported were near the lower as well as the upper limits of oil, two positions where it is thought that the oil comes into contact with water. Polymerization, due to the catalytic action of water, is a possible explanation of these heavy oils, or in migration of the oil driven by water the more viscous heavy oils may have lagged behind, becoming concentrated next to the water. Moreover, it is a fact of common observation that the heavier oils mix readily with water, especially in the presence of suspended clay. Ralph Arnold reports that in the California oil fields the oil which is associated with water in the sands is heavier than the oil from adjacent dry parts of the same sands. In the preceding paper on the Boulder oil field (pp. 514–515) a similar condition is described. It is evident, therefore, that the occurrence of heavier oil above and below the productive zone at Florence may be due to the influence of water.

[a] Eldridge, G. H., Florence oil field, Colorado: Proc. Am. Inst. Min. Eng., vol. 20, 1892, p. 16.

METHODS OF LOCATING WELLS.

It will be observed on examining the well map (Pl. XXIV) that the symbols indicating producing wells are grouped together in certain localities. These localities are also characterized by a large number of wells that have produced over a million gallons. It is evident that drilling success has been much greater in such areas than in the surrounding areas, where, as the map indicates, only traces of oil and gas and dry wells have been struck. Obviously it will be advantageous to locate new wells on the margins of these favorable areas and in the larger undrilled parts of these areas. This method of locating wells, by following close to the location of previous successful wells, was recommended by R. C. Hills in his report to the United Oil Company.

Less certain is an untried method which the writer has devised that is based on the apparent underground distribution of oil. By drawing cross sections of the oil field it has been found that in certain localities the upper limit of productive oil rises considerably above its general level. These areas where the upper limit of productive oil is high have produced the greater part of the oil, and drilling success within them has been much greater than in the surrounding areas, where the upper limit of productive oil is low. The oil is evidently concentrated in the parts of the rock where it approaches nearest to the surface.

The proposed method of locating wells consists of outlining the parts of the field where the upper limit of productive oil is relatively high and of selecting the undrilled parts of these areas for new wells. In the final report on this field about twenty cross sections of the field will be printed in order to show the changes of position of the upper limit of productive oil. In order that these cross sections may be as accurate as possible, it is hoped that the few independent oil companies who have not furnished records of their wells will endeavor to find these records and send them to the Geological Survey.

On account of the small size of fissures and their probable lack of vertical continuity it seems hardly possible to strike a fissure underground which has been observed at the surface. The location of fissures and small faults should therefore not be considered in deciding the location of wells. Nor should any consideration be given to small anticlines or to the broad anticlinal cross folds, because these have no relation to the distribution of oil.

The spacing of wells is an important matter about which very little information can be given. On account of the fortuitous nature of the direction, length, and intercommunication of fissures it is not possible to make an absolutely safe rule determining the distance between wells. In most of the proved instances of one well draining another the distance between them has been less than 400 feet; but in two probable cases of interference of wells the distance was nearly 1,000 feet. Against these observations should be placed about one hundred others in which wells less than 25 feet apart have not affected one another. Interference between wells that are closely spaced in a north-south direction has not yet been proved, and numerous instances of the lack of such interference might be mentioned. In view of the impervious nature of the shale and the preponderant influence of east-west fissures, it seems safe to locate wells less than 100 feet apart in any approximately north-south direction, ranging between N. 50° E. and N. 60° W. Wells should not be located within 400 feet nearly east or west of big active producers, because of the danger of injury to the latter.

EXTENSIONS OF THE FIELD.

The eastern limit of the field appears to be a north-south line of steep dips that runs through secs. 10, 15, 22, 27, and 34, T. 19 S., R. 69 W. In T. 20 S., R. 69 W., this line of steeper dips takes a west-southwest course toward the south quarter corner of sec. 32. Water penetrating down along the more steeply dipping beds and through fissures along the line of sharp flexure is believed to determine the eastern limit.

South of the field, in the west half of T. 20 S., R. 69 W., the geologic conditions that are capable of surface observation, such as stratigraphy and structure, have the same character as in the productive territory. There is therefore no good geologic reason for thinking that the field can not be extended through T. 20 S., but only seven successful wells have yet been drilled in this township south of the northern row of sections. As already stated, there is evidence tending to show that water has been an important factor in determining the present distribution and concentration of oil in the Florence field. The probable effect of water south of the field would be to constrict the oil territory in that direction, owing to the shorter distance between the water-bearing Laramie rocks or the front of the Wet Mountains west of the field and the belt of steeply dipping rocks east of the field. For the same reason the steeper dips of the Pierre shale in T. 21 S. must be regarded as unfavorable.

The northern limit of the field is not well defined. Several good producers have been brought in north of Arkansas River, three of which were in the NW. ¼ sec. 6, T. 19 S., R. 69 W. Mr. Gumaer reports that the old Robinson well, which was drilled in 1884 a mile north of Cyanide, in the NE. ¼ sec. 5, T. 19 S., R. 69 W., struck oil at a depth of 1,220 feet. After producing about 3 barrels a day for twenty days the well was drilled deeper to 1,500 feet, without encountering more oil, and abandoned. A dry well was drilled about the same time by the Colorado Oil Company in sec. 4, about a mile east of the Robinson well. The geologic conditions of the W. ½ sec. 9 and the N. ½ sec. 8 are not unfavorable for the accumulation of oil.

West of sec. 8 the area in the northwest corner of the region shown on the map (Pl. XXIV), included in secs. 36, 1, 12, 6, and 7, must be regarded as unfavorable territory, because of the number of dry wells drilled in it. A marked synclinal axis runs about N. 10° E. from the southwest corner of sec. 6, west of wells Nos. 206 and 207 and east of wells Nos. 211 and 216 of the United Oil Company. The wells were all dry except No. 206, which had a trace of oil at 1,810 feet. No. 207, however, was only 1,850 feet deep. These test wells indicate that the lower part of the syncline is practically barren of oil.

A location in the neighborhood of Brookside, 2 miles farther west, near the southeast corner of sec. 3, T. 19 S., R. 20 W., would have the same position relative to the north side of the synclinal basin that the developed field has to the east side of the basin. A test well in that neighborhood would seem desirable, but it should be remembered that purely geologic considerations, such as that on which this statement is made, have very little value in the Florence field.

The western limit of the productive territory is sinuous and indefinite, but apparently does not approach within one-fourth of a mile of the west line of R. 69 W. In the north-south strip of land lying from one-fourth to one-half mile east of the township line nine out of twenty-one wells, or 43 per cent, produced some oil. This figure corresponds favorably with the success in the central parts of the field. West of this strip of land, which is largely barren itself, no producing wells have been found, and west of the township line not even a trace of oil has been found in any of the eight wells drilled by the United Oil Company to depths of 1,800 to 2,400 feet. It is highly probable that T. 19 S., R. 70 W., is barren, with the possible exception of the neighborhood of Brookside, which remains to be tested.

PRESSURE.

The oil and gas wells in the field have a flowing pressure of about 5 pounds to the square inch. A few gas wells gave pressure readings of 35 to 75 pounds to the square inch, but these are exceptional. The actual pressure within the oil-filled pores of the rock must be far in excess of these figures. It must be sufficient to raise the column of oil 500 to 2,500 feet high. This requires a pressure of 188 to 810 pounds to the square inch. The higher figure is regarded as nearer the truth, because the greater part of the pressure must be used up in forcing the oil through the pores.

A definite relation exists between the height of initial rise of oil in the well and the depth at which the oil is struck. In a general way the deeper the oil the higher can be the initial rise. It is not true that all the deeper wells have high pressure, but the maximum and average pressures in the deeper wells increase with depth.

The pressure is probably maintained at a very low rate of decline by the expansive property of the gas in the rock pores. The reasons why the gas is under pressure are largely theoretical and will be discussed in the final report. It may be said briefly that hydrostatic pressure can not be effective in the Florence field in the same way as in the Boulder and other oil fields; likewise the pressure is not due to the weight of the rock, because the pressure is much too low, and moreover, there is good reason to believe that in this field the shale is self-supporting on the walls of open fissures, except possibly below 3,000 feet. The source of pressure lies possibly in the forces of capillary action of water and oil.

RELATION TO GAS.

In all the pumping wells there is some gas mixed with the oil. The relative amount of gas is unusually low, amounting in a few wells to less than the volume of the oil. Many wells produce more gas than oil, but in most of these the gas comes from a higher horizon than the oil. The exceptions are all old wells. It is practically a rule without exceptions that the amount of gas in the oil increases as a well gets older. The significance of this rule will be discussed in the final report. No water ever follows the exhaustion of the oil.

Only ten wells are being operated for gas alone. Several of the oil wells produce enough gas to run the boilers, and nearly all produce enough gas to illuminate the wells. Practically all of the gas is used for pumping the oil, either by burning it under boilers or by using it in gas engines. The surplus gas from well No. 16 of the Florence Oil and Refining Company and from the adjacent well No. 2 of the Triumph Oil Company supplies half a dozen dwellings in Florence.

Gas is especially abundant above the productive oil zone, and in this part of the rock it is usually associated with streaks of oil. A few small flows of gas have been struck within a few hundred feet of the surface, but they were quickly exhausted, and it is thought that they have no relation to the gas below.

PHYSICAL PROPERTIES.

The Florence oil is a paraffin oil, dark olive-green by reflected light and reddish brown by transmitted light. Very thin films are yellowish brown.

The mean specific gravity of 48 samples from wells producing in December, 1908, is 0.8709 (equivalent to 30.7° Baumé). The highest specific gravity in these wells is 0.8762 (equivalent to 30.1° Baumé), from the Florence Oil and Refining Company's well No. 42, and the lowest 0.8664 (equivalent to 31.6° Baumé), from Philip Griffith's well No. 17. The oil is generally heavier at the north end of the field than at the south end, but in any locality there is much variation within the narrow range of gravity (1.5° Baumé) mentioned above.

Within the productive zone of shale there is no relation between depth and specific gravity, but above this zone traces of heavier oil have been found in the northern part of the field, and below the productive zone some heavy oil (specific gravity 0.9047, or 24.7° Baumé), was found at a depth of 3,660 feet in well No. 349 of the United Oil Company. As mentioned on page 520, there is some heavy black oil (specific gravity 0.965, or 15° Baumé) in the Morrison formation about 2,600 feet stratigraphically below the productive zone.

The oil in the older wells is heavier than that in the younger wells. By plotting the relation of the specific gravity to the age of the well on coordinate paper, and connecting the mean center points on such a diagram, it is found that the specific gravity increases approximately 0.00015 per year. This observation corroborates the conclusion of David T. Day,[a] that shale has the power of retarding the capillary movement of the more viscous elements of crude oil.

The temperature of the oil in the wells varies from 90° to 135° F., increasing with depth at the rate of about 1° F. for every 44 feet. This high gradient is probably due to the low conductivity of the dry shale.

The oil contains practically no sulphur. A small trace of water is found by distillation, but the quantity is too small to be detected by the eye in the tanks or vessels in which the oil has stood even for several weeks. The oil is practically free from water.

A small amount of mud accumulates in many of the wells and necessitates frequent cleaning. In three of the 48 samples of crude oil collected there is a noticeable deposit of very fine white clay, which has settled to the bottom of the bottles during the five months that they have been standing.

Impure, black paraffin begins to separate from the oil within the wells and accumulates on the pump rods. It interferes little, if at all, with the operation of the wells. The buried pipe lines do not become clogged, and have required only one cleaning in ten years. Surface pipe lines could not be operated in cold weather on account of the high viscosity of the oil and the amorphous nature of the paraffin.

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[a] Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. U. S. Geol. Survey No. 365, 1908.

TECHNOLOGY.

The oil is pumped directly from the well tanks through buried pipe lines to tanks at the refineries. The United Oil Company's wells in the southern part of the field pump their oil to a relay station, where larger pumps move it on to the refineries.

There are two refineries, of which the larger, having four stills, each of 600 barrels' capacity, belongs to the United Oil Company; and the smaller, having six stills, each of about 150 barrels' capacity (estimated), belongs to the Florence Oil and Refining Company. At the latter plant the only products recovered are gasoline, kerosene, and gas oil, the residue being sold as fuel oil. Besides these products "Mineral Seal" or signal oil, paraffin wax, and many varieties of lubricating oil are made by the plant of the United Oil Company. All products of the field except paraffin wax are marketed through the Continental Oil Company. All the wax is purchased by the Dupont Powder Company and used in the manufacture of dynamite. The gas oil is used by the Denver Gas and Electric Company in enriching illuminating gas and by the plants at Denver, Salt Lake, and Ogden which make the Pintsch gas familiar to railway travelers.

The results of distillation in the United Oil Company's refinery are:

Distillation at refinery of United Oil Company, Florence, Colo.

	Per cent.
Naphtha, gravity 65° B	4.15
Water-white oil, gravity 45° B	30.45
"Mineral Seal" oil, gravity 36.5° B	2.5
Gas distillate	22.9
Wax distillate, gravity 29.2° B	40.0

The "Mineral Seal" oil is more familiar as "signal oil," the name under which it is marketed by the Signal Oil Company, by which the product is handled. The wax distillate yields 10 per cent of paraffin wax, equivalent to about 4 per cent of the crude oil, and 90 per cent of pressed oil. The pressed oil yields 35 per cent of engine oils and 65 per cent of light neutral oils. The latter two groups of oils are altered by filtration and mixing to make different varieties of lubricating oils ranging from light machine oils to heavy black lubricants for car axles. No axle grease or vaseline is being made at the present time.

For comparison with the oils of other regions, the following standard analysis is inserted. This analysis was made under the direction of David T. Day, in the laboratory of the Geological Survey, on a sample of oil from well No. 385 of the United Oil Company. The sample was not fresh at the time of the analysis and hence may be too low in gasoline. The gravity was 30.0° Baumé.

Analysis of oil from company's well No. 385, Florence, Colo.

Gasoline	1.5
Burning oil, specific gravity 0.7988	27.0
Residuum, specific gravity 0.9079	70.2
Paraffin	9.23

HISTORY OF PRODUCTION.

The production of oil began in 1862, when a small still was operated by A. M. Cassedy at an oil spring on Oil or Fourmile Creek, 8 miles northeast of Florence. Most of the oil was obtained from shallow wells 20 to 50 feet deep, in the gravel on the east bank of the creek. The refined product sold in the local markets for $2 to $6 a gallon.

Encouraged by this occurrence of oil in the foothills, Mr. Cassedy induced Isaac Canfield to help him drill a deep well out in the valley. A point about 12 miles south-southeast of the oil spring was selected, near the present town of Coal Creek. In 1876 oil was struck in this well at a depth of 1,187 feet. In the next twelve years about twenty other wells were sunk by B. G. Peabody, A. M. Cassedy, James A. McCandless, J. Wallace, and other men, who organized companies known as the Arkansas Valley Oil and Land Company, the Land Investment Coal and Iron Company, the Colorado Oil Company, and the Canon City Oil Company. These companies obtained many successful wells and started the production of oil on a commercial scale. There are no reliable data of the production of oil until 1887, when the Florence Oil Company (later incorporated as the Florence Oil and Refining Company) was organized and the other companies were amalgamated in the United Oil Company, which has since remained the principal producer of oil in the Rocky Mountain region.

The annual production of the field in the last fifteen years is very uniform in comparison with that of most oil fields of limited area. It has not varied far from 400,000 barrels a year, except in years when the number of wells drilled was greatly increased or decreased. As the drilling success seems to be nearly as good in recent years as in the past, it is practically certain that the decline in production in 1906 and 1907 was due to the small number of wells (10) drilled by the United Oil Company in the two preceding years (1905-6) and to the fact that the independent companies stopped drilling at that time.

The following table of annual production of the field is probably reliable within 15,000 barrels a year since 1893, and within 25,000 barrels a year previous to 1893. The production of several of the independent companies between 1892 and 1900 has been estimated and included in the totals.

Annual production of crude oil of the Florence oil field.

[Barrels.]

1862–1886	(?) 350,000	1899	413,969
1887	154,769	1900	383,550
1888	180,422	1901	438,082
1889	262,203	1902	404,208
1890	249,329	1903	452,398
1891	309,950	1904	494,716
1892	379,148	1905	402,486
1893	487,322	1906	319,532
1894	429,381	1907	300,230
1895	464,004	1908	327,199
1896	447,112		
1897	401,175		8,510,318
1898	469,133		

DRILLING SUCCESS.

As in all other oil fields, the success of drilling declines as the field grows older. In the period of the drilling of the first wells, 1878 to 1891, about 65 per cent of the wells struck oil in quantities sufficient to warrant the pumping of the wells. Since 1891 only 40 per cent of the wells have been successful. The following table shows in detail the percentage of wells of the United Oil Company which struck pumping oil between 1887 and 1908:

Annual percentage of successful wells of United Oil Company in the Florence oil field.

1887–88 [a]	72	1898	40
1889	63	1899	26
1890	50	1900	42
1891	75	1901	50
1892	43	1902	43
1893	40	1903	40
1894	11	1904	41
1895	48	1905–6 [b]	55
1896	55	1907	37
1897	41	1908	41

The decline of drilling success in the field since 1890 has been remarkably small. This is best shown by the dotted line on figure 15, which represents the average number of gallons obtained by the United Oil Company for each well drilled in each year. It will be noted on examining this diagram that the drilling success from 1901 to 1908, inclusive, was much better than the success in the earlier period from 1896 to 1900. These figures are especially significant because the company has indulged in very little "wildcatting" outside of proved territory. The low production of the years 1905, 1906, and 1907 is clearly due to the small number of wells drilled

[a] Only 14 wells were drilled in the two years 1887 and 1888.
[b] Only 10 wells were drilled in the two years 1905 and 1906.

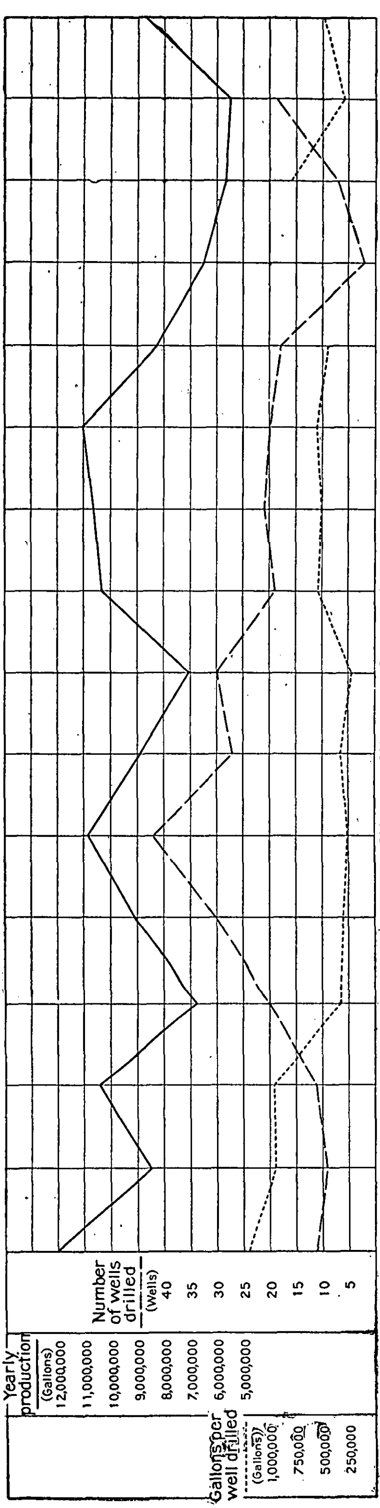


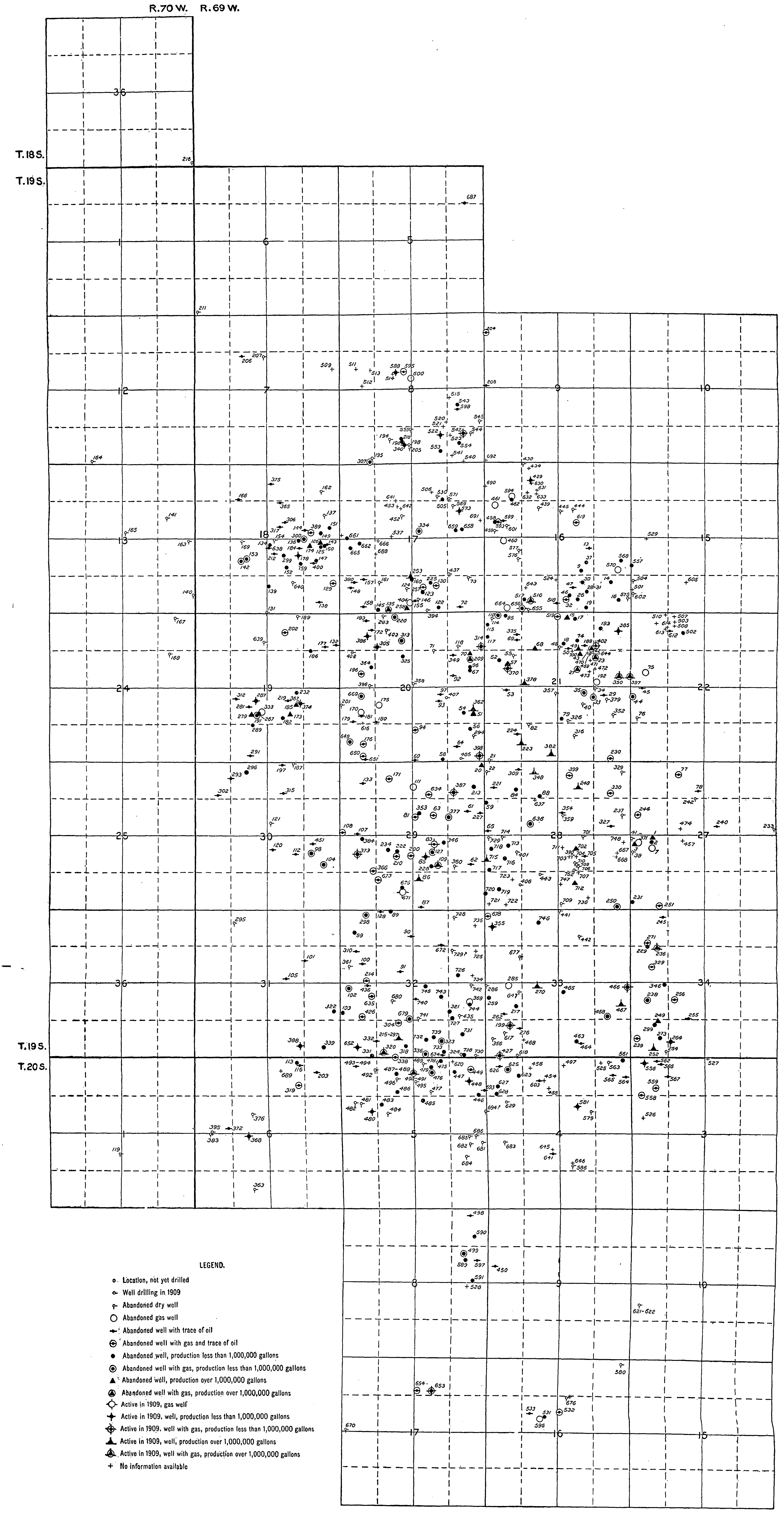
FIGURE 15.—Diagram showing drilling success of United Oil Company in Florence oil field, Colorado, 1887–1908.

in 1905 and 1906. On account of the small number of wells drilled in 1905 the erratic figure obtained for gallons per well drilled in that year has not been platted. This diagram must be regarded as very encouraging, because it indicates such unusual uniformity in drilling success for the last thirteen years. Although the field clearly passed its prime long ago, its exhaustion in the near future is not to be expected.

With the continued cooperation of those having information about the wells, the geologic study briefly summarized in this paper can be made complete, giving better knowledge of the way the oil lies in the rocks. It is hoped that this knowledge will lessen the chances of drilling dry holes and thereby reduce drilling expenses and prolong the life of the field.

EXPLANATION OF WELL MAP.

The map (Pl. XXIV) shows the location and character of about 700 wells. It is very imperfect for the wells of the Florence Oil and Refining Company on account of the poor records kept by that company. The same remark applies to the earlier wells of the Rocky Mountain Oil Company and to many wells of the smaller companies. For publication on the final map the writer will be grateful for any corrections which can be made by those having knowledge of the wells.



WELL MAP OF THE FLORENCE OIL FIELD, COLORADO.

By C. W. Washburne.

The only symbol on the map requiring explanation is the triangle used for large producers. In the case of abandoned wells this triangle designates wells that have produced over a million gallons. In the case of active wells the triangle with points designates either wells that have produced over a million gallons or wells with a very large monthly production and a low rate of decline, indicating that they will probably produce over a million gallons. The symbol is used not to show the present character of a well but rather to show the oil-bearing character of the locality.

On the map, well numbers from 1 to 407 are assigned to corresponding wells of the United Oil Company, numbers 501 to 611 are assigned consecutively to wells 1 to 111 of the Florence Oil and Refining Company with the exception of a few wells whose numbers are unknown, and numbers 701 to 752 correspond to wells 1 to 52, respectively, of the Rocky Mountain Oil Company. Numbers omitted are reserved for unlocated wells about which no information has yet been received. The numbers are explained by the following table:

Key to well numbers on Plate XXIV.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
1	United Oil Co.	1	NW.-SW	27	19	69
2	do	2	NW.-SW	27	19	69
3	do	3	NW.-SW	27	19	69
	do	4	Not known.			
	do	5	Do.			
	do	6	Do.			
7	do	7	N.W.-SW	27	19	69
	do	8	Not known.			
9	do	9	NW.-SE	16	19	69
	do	10	Not known.			
	do	11	Do.			
	do	12	Do.			
13	do	13	NW.-SE	16	19	69
14	do	14	SE.-SE	16	19	69
15	do	15	NW.-NE	21	19	69
16	do	16	SE.-SE	16	19	69
17	do	17	NW.-NE	21	19	69
18	do	18	NW.-NE	21	19	69
19	do	19	SW.-SE	16	19	69
20	do	20	NE.-NE	29	19	69
21	do	21	SW.-SW	21	19	69
22	do	22	NW.-NW	28	19	69
23	do	23	SE.-NE	21	19	69
	do	24	Not known.			
	do	25	Do.			
26	do	26	SW.-SE	16	19	69
27	do	27	SW.-NE	21	19	69
28	do	28	SW.-SE	16	19	69
29	do	29	NE.-SE	21	19	69
30	do	30	SW.-SE	16	19	69
31	do	31	SW.-SE	16	19	69
32	do	32	SW.-SE	16	19	69
33	do	33	NW.-SE	21	19	69
34	do	34	NE.-SE	21	19	69
35	do	35	NW.-SE	21	19	69
	do	36	Not known.			
37	do	37	NW.-SE	16	19	69
38	do	38	NW.-SW	27	19	69
	do	39	Not known.			
40	do	40	NW.-SE	21	19	69
41	do	41	NW.-NW	27	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
42	United Oil Co	42	SW.-NE	21	19	69
43	....do	43	SW.-NE	21	19	69
44	....do	44	NW.-SW	22	19	69
45	....do	45	NW.-SW	22	19	69
46	....do	46	SW.-SE	16	19	69
47	....do	47	SW.-SE	16	19	69
48	....do	48	SW.-NE	21	19	69
49	....do	49	SW.-NE	21	19	69
50	....do	50	SW.-NE	21	19	69
51	....do	51	NE.-SE	20	19	69
52	....do	52	SW.-NW	21	19	69
53	....do	53	NW.-SW	21	19	69
54	....do	54	NE.-SE	20	19	69
55	....do	55	SW.-NW	21	19	69
56	....do	56	SE.-SE	20	19	69
57	....do	57	SW.-NW	21	19	69
58	....do	58	SW.-SE	20	19	69
59	....do	59	SW.-NW	28	19	69
60	....do	60	SW.-SW	20	19	69
61	....do	61	SE.-NE	29	19	69
62	....do	62	NE.-SE	29	19	69
63	....do	63	SW.-NE	29	19	69
64	....do	64	SE.-SE	20	19	69
65	....do	65	SW.-NW	28	19	69
	....do	66	Not known.			
67	....do	67	SE.-NE	20	19	69
68	....do	68	SE.-NW	21	19	69
69	....do	69	NW.-NW	21	19	69
70	....do	70	SE.-NE	20	19	60
71	....do	71	SW.-NE	20	19	69
72	....do	72	SE.-SE	17	19	69
73	....do	73	SE.-SE	17	19	69
74	....do	74	NW.-NE	21	19	69
75	....do	75	SW.-NW	22	19	69
76	....do	76	NW.-SW	22	19	69
77	....do	77	NE.-NW	27	19	69
78	....do	78	NE.-NW	27	19	69
79	....do	79	NW.-SE	21	19	69
	....do	80	SW.-NE	29	19	69
81	....do	81	SW.-NE	29	19	69
82	....do	82	SE.-SW	21	19	69
83	....do	83	NW.-SE	29	19	69
84	....do	84	NW.-NW	28	19	69
85	....do	85	NW.-SE	29	19	69
86	....do	86	SW.-SE	29	19	69
87	....do	87	SW.-SE	29	19	69
88	....do	88	NE.-NW	28	19	69
89	....do	89	NE.-NW	32	19	69
90	....do	90	NE.-NW	32	19	69
91	....do	91	SE.-NW	32	19	69
92	....do	92	SE.-NE	20	19	69
93	....do	93	NW.-SE	20	19	69
94	....do	94	SW.-SE	20	19	69
95	....do	95	NW.-NW	21	19	69
96	....do	96	SE.-NE	20	19	69
97	....do	97	NW.-SE	20	19	69
98	....do	98	NE.-SE	30	19	69
99	....do	99	NW.-NW	32	19	69
100	....do	100	SW.-NW	32	19	69
101	....do	101	SE.-NE	31	19	69
102	....do	102	NW.-SW	32	19	69
103	....do	103	NW.-SW	31	19	69
104	....do	104	NE.-SE	30	19	69
105	....do	105	SW.-NE	31	19	69
	....do	106	Not drilled.			
107	....do	107	SW.-NW	29	19	69
108	....do	108	SW.-NW	29	19	69
109	....do	109	NW.-SE	29	19	69
110	....do	110	NW.-NW	21	19	69
111	....do	111	NW.-NE	29	19	69
112	....do	112	NW.-SE	30	19	69
113	....do	113	NW.-NE	6	20	69
114	....do	114	NW.-NW	21	19	69
115	....do	115	NW.-NW	21	19	69
116	....do	116	NW.-NE	6	20	69
117	....do	117	NW.-NW	21	19	69
118	....do	118	NE.-NE	20	19	69
119	....do	119	NE.-SW	1	20	70

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location. Quarter.	Section.	Township S.	Range W.
120	United Oil Co.	120	NW.-SE.	30	19	69
121	....do.	121	SW.-NE.	30	19	69
122	....do.	122	SW.-SE.	17	19	69
123	....do.	123	SW.-SE.	17	19	69
124	....do.	124	SE.-SW.	17	19	69
125	....do.	125	NE.-SE.	18	19	69
126	....do.	126	NE.-SE.	18	19	69
127	....do.	127	NW.-SE.	29	19	69
128	....do.	128	NE.-NW.	32	19	69
129	....do.	129	SE.-SE.	18	19	69
130	....do.	130	SW.-SE.	17	19	69
131	....do.	131	SW.-SE.	18	19	69
132	....do.	132	NE.-NE.	19	19	69
133	....do.	133	NW.-NW.	29	19	69
134	....do.	134	NW.-SE.	18	19	69
135	....do.	135	SE.-SW.	17	19	69
136	....do.	136	NW.-SE.	18	19	69
137	....do.	137	SE.-NE.	18	19	69
138	....do.	138	SE.-SE.	18	19	69
139	....do.	139	SW.-SE.	18	19	69
140	....do.	140	SE.-SE.	13	19	69
141	....do.	141	SE.-NE.	13	19	70
142	....do.	142	NE.-SW.	18	19	69
143	....do.	143	NE.-SE.	18	19	69
144	....do.	144	SE.-NE.	18	19	69
145	....do.	145	SE.-SW.	17	19	69
146	....do.	146	SW.-SE.	17	19	69
147	....do.	147	NE.-SE.	18	19	69
148	....do.	148	SW.-SW.	17	19	69
149	....do.	149	SE.-NE.	18	19	69
150	....do.	150	NE.-SE.	18	19	69
151	....do.	151	SE.-NE.	18	19	69
152	....do.	152	NW.-SE.	18	19	69
153	....do.	153	NE.-SW.	18	19	69
154	....do.	154	NW.-SE.	18	19	69
155	....do.	155	SW.-SE.	17	19	69
156	....do.	....	Not drilled.			
157	....do.	157	SW.-SW.	17	19	69
158	....do.	158	SW.-SW.	17	19	69
159	....do.	159	NW.-SE.	18	19	69
160	....do.	160	SE.-SW.	17	19	69
161	....do.	161	SE.-SW.	17	19	69
162	....do.	162	NE.-NE.	18	19	69
163	....do.	163	NE.-SE.	13	19	70
164	....do.	164	SE.-SW.	12	19	70
165	....do.	165	SW.-NE.	13	19	70
166	....do.	166	NE.-NW.	18	19	69
167	....do.	167	NE.-NE.	24	19	70
168	....do.	168	SE.-NE.	24	19	70
169	....do.	169	NE.-SW.	18	19	69
170	....do.	170	NW.-SW.	20	19	69
171	....do.	171	NE.-NW.	29	19	69
172	....do.	172	NW.-NW.	20	19	69
173	....do.	173	NW.-SE.	19	19	69
174	....do.	174	NE.-SE.	18	19	69
175	....do.	175	NE.-SW.	20	19	69
176	....do.	176	SW.-SW.	20	19	69
177	....do.	177	NE.-NE.	19	19	69
178	....do.	178	NW.-SE.	18	19	69
179	....do.	179	NW.-SW.	20	19	69
180	....do.	180	NE.-SW.	20	19	69
181	....do.	181	NW.-SW.	20	19	69
182	....do.	182	NW.-SE.	19	19	69
183	....do.	183	NW.-NW.	20	19	69
184	....do.	184	NW.-SE.	18	19	69
185	....do.	185	NW.-SE.	19	19	69
186	....do.	186	SE.-NE.	19	19	69
187	....do.	187	NW.-NE.	30	19	69
188	....do.	188	NW.-NE.	21	19	69
189	....do.	189	NW.-NE.	19	19	69
190	....do.	190	SE.-SW.	8	19	69
191	....do.	191	NE.-SW.	19	19	69
192	....do.	192	SE.-NE.	21	19	69
193	....do.	193	NE.-NE.	21	19	69
194	....do.	194	SE.-SW.	8	19	69
195	....do.	195	SW.-SW.	8	19	69
196	....do.	196	SW.-NW.	20	19	69
197	....do.	197	NW.-NE.	30	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location. Quarter.	Section.	Township S.	Rang W.
198	United Oil Co.	198	SE.-SW	8	19	6
199	do	199	SW.-SW	33	19	6
200	do	200	NE.-SW	29	19	6
201	do	201	NW.-SW	20	19	6
202	do	202	NW.-NE	19	19	69
203	do	203	NE.-NE	6	20	69
204	do	204	NW.-NW	9	19	69
205	do	205	SE.-SW	8	19	69
206	do	206	SE.-NW	7	19	69
207	do	207	SE.-NW	7	19	69
208	do	208	SW.-NW	9	19	69
209	do	209	SE.-NE	20	19	69
210	do	210	NE.-SW	29	19	69
211	do	211	SW.-SW	6	19	69
212	do	212	NW.-SE	18	19	69
213	do	213	NE.-NE	29	19	69
214	do	214	SW.-NW	32	19	69
215	do	215	SE.-SW	32	19	69
216	do	216	SE.-SE	36	18	70
217	do	217	NW.-SW	33	19	69
218	do	218	SE.-SW	8	19	69
219	do	219	NW.-SE	19	19	69
220	do	220	NE.-NW	20	19	69
221	do	221	NW.-NW	28	19	69
222	do	222	NE.-SW	29	19	69
223	do	223	SW.-SW	21	19	69
224	do	224	SW.-SW	21	19	69
225	do	225	SW.-SE	17	19	69
226	do	226	NW.-SE	29	19	69
227	do	227	SE.-NE	29	19	69
	do	228	Not known.			
229	do	229	SW.-SW	34	19	69
230	do	230	SE.-NE	21	19	69
231	do	231	SW.-SW	27	19	69
232	do	232	NW.-SE	19	19	69
233	do	233	SE.-NE	27	19	69
234	do	234	NE.-SW	29	19	69
	do	235	SE.-NW	3	20	70
236	do	236	SW.-NW	34	19	69
237	do	237	SE.-NE	28	19	69
238	do	238	NW.-SW	34	19	69
239	do	239	SW.-SW	34	19	69
240	do	240	SW.-NE	27	19	69
	do	241	Not known.			
242	do	242	SE.-NW	27	19	69
	do	243	Not drilled.			
244	do	244	SW.-NW	27	19	69
245	do	245	NW.-NW	34	19	69
246	do	246	NW.-SW	34	19	69
	do	247	Not drilled.			
248	do	248	NW.-NE	28	19	69
249	do	249	SW.-SW	34	19	69
250	do	250	SE.-SE	28	19	69
251	do	251	SW.-SW	27	19	69
252	do	252	SW.-SW	34	19	69
253	do	253	SW.-SE	17	19	69
254	do	254	SW.-SW	34	19	69
255	do	255	NE.-SW	34	19	69
256	do	256	NE.-SW	34	19	69
257	do	257	SW.-SE	17	19	69
258	do	258	SE.-SW	17	19	69
259	do	259	NW.-SW	33	19	69
	do	260	Not drilled.			
	do	261	Not drilled.			
262	do	262	NW.-SW	33	19	69
	do	263	Not drilled.			
264	do	264	SE.-SW	34	19	69
	do	265	Not drilled.			
	do	266	Not known.			
267	do	267	NE.-SW	19	19	69
	do	268	Not drilled.			
	do	269	Do.			
270	do	270	NE.-SW	33	19	69
271	do	271	NW.-NW	34	19	69
	do	272	Not drilled.			
273	do	273	SW.-SW	34	19	69
	do	274	Not drilled.			
	do	275	Not known.			

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
276	United Oil Co.	276	SW.-SW.	33	19	69
	....do.	277	Not known.			
	....do.	278	Not drilled.			
279	....do.	279	NE.-SW.	19	19	69
	....do.	280	Not drilled.			
281	....do.	281	NE.-SW.	19	19	69
	....do.	282	Not known.			
283	....do.	283	NE.-NW.	20	19	69
	....do.	284	Not drilled.			
285	....do.	285	NW.-SW.	33	19	69
286	....do.	286	NW.-SW.	33	19	69
287	....do.	287	NE.-SW.	19	19	69
	....do.	288	Not known.			
289	....do.	289	SE.-SW.	19	19	69
	....do.	290	Not drilled.			
291	....do.	291	SE.-SW.	19	19	69
	....do.	292	Not known.			
293	....do.	293	NE.-NW.	30	19	69
294	....do.	294	SE.-SE.	20	19	69
295	....do.	295	NE.-NW.	31	19	69
296	....do.	296	NE.-NW.	30	19	69
297	....do.	297	SE.-SW.	32	19	69
298	....do.	298	NW.-NW.	32	19	69
299	....do.	299	NW.-SE.	18	19	69
300	....do.	300	SE.-NE.	18	19	69
	....do.	301	Not known.			
302	....do.	302	NW.-NW.	30	19	69
	....do.	303	Not drilled.			
304	....do.	304	SE.-SW.	32	19	69
305	....do.	305	NE.-NW.	20	19	69
306	....do.	306	SW.-NE.	18	19	69
307	....do.	307	SW.-SW.	8	19	69
	....do.	308	Not drilled.			
309	....do.	309	NW.-NW.	28	19	69
310	....do.	310	SW.-NW.	32	19	69
	....do.	311	Not drilled.			
312	....do.	312	NE.-SW.	19	19	69
313	....do.	313	NE.-NW.	20	19	69
314	....do.	314	NE.-NE.	20	19	69
315	....do.	315	NW.-NE.	20	19	69
316	....do.	316	SW.-SE.	21	19	69
317	....do.	317	SW.-NE.	18	19	69
318	....do.	318	SE.-SW.	32	19	69
319	....do.	319	NW.-NE.	6	20	69
320	....do.	320	SE.-SW.	32	19	69
321	....do.	321	NE.-SE.	32	19	69
322	....do.	322	NE.-SE.	31	19	69
323	....do.	323	SW.-SE.	32	19	69
324	....do.	324	SW.-SE.	32	19	69
325	....do.	325	SE.-NW.	20	19	69
326	....do.	326	NW.-SE.	21	19	69
327	....do.	327	SE.-NE.	28	19	69
	....do.	328	Not drilled.			
329	....do.	329	NE.-NE.	28	19	69
330	....do.	330	NE.-NE.	28	19	69
331	....do.	331	SW.-SW.	32	19	69
332	....do.	332	SW.-SW.	32	19	69
333	....do.	333	NE.-SW.	19	19	69
334	....do.	334	SW.-NE.	17	19	69
335	....do.	335	NW.-NW.	21	19	69
336	....do.	336	SW.-SE.	32	19	69
337	....do.	337	NW.-SW.	29	19	69
338	....do.	338	SE.-SW.	32	19	69
339	....do.	339	SE.-SE.	31	19	69
340	....do.	340	SE.-SW.	8	19	69
	....do.	341	Not drilled.			
	....do.	342	Do.			
	....do.	343	Do.			
	....do.	344	Do.			
	....do.	345	Do.			
346	....do.	346	NW.-SE.	29	19	69
	....do.	347	Not drilled.			
348	....do.	348	NE.-NW.	28	19	69
349	....do.	349	SE.-NE.	20	19	69
350	....do.	350	SE.-NE.	21	19	69
	....do.	351	Not known.			
352	....do.	352	NE.-SE.	21	19	69
353	....do.	353	SW.-NE.	29	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location. Quarter.	Section.	Township S.	Range W.
354	United Oil Co	354	SW.-NE	28	19	69
355	....do	355	NW.-NW	33	19	69
356	....do	356	SW.-SW	33	19	69
357	....do	357	NE.-SW	21	19	69
358	....do	358	SW.-NE	20	19	69
359	....do	359	SW.-NE	28	19	69
360	....do	360	NE.-SE	29	19	69
361	....do	361	SW.-NW	32	19	69
362	....do	362	NE.-SE	20	19	69
363	....do	363	SE.-SW	6	20	69
364	....do	364	SW.-NW	20	19	69
365	....do	365	SW.-NE	18	19	69
366	....do	366	NW.-SW	29	19	69
367	....do	367	NW.-SE	19	19	69
368	....do	368	NE.-SW	6	20	69
369	....do	369	NE.-SE	32	19	69
370	....do	370	SW.-NW	21	19	69
371	....do	371	NW.-SW	27	19	69
372	....do	372	SW.-NW	6	20	69
373	....do	373	NW.-SW	29	19	69
374	....do	374	NW.-SE	19	19	69
375	....do	375	NW.-NE	16	19	69
376	....do	376	SE.-NW	6	20	69
377	....do	377	SE.-NE	29	19	69
378	....do	378	SE.-NW	21	19	69
379	....do	379	NE.-SE	21	19	69
380	....do	380	SW.-SW	17	19	69
	....do	381	Not drilled.			
382	....do	382	SE.-SW	21	19	69
383	....do	383	NW.-SW	6	20	69
384	....do	384	NW.-SW	29	19	69
385	....do	385	NE.-NE	21	19	69
386	....do	386	NW.-NW	20	19	69
387	....do	387	NE.-NE	29	19	69
388	....do	388	SW.-SE	31	19	69
389	....do	389	SE.-NE	18	19	69
390	....do	390	NW.-SE	28	19	69
	....do	391	Not drilled.			
392	....do	392	SW.-NW	34	19	69
393	....do	393	Not drilled.			
394	....do	394	SW.-SE	17	19	69
395	....do	395	SW.-NW	6	20	69
396	....do	396	SW.-NW	20	19	69
397	....do	397	SE.-NE	21	19	69
398	....do	398	SE.-SE	20	19	69
399	....do	399	NW.-NE	28	19	69
400	....do	400	NE.-SE	18	19	69
401	....do	401	NW.-SW	28	19	69
402	....do	402	NE.-NE	21	19	69
403	....do	403	NE.-NW	20	19	69
404	....do	404	SE.-SW	17	19	69
405	....do	405	SE.-SE	20	19	69
406	....do	406	SW.-SW	28	19	69
407	....do	407	NW.-NW	20	19	69
408	....do	408	SW.-NW	20	19	69
426	American Oil Co	1	NW.-SW	32	19	69
427	Arkansas Valley Oil Co	1	SW.-SW	33	19	69
	Blaney Oil, Gas and Refining Co	1	Not located.			
429	....do	2	NE.-NW	16	19	69
430	....do	3	NE.-NW	16	19	69
	....do	4	Not located.			
	....do	5	Do.			
	....do	6	Do.			
434	....do	7	NE.-NW	16	19	69
435	Birmingham Oil Co	1	NE.-SE	32	19	69
436	Isaac Canfield	1	NW.-SW	32	19	69
437	Carbon Oil Co	1	NE.-SE	17	19	69
438	Centennial State Oil and Development Co	1	Not located.			
439	....do	2	SE.-NW	16	19	69
440	....do	3	Not located.			
441	Central Oil Co	1	NW.-NE	33	19	69
442	....do	2	NW.-NE	33	19	69
443	....do	3	SE.-SW	26	19	69
444	City Park Oil Co	1	SW.-NE	16	19	69
445	....do	2	SW.-NE	16	19	69
446	Columbia Crude Oil Co	1	NE.-NE	5	20	69
447	....do	2	NE.-NE	5	20	69
448	....do	3	NE.-NE	5	20	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
449	Columbia Crude Oil Co	4	NE.-NE	5	20	69
450	....do	7	SW.-NW	9	20	69
451	Empire Oil Co	1	NE.-SE	30	19	69
452	....do	2	SE.-NW	17	19	69
453	....do	3	SE.-NW	17	19	69
454	Florence Consolidated Oil Co	1	NE.-NW	4	20	69
455	....do	2	NE.-NW	4	20	69
456	....do	3	NE.-NW	4	20	69
457	Unknown		NE.-SW	27	19	69
458	Frazer Oil Co	1	SW.-NW	16	19	69
459	....do	2	SW.-NW	16	19	69
460	....do	3	NW.-SW	16	19	69
461	....do	4	SW.-NW	16	19	69
462	....do	5	NW.-NW	16	19	69
463	Fremont Oil and Gas Co	1	SW.-SE	33	19	69
464	....do	2	SW.-SE	33	19	69
465	....do	3	NW.-SE	33	19	69
466	....do	4	NE.-SE	33	19	69
467	....do	5	NE.-SE	33	19	69
468	....do	6	NE.-SE	33	19	69
469	Unknown		SW.-NE	21	19	69
470	....do		SW.-NE	21	19	69
471	....do		SW.-NE	21	19	69
472	....do		SE.-NE	21	19	69
473	....do		SW.-NE	21	19	69
474	....do		SE.-NW	27	19	69
475	Philip Griffith	1	NW.-NE	5	20	69
476	....do	2	NW.-NE	5	20	69
477	....do	3	NW.-NE	5	20	69
478	....do	4	NW.-NE	5	20	69
479	....do	5	NW.-NE	5	20	69
480	....do	6	SW.-NW	5	20	69
481	....do	7	SW.-NW	5	20	69
482	....do	8	SW.-NW	5	20	69
483	....do	9	SE.-NW	5	20	69
484	....do	10	SE.-NW	5	20	69
485	....do	11	SW.-NE	5	20	69
486	....do	12	NE.-NW	5	20	69
487	....do	13	NE.-NW	5	20	69
488	....do	14	NE.-NW	5	20	69
489	....do	15	NW.-NE	5	20	69
490	....do	16	NW.-NE	5	20	69
491	....do	17	NW.-NE	5	20	69
492	....do	18	NW.-NW	5	20	69
493	....do	19	NW.-NW	5	20	69
494	....do	20	NW.-NW	5	20	69
495	....do	21	NW.-NE	5	20	69
496	....do	22	NE.-NW	5	20	69
497	Max Grosmeyer	1	NW.-NE	4	20	69
498	Hiawatha Oil Co	1	NE.-NE	8	20	69
499	....do	2	SE.-NE	8	20	69
	....do	3	Not located.			
501	Florence Oil and Refining Co	1	SW.-SW	15	19	69
502	....do	2a	NE.-NW	22	19	69
503	....do	3	NE.-NW	22	19	69
504	....do	4	SW.-SW	15	19	69
505	....do	5	NW.-NE	17	19	69
506	....do	6	NW.-NE	17	19	69
507	....do	7	NE.-NW	22	19	69
508	....do	8	NE.-NW	22	19	69
509	....do	(?)	SE.-NE	7	19	69
510	....do	10	NW.-NW	22	19	69
511	....do	(?)	SW.-NW	8	19	69
512	....do	(?)	SW.-NW	8	19	69
513	....do	(?)	SW.-NW	8	19	69
514	....do	(?)	SE.-NW	8	19	69
515	....do	(?)	NE.-SE	8	19	69
516	....do	16	SE.-SW	16	19	69
517	....do	17	SE.-SW	16	19	69
518	....do	18	SE.-SW	16	19	69
519	....do	19	NE.-NW	21	19	69
520	....do	(?)	NW.-SE	8	19	69
521	....do	(?)	SW.-SE	8	19	69
522	....do	(?)	SW.-SE	8	19	69
523	....do	(?)	SE.-SE	8	19	69
524	....do	(?)	SE.-SW	16	19	69
525	....do	(?)	NE.-NE	4	20	69
526	....do	(?)	SW.-NW	3	20	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location. Quarter.	Section.	Township S.	Range W.
527	Florence Oil and Refining Co	(?)	NW.-NE	3	20	69
528	....do	(?)	NE.-SE	8	20	69
529	....do	(?)	NW.-SW	15	19	69
530	....do	(?)	NW.-NE	17	19	69
	....do	31-36	Not located.			
537	....do	37	NE.-SW	17	19	69
	....do	38, 39	Not located.			
540	....do	40	SE.-SE	8	19	69
541	....do	41	SE.-SE	8	19	69
542	....do	42	SE.-SE	8	19	69
543	....do	43	NE.-SE	8	19	69
544	....do	44	NE.-SE	8	19	69
545	....do	45	SE.-SE	8	19	69
	....do	46-52	Not located.			
553	....do	53	SW.-SE	8	19	69
554	....do	54	SE.-SE	8	19	69
555	....do	55	SE.-SW	8	19	69
556	....do	56	NW.-NW	3	20	69
557	....do	57	NW.-SW	15	19	69
558	....do	58	NW.-NW	3	20	69
559	....do	59	NW.-NW	3	20	69
	....do	60	Not located.			
561	....do	61	NE.-NE	4	20	69
562	....do	62	NW.-NW	3	20	69
563	....do	63	NE.-NE	4	20	69
564	....do	64	NE.-NE	4	20	69
565	....do	65	NE.-NE	4	20	69
566	....do	66	NW.-NW	3	20	69
567	....do	67	NW.-NW	3	20	69
568	....do	68	NE.-SE	16	19	69
569	....do	69	SE.-NE	17	19	69
570	....do	70	NE.-SE	16	19	69
571	....do	71	NE.-NE	17	19	69
	....do	72	Not located.			
573	....do	73	SE.-NE	17	19	69
574	....do	74	Not located.			
575	....do	75	SE.-SE	16	19	69
576	....do	76	NW.-SW	16	19	69
577	....do	77	NW.-SW	16	19	69
	....do	78	Not located.			
579	....do	79	SW.-NE	4	20	69
580	....do	80	NE.-NE	16	20	69
581	....do	81	SW.-NE	4	20	69
	....do	82-85	Not located.			
586	....do	86	NW.-SE	4	20	69
	....do	87	Not located.			
588	....do	88	SE.-NW	8	19	69
589	....do	89	SE.-NE	8	20	69
590	....do	90	NE.-NE	8	20	69
591	....do	91	SE.-NE	8	20	69
	....do	92	Not located.			
593	....do	93	SW.-NW	16	19	69
594	....do	94	NW.-NW	16	19	69
595	....do	95	SE.-NW	8	19	69
596	....do	96	SE.-NW	16	20	69
597	....do	97	SE.-NE	8	20	69
598	....do	98	NE.-SE	8	19	69
599	....do	99	SW.-NW	16	19	69
600	....do	100	SW.-NE	8	19	69
601	....do	101	SW.-NW	16	19	69
602	....do	102	SW.-SW	16	19	69
603	....do	103	NE.-NW	4	20	69
	....do	104	Not located.			
605	....do	105	SE.-SW	15	19	69
	....do	106	Not located.			
612	....do	2b	NE.-NW	22	19	69
613	....do	2c	NW.-NW	22	19	69
614	....do	2d	NE.-NW	22	19	69
616	N. P. Hill	1	NW.-SW	20	19	69
617	....do	2	SW.-SW	33	19	69
618	....do	3	SW.-SW	33	19	69
619	Junction Oil Co	1	SW.-NE	16	19	69
620	Mr. Kirk	.....	NE.-NE	5	20	69
621	Keystone Oil Co	1	NW.-SW	10	20	69
622	....do	2	NW.-SW	10	20	69
623	....do	3	NW.-NW	4	20	69
	....do	4	Not located.			
625	....do	5	NW.-NW	4	20	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
626	Keystone Oil Co	6	NW.-NW	4	20	69
627	....do	7	NW.-NW	4	20	69
628	....do	8	NW.-NW	4	20	69
629	....do	9	SW.-NW	4	20	69
630	Blaney Oil, Gas, and Refining Co		NE.-NW	16	19	69
631	....do		NE.-NW	16	19	69
632	....do		NE.-NW	16	19	69
633	Unknown	3	NE.-NW	16	19	69
634	McComas Oil Co	1	NW.-NE	29	19	69
635	National Oil Co	1	NW.-SW	32	19	69
636	....do	2	SE.-NW	28	19	69
637	....do	3	SE.-NW	28	19	69
638	Oak Creek Oil Co	1	NW.-SE	18	19	69
639	....do	2	NE.-NW	19	19	69
640	Petroleum Oil Co	1	SW.-SE	18	19	69
641	Unknown		SE.-NW	17	19	69
642	....do		SE.-NW	17	19	69
643	....do		SE.-SW	16	19	69
644	....do		SW.-NE	21	19	69
645	Reservoir Oil Co	5	NE.-SW	4	20	69
646	....do	6	NW.-SE	4	20	69
647	Sterling Oil Co	1	NW.-SW	33	19	69
648	Stadacona Oil Co	1	Near Wetmore, Colo.			
649	....do	2	SW.-SW	20	19	69
650	....do	3	SW.-SW	20	19	69
651	....do	4	SW.-SW	20	19	69
652	....do	5	SW.-SW	32	19	69
653	Simon Smith	1	NW.-NE	17	20	69
654	....do	2	NW.-NE	17	20	69
655	Triumph Oil Co	1	SE.-SW	16	19	69
656	....do	2	SE.-SW	16	19	69
	....do	3	Not located.			
658	....do	4	SE.-NE	17	19	69
659	....do	5	SE.-NE	17	19	69
	....do	6	Not located.			
661	....do	7	SW.-NW	17	19	69
662	....do	8	NW.-SW	17	19	69
	....do	9	Not located.			
664	....do	10	SW.-SW	16	19	69
665	....do	11	NW.-SW	17	19	69
666	....do	36	NE.-SW	17	19	69
667	Unknown		NE.-SE	28	19	69
668	....do		NE.-SE	28	19	69
669	....do		NW.-SW	20	19	69
670	Independent Oil Co	1	SW.-NW	17	20	69
671	Union Oil Mining and Development Co	1	SE.-SW	29	19	69
672	....do	2	NW.-NE	32	19	69
673	....do	3	SE.-SW	29	19	69
674	....do	4	SW.-SE	32	19	69
675	....do	5	SE.-SW	29	19	69
676	Wilkes-Barre-Colorado Oil Co		SW.-NE	16	20	69
677	West Lebanon Oil Co	1	SW.-NW	33	19	69
678	....do	2	NW.-NW	33	19	69
679	....do	3	NE.-SW	32	19	69
680	....do	4	NE.-SW	32	19	69
681	Victor Oil Co	1	NE.-SE	5	20	69
882	....do	2	NE.-SE	5	20	69
683	....do	3	NW.-SW	4	20	69
684	....do	4	NE.-SE	5	20	69
685	....do	5	NE.-SE	5	20	69
686	....do	6	NE.-SE	5	20	69
687	"Robinson" well		NE.-NE	5	19	69
688	Unknown		NE.-SW	17	19	69
689	Mr. Caldwell	1	NW.-NE	6	20	69
690	Lobach Oil Co		NW.-NW	16	19	69
691	....do		SE.-NE	17	19	69
692	Continental Oil Co	1	SW.-SW	9	19	69
693	Columbia Crude Oil Co	5	NE.-NE	5	20	69
694	....do	6	SE.-NE	5	20	69
701	Rocky Mountain Oil Co	1	NW.-SE	28	19	69
702	....do	2	NW.-SE	28	19	69
703	....do	3	NW.-SE	28	19	69
704	....do	4	NW.-SE	28	19	69
705	....do	5	NW.-SE	28	19	69
706	....do	6	NW.-SE	28	19	69
707	....do	7	SW.-SE	28	19	69
708	....do	8	NW.-SE	28	19	69
709	....do	9	SW.-SE	28	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map	Owner.	Owner's No.	Location. Quarter.	Section.	Township S.	Range W.
710	Rocky Mountain Oil Co	10	NW.-SE	28	19	69
711	.....do	11	NW.-SE	28	19	69
712	.....do	12	SW.-SE	28	19	69
713	.....do	13	NW.-SW	28	19	69
714	.....do	14	NW.-SW	28	19	69
715	.....do	15	NW.-SW	28	19	69
716	.....do	16	NW.-SW	28	19	69
717	.....do	17	NW.-SW	28	19	69
718	.....do	18	NW.-SW	28	19	69
719	.....do	19	SW.-SW	28	19	69
720	.....do	20	SW.-SW	28	19	69
721	.....do	21	SW.-SW	28	19	69
722	.....do	22	SW.-SW	28	19	69
723	.....do	23	SW.-SW	28	19	69
	.....do	24	Not located.			
725	.....do	25	SE.-NE	32	19	69
726	.....do	26	SE.-NE	32	19	69
727	.....do	27	NE.-SE	32	19	69
728	.....do	28	NE.-NE	32	19	69
729?	.....do	29	SE.-NE	32	19	69
730	.....do	30	SE.-SE	32	19	69
731	.....do	31	SE.-SE	32	19	69
732	.....do	32	SW.-SE	32	19	69
733	.....do	33	SW.-SE	32	19	69
734	.....do	34	SE.-NE	32	19	69
735	.....do	35	NE.-NE	32	19	69
736	.....do	36	SW.-SE	28	19	69
737	.....do	.....	Not located.			
738	.....do	38	SE.-SE	32	19	69
739	.....do	39	SW.-SE	32	19	69
740	.....do	40	NW.-SE	32	19	69
741	.....do	41	NW.-SE	32	19	69
742	.....do	42	NE.-SE	32	19	69
743	.....do	43	NW.-SE	32	19	69
744	.....do	44	NE.-SE	32	19	69
745	.....do	45	NW.-SE	32	19	69
746	.....do	46	NE.-NW	32	19	69
747	.....do	47	SW.-SE	28	19	69
748	.....do	48	NE.-SE	28	19	69
	.....do	49-51	Not located.			
752	.....do	52	NW.-SE	28	19	69

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