PETROLEUM AND NATURAL GAS.

THE SALT LAKE OIL FIELD NEAR LOS ANGELES, CAL.

By Ralph Arnold.

Introduction.—Since the completion, four years ago, of the examination of the California oil districts by the late G. H. Eldridge, one of the most important fields in the State has been developed near the city of Los Angeles. This field, locally known as the Salt Lake from its first important producing company, has grown from a position of comparative insignificance in 1902 to that of possibly the premier field of southern California in 1905.

Location and topography.—The Salt Lake oil field occupies an area approximately a mile square, 7 miles west of the business portion of Los Angeles, Cal. (see fig. 12). The field is a part of the Los Angeles-Santa Monica plain, which extends southward with a gradually lessening slope from the base of the Santa Monica Range toward the hills southwest of Los Angeles. With the exception of a few unimportant ravines which run in a general southwesterly direction across the plain and an extensive slope which descends gradually from the field northwestward toward Sherman, there is little to break the topographic monotony in the vicinity of the wells. A small artificial lagoon, made by the removal of large quantities of brea, occupies a depression about 75 by 150 yards near the center of the southern part of the field. Reference will be made to this lagoon later in the discussion.

Geologic formations.—Alluvium and Pleistocene deposits of gravel, sand, and clay cover the plain in the region of the Salt Lake field, but surface outcrops of other beds are to be found no nearer than about 2 miles from the present developed territory. The well logs and a study of the adjacent region indicate, however, that the formations involved in the geology of this field include at least a part of those exposed to the east, in the vicinity of the Los Angeles city field, and consist of (a) 2,000+ feet of lower Miocene sandstone, (b) 2,000± feet of middle and possibly upper Miocene shales and thin-bedded sandstones, (c) 2,000+ feet of Pliocene clayey and sandy shale, sandstone, and gravel, and (d) an unconformable capping of Pleistocene gravel, sand, and clay varying in thickness from 40 to at least 100 feet or more, the whole covered by alluvium.

The lower Miocene sandstones are coarse, arkose, and heavy bedded, gray to rusty brown in color, sometimes concretionary in structure, and often jointed. They are interbedded at irregular intervals by smaller amounts of dark-colored earthy and lighter siliceous shales. Toward the top of the series, however, the shales become relatively more abundant. No sharp line of demarcation separates the sandstones from the overlying series, which consists largely of shales of middle and possibly upper Miocene age. The lower 1,000 feet of this series are made up of hard, white, thinly laminated siliceous shale, occurring in bands 200 feet or less in thickness, alternating with thinner bands of sandstone similar to those of the lower Miocene. About 1,000 feet of soft, thin-bedded sandstone and sandy shale, with some hard siliceous members and coarser sandstone toward the top, overlie the white-shale beds. The upper portion of this upper shale series, and possibly some of the strata of the superjacent formation yield the oil, the most productive sands appearing to lie beneath the uppermost prominent band of hard siliceous shale. The oil is probably derived from the diatoms and other minute vegetable remains found in the underlying shale, and finds its way into the sandy layers at the top of the series mainly through the multitude of joint cracks which penetrate both the shale and sandstone. The Miocene shales are overlain (probably unconformably, although having the same general dip) by at least 2,000 feet of Pliocene sediments, which in the Salt Lake field appear to consist largely of clayey shale

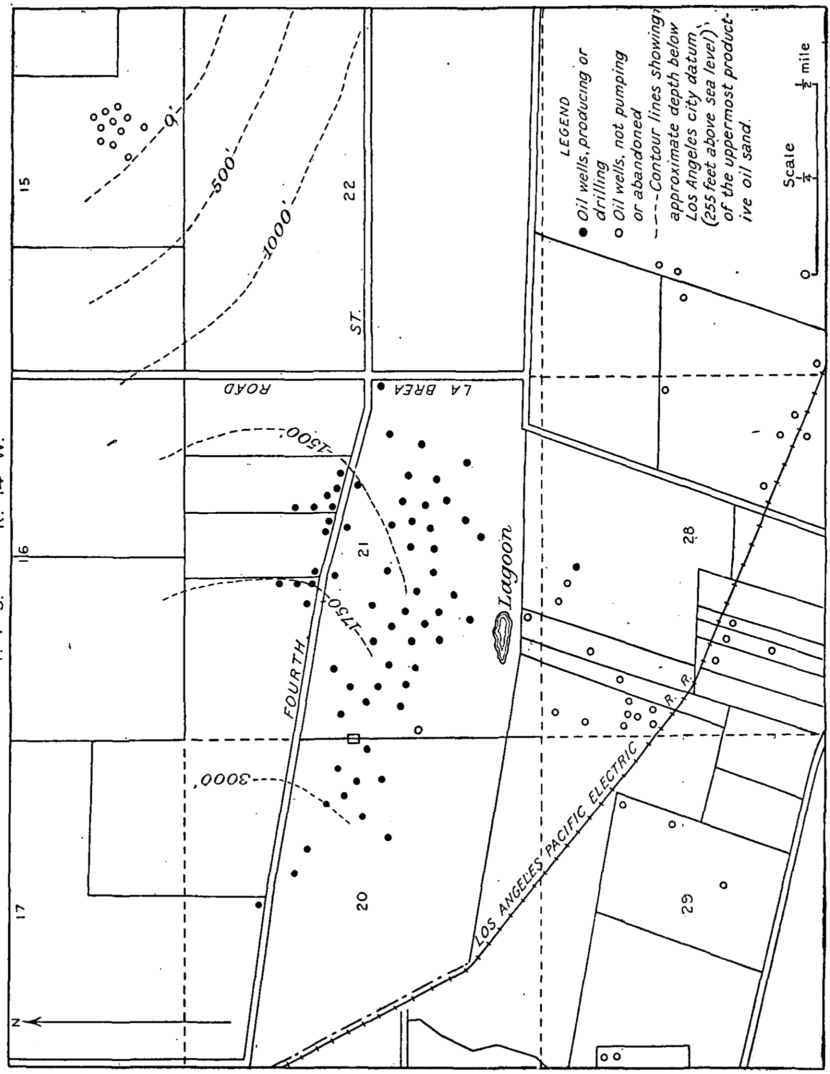

FIG. 12.—Map of the Salt Lake oil field, 7 miles west of Los Angeles, Cal.

with occasional interbedded sandy or gravelly layers. The Pleistocene beds are made up of clay, sand, and gravel, the clay predominating, and are often highly impregnated with oil, forming brea.

Great deposits of this brea occur in the immediate vicinity of the lagoon and north and northwest of it for a considerable distance. Numerous bones of extinct Pleistocene mammals, such as the saber-toothed tiger, elephant, giant sloth, cave bear, camel, and dog are embedded in this brea, and indicate not only the age of the deposits but also the important fact that the conditions favorable to the accumulation of the brea have been in existence here at least since the middle or latter part of the Pleistocene epoch. Heavy oil exudes from the banks of the lagoon and from some of the minor brea pits, while the constant escape of natural gas is evidenced by the continuous streams of bubbles which rise to the surface of the water in the different depressions.

Geology of the wells.—The wells usually penetrate, for the first 50 to 100 feet or more, alluvium and clay, with varying amounts of coarse sand and gravel, representing the Pleistocene covering of the older formations. These deposits carry water, which in some instances is mineralized, in one or more of the beds. A little heavy oil or asphaltum is also occasionally found in the superficial deposits. In fact, in some parts of the field the oil appears to impregnate the soil and rocks "from the grass roots down." From the Pleistocene to the first important oil sand (which is struck at from 1,000 to 3,000 feet) the beds consist of soft sandy shale ("adobe") and clayey shale, with occasional 1 to 6 foot layers of hard siliceous or calcareous shale ("shell") and sometimes a little sand and gravel. This series belongs in large part to the Pliocene. Oil and gas, increasing in quantity downward, are found in many of the beds of this series, the largest accumulations usually occurring just beneath the hard, impervious "shell" layers. Salt water is also encountered at various depths, the more aqueous horizons appearing at about 150 feet above and between 950 and 1,000 feet above the top of the uppermost productive sand. Another bed carrying salt water is encountered about 150 feet below the lowest important oil sand. This water attains a temperature of 110° in some of the wells. The oil zone proper varies in thickness from 150 to nearly 500 feet, and consists of alternating thick-bedded rather coarse sand and clayey shale and "shell." Whether or not the sand occurs as persistent layers, or rather as lenses, is problematical, although it is highly probably that it is present in both forms within the area under discussion. This much is known, however, that the uppermost important sand in the wells over a large part of the field appears to occupy the same horizon. The lower limit of the productive zone is usually a sterile white sand, sometimes locally hardened, which yields, at a depth of 150 feet or more below its top, large quantities of warm or hot salt water. One well, it is said, struck some 11° oil in this lowest salt-water stratum. A typical section through the oil zone, where the dip is approximately 15°, is as follows:

Typical section of oil-sand zone in Salt Lake field.

	Feet.
Sandy shale ("adobe")	300+
Oil sand	20
Clayey shale	30
Oil sand	10
Clayey shale	20
Oil sand	20
Hard shale	2
Oil sand	123
Tough brown shale	10
Oil sand	25
Clayey shale	10
Oil sand	10
Clayey shale	86
Oil sand	129
White sand	150
Sand with salt water (hot) and occasionally some 11° oil	200+
Total productive sand	337

Structure.—Owing to the almost complete absence of surface evidence in the immediate vicinity, the determination of the local structure of the Salt Lake field rests largely on the interpretation of the well logs. All of these, unfortunately, were not available at the time of the writer's visit to the field, so that the conclusions reached, although probably correct in the main, lack that detail and definiteness which is so desirable in an economic report of this sort.

The strictly local structure of the field under discussion will be more fully comprehended if its description is prefaced by a word in regard to the general structure of the Los Angeles district as a whole. Practically all the productive oil sands of the different Los Angeles fields lie on the south limb of a flexure, usually a more or less well-defined anticline, whose axis extends in a westerly direction from the vicinity of the Catholic cemetery on Buena Vista street to the region approximately half a mile north of Westlake Park, where it bends about 20° north and extends to a point about three-fourths of a mile southeast of Colegrove and something over a mile northeast of the Salt Lake field. Here it appears to bend to the north again, probably trending about N. 60° W. In the Los Angeles city field—that is, between the Catholic cemetery and the Westlake Park region—the south limb of the flexure dips normally at angles varying from 30° to 80°, while to the west, along that portion having a northwesterly trend, the dips flatten to 20° or 25°. The Salt Lake oil field is located on the northwestern flank of a minor but probably somewhat complex fold or flexure developed on the comparatively low-dipping southwest limb of the major flexure just described.

The exact nature of the local flexure is not known, but it is probably an anticline, possibly complicated by faulting, with its axis extending in a general northeast-southwest direction. The available evidence appears to indicate that the flexure extends from near the center of the SE. ¼ sec. 15, T. 1 S., R. 14 W., at least as far as the lagoon in the SW. ¼ sec. 21, but whether or not it continues farther to the southwest is problematical. The large accumulations of brea in the immediate vicinity of the lagoon and to the north and northwest of it, in addition to the constantly exuding oil and escaping gas over the same area, indicate some sort of a profound local disturbance or fracture in the underlying beds. If this disturbance has an extensive longitudinal dimension in a northwesterly direction from the lagoon, as some of the evidence appears to suggest, then it is possible that this northwesterly trending disturbance may cut off the Salt Lake flexure from a southwesterly extension beyond the lagoon. If, however, the disturbance in the vicinity of the lagoon is of the nature of a local bulge or dome in the underlying beds, it is very likely that the Salt Lake flexure may have a considerable southwestern prolongation.

The map (fig. 12, p. 358), on which the dotted contour lines show the probable distance of the top of the uppermost important oil sand below the Los Angeles city datum (255 feet above sea level), illustrates the writer's ideas concerning the structure of the northwest limb of the Salt Lake flexure. From this it will be seen that the strike of the oil sand swings around from a nearly east-west line in the region north of the lagoon to a direction slightly west of north in the NE. ¼ sec. 21. The dip of the sand in the region about the center of sec. 21 does not appear to be much more than 10° or 15°, but it increases rapidly in steepness both southeast up and northwest down the dip. The region immediately southeast of the Salt Lake flexure, although supporting some small producing wells—one of which attains a depth of nearly 3,000 feet—does not compare in productiveness with the territory to the northwest. This condition may be explained on several hypotheses, the two most probable being either (*a*) that the Salt Lake flexure is accompanied by faulting which has dropped the productive sands on the southeast down out of reach of the drill or raised them up to such an elevation that they were eroded away in a period subsequent to the faulting, or (*b*) that the continuation of the productive beds passes over the flexure (in this case an anticline) and down on the southeastern flank, but under conditions unsuited to the accumulation of the oil in the large quantities encountered on the northwestern limb.

Suggestions for future development.—Anyone at all familiar with the conditions of occurrence of petroleum in the California fields knows that any but the most tentative predictions as to the location of the oil are extremely hazardous. The following suggestions, based on the evidence in hand, although lacking definiteness for the reasons above stated, may be of some assistance to those engaged in developing this field.

It seems probable that the productive zone of the Salt Lake field extends northward, and possibly a little westward, from the territory now developed. Just where the northern limit is located is problematical, but it is quite certain that it is considerably south of the base of the Santa Monica Range. Within this northern extension the beds in general dip to the west, and for this reason the most productive area will doubtless be found west of La Brea road. East of this road the oil sands approach the surface and consequently yield smaller quantities and heavier oil than do the same beds farther down the dip. As shown by several wells drilled in the region southeast of the Salt Lake flexure, this territory does not appear to offer many inducements for exploitation, at least in the immediate vicinity of the Salt Lake field. Farther east, however, in the region west and southwest of Westlake Park, in case deep wells strike a local flexure similar to that in the Salt Lake field, such wells should yield large quantities of oil and gas. If the disturbance or fracture before mentioned as occurring in the vicinity of the lagoon does not have a northwestern extension, terminating the Salt Lake flexure and the productive zone on its northwest flank, then it appears highly probable that deep wells will strike productive sand in the southern part of sec. 20 and the northern parts of secs. 29 and 30, T. 1 S., R. 14 W.

Development.—There are at the present time between 75 and 80 productive or drilling wells in the Salt Lake field, belonging to the following companies: Salt Lake Oil Company, about 50 or 55; Arcturus Oil Company, 9; Utah Oil Company, 1 (these three companies controlled by the Associated Oil Company); A. F. Gilmore, 4; Pacific Light and Power Company, 4; E. P. Clark Oil Company, 7. In addition to the wells mentioned above there are several comparatively shallow small producers, belonging to the last-named company. These are located near the northern half of the line separating secs. 28 and 30 and are pumped intermittently. The wells northwest of the Salt Lake flexure vary from 1,200 to over 3,100 feet in depth. The deeper wells are as a rule the more productive and yield the lighter oil. The individual wells produce from 20 to over 1,000 barrels a day, the average being somewhere in the neighborhood of 200 barrels. Owing to the tremendous gas pressure in this field, nearly all the wells "gush" when they first come in, and it is said that one of the deep wells produced about 18,000 barrels a day for a short time after its inception. The gravity of the oil varies from 11° to 22°, the heaviest oil coming, it is said, from an isolated sand below the regular productive zone. The average for the field is between 16° and 18°.

Production, storage facilities, and transportation.—The production of the Salt Lake field has risen from a few thousand barrels in 1902 to something over 2,000,000 barrels in 1905. Facilities for handling and storing the oil have kept pace with the increase in production until at the present time the storage capacity of the field is about 390,000 barrels, 20,000-barrel to 55,000-barrel steel tanks being largely used. An 8-inch pipe line connects the field directly with Los Angeles, and smaller lines run from some of the properties to tanks and racks on the line of the Los Angeles Pacific Electric Railroad, immediately south of the field. The oil is used principally in supplying the local Los Angeles market, although considerable quantities are said to be shipped to outside points.

The large quantities of gas which come from the wells are used mainly for the generation of power for operating and development, although a small amount is used in the field for domestic purposes.

THE NINEVEH AND GORDON OIL SANDS IN WESTERN GREENE COUNTY, PA.

By Frederick G. Clapp.

INTRODUCTION.

Location.—The area discussed in the present paper is located in the extreme southwest corner of the State of Pennsylvania, midway between Moundsville, W. Va., Waynesburg, Pa., Mannington, W. Va., and Washington, Pa. The interest of the region lies chiefly in the fact that several geologic horizons underlying the surface have proved productive of oil and gas. The Nineveh, Bristoria, and New Freeport oil fields and the Richhill and Hoovers Run gas fields are situated here.

General statement.—Field and office work in 1904–5 by the writer and Frank W. De Wolf has given a better understanding of the oil and gas sands of this region, and demonstrated some errors in the drillers' identifications of certain sands. By careful study of a great number of well sections throughout this and adjoining areas it has been found that the oil horizon known by the name of "Gordon sand" in western Greene County is not equivalent to the sand of that name in the Washington oil field several miles northeast. The purpose of this report is to correct previous errors in such identifications.

PREVIOUS IDENTIFICATION OF SANDS.

The Gordon sand was first discovered in southwestern Pennsylvania in a well on the Gordon farm near Washington, drilled in August, 1885. This well lies in the Washington oil field, which for several years produced large quantities of oil from the Gantz, Fifty-foot, and Gordon horizons. The Gantz well in that field penetrated the Gordon sand 2,416 feet below the surface, or 244 feet below the top of the Gantz sand. During subsequent drilling both these horizons and also the Fifty-foot sand were traced from Washington into eastern Washington and Greene counties, and the names given at Washington came to be used over large areas in western Pennsylvania.

Thus it happened that when operations first commenced in the Nineveh field, in western Greene County, the names Gordon and Fourth were applied to sands which were then supposed to be equivalent to the beds bearing those names at Washington. In the Richhill gas field, several miles southwest of Nineveh, and occasionally in the Nineveh oil district, the name "Nineveh," "Nineveh Thirty-foot," or simply "Thirty-foot" sand has sometimes been used for the sand called Gordon at Nineveh. The name Nineveh is said to have been first used by Mr. John Worthington, and it seems to be the most appropriate name for this sand, which lies 75 to 100 feet above the true Gordon sand and 100 feet below the top of the Fifty-foot sand. This name has been used by most of the drillers of the Natural Gas Company of West Virginia in the Richhill field. In some other parts of western Greene County, in particular by certain drillers, the names Nineveh and Gordon have been correctly used. Such is true of a majority of the wells in Wayne Township and of a few in Center, Morris, and Springhill townships.

Throughout the Nineveh, Bristoria, and New Freeport oil fields, extending from Nineveh southwestward to Higbee and then southward to the West Virginia line south of Deep Valley, however, the name "Gordon" has been more generally given to the Nineveh sand.

The term "Fourth sand" has generally been applied to the true Gordon sand, and the name "Gordon Stray," when not used for the Nineveh, has designated any bed a short distance above what the drillers considered the Gordon sand.

CORRECT IDENTIFICATION OF SANDS.

Previous discussion of this question.—The only published intimation of a possible mistake in correlation of these sands is a statement by I. C. White,[a] in which he expresses some doubt on the subject, as follows:

The oil sand struck at 2,935 feet in the Smith well, 2,049 feet below the Pittsburg coal, by Mr. Worthington, in July, 1888, was identified by him as the Gordon sand of Washington County to the north, and has ever since been so designated by the oil fraternity, having proved productive of oil and gas in a nearly continuous belt from Nineveh southwestward into Wetzel and other counties of West Virginia for a distance of 50 to 60 miles or more.

Mr. Worthington and others (the writer included) have sometimes thought it possible that this very productive horizon of the New Freeport district in Greene County might not represent the Gordon sand of Washington, but possibly the "Thirty-foot" sand between it and the "Fifty-foot" horizon. But this inference is formed only upon the lessened interval (2,050 feet instead of 2,100 feet) between the sand in question and the Pittsburg coal, but as this interval is but 50 feet less than at Washington, and is the same as it is in Butler County, between the Pittsburg coal and the great Third oil sand of the Butler, Armstrong, Clarion, and other producing fields of the Venango sand region to the northeast, it appears quite probable that the original identification as given in 1 5 is correct. At any rate, it is the nomenclature universally used by the oil-producing interests in Greene, Wetzel, Marshall, Tyler, and Doddridge counties.

To I. C. White, therefore, belongs the credit of having first questioned in print the correlation. The evidence collected by the present writer, and given as follows, may be regarded as decisive proof of the correct correlations:

Evidence from comparison of well sections.—In studying the underground stratigraphy of Washington and Greene counties a great number of well records have been plotted on a uniform scale and placed side by side with the various persistent horizons, such as the Pittsburg coal and Big Injun sands, in agreement.

The following table shows the important beds encountered by the drill and used in this correlation. The principal datum horizon of the region and the one used by all drillers in measuring to the various sands is the Pittsburg coal, which lies from 300 to 1,300 feet below the mouth of the well. Other beds which are easily recognized are the Little Lime and Big Lime, the Big Injun sand, and the various beds of red shale.

Drillers' terms for oil and gas rocks, etc., and their geologic correlations.

Geologic formation.	Name applied by drillers.	Geologic name.	Approximate maximum thickness.	Approximate minimum and maximum intervals to top of bed from Pittsburg coal.[b]	Correlation with sands in neighboring fields.
			Feet.	*Feet.*	
Washington	Washington coal	Washington coal	3	+420-550	
	Bluff sand	Waynesburg sandstone.	60	+330-450	
Monongahela	Waynesburg coal	Waynesburg coal	5	+270-400	
	Mapletown coal	Sewickley coal	8	+90-120	
	Pittsburg coal	Pittsburg coal	10	0	
Conemaugh	Murphy sand	Morgantown sandstone.	30	−170-240	
	Little Dunkard sand.	Saltsburg sandstone.	100	−300-420	
	Big Dunkard or Hurry-up sand.	Mahoning sandstone.	150	−420-600	

[a] Rept. Geol. Survey West Virginia, vol. 1 (a), 1904, p. 132.
[b] + indicates above Pittsburg coal; − indicates below Pittsburg coal.

Drillers' terms for oil and gas rocks, etc., and their geologic correlations—Continued.

Geologic formation.	Name applied by drillers.	Geologic name.	Approximate maximum thickness.	Approximate minimum and maximum intervals to top of bed from Pittsburg coal.	Correlation with sands in neighboring fields.
			Feet.	*Feet.*	
Allegheny	Upper Freeport (Connellsville) coal.	Upper Freeport coal.	(?)5	– 570-670	
	Gas sand	Freeport, Kittanning or Clarion sandstone.	150	– 650-850	
Pottsville	Salt sand	Pottsville sandstones.	(?)200	– 850-950	
Unconformity.					
Mauch Chunk	Red rock or shale.	Mauch Chunk shale.	150	– 960-1,060	
	Little Lime (or Salvation sand). Pencil Cave. Big Lime.	Greenbrier limestone.	100	– 960-1,160	Salvation sand=Maxton sand.
Pocono	Big Injun sand	Burgoon sandstone.	300	–1,070-1,300	Mountain sandstone.
	Thirty-foot sand		100	–1,700-1,900	Berea or Butler County gas sand.
	Red shale	Bedford (?) shale.	20	–1,800-1,980	
	Gantz sand		40	–1,850-1,950	Hundred-foot sand or First sand.
	Fifty-foot sand		60	–1,900-2,030	
Chemung	Nineveh, or Nineveh 30-foot sand.	Catskill beds	40	–2,000-2,120	Mistaken for Gordon in this area.
	Red rock		20	–2,000-2,140	
	Gordon Stray sand.		40	–2,100-2,250	
	Gordon sand		100	–2,080-2,290	Third sand, sometimes mistaken for Fourth sand.
	Fourth sand		40	–2,150-2,320	
	Fifth sand		40	–2,220-2,350	McDonald sand.
	Bayard sand		12	–2,350-2,480	Sixth sand.
	Elizabeth sand		10	–2,400-2,550	

In studying the wells with a view to tracing the sands, a line of wells was taken, beginning at the original Gantz well, near the Gordon well in Washington, and extending southward to the Fonner field and thence to all parts of western Greene County. In this tracing the Gordon sand was found to maintain its interval of 150 to 200 feet below the top of the Fifty-foot sand and to lie below the sand hitherto called "Gordon" in the Nineveh oil field. In the Gantz well the Nineveh sand is not recorded, but in the Baker well near Lone Pine, midway between Washington and the Greene County line, the sand occurs 102 feet below the top of the Fifty-foot sand. In that region and very frequently throughout eastern Washington County the name Gordon Stray has been applied to the sand at this horizon. In the Baker well the sand attains an unusual thickness. South of this well the next good section in line is that of the Fonner No. 2. In this well the Nineveh sand consists of 13 feet of red sand lying 48 feet below the top of the Fifty-foot; a second red rock occurs 68 feet below it and a few feet above the Gordon sand. The John Lewis well, 2.2 miles north of Nineveh, offers the next complete record, and this is the farthest well northeast in which the mistake in correlation is known to have been made. The term Gordon has been used by the drillers to designate the Nineveh sand. From the Lewis well this sand can be traced almost continuously the entire length of the oil district, being known to the drillers in this county either as "Gordon" or "Gordon Stray."

Evidence from position of Catskill red beds.—The accuracy of the tracing is facilitated by several red shales and other beds associated with the sands. The most important of these is a thin red bed which generally lies directly below the Nineveh sand. Sometimes, as in the Fonner well, the Nineveh sand itself is red. This horizon is not always red, but the color occurs so frequently that when carefully correlated there is little danger of making a permanent mistake in identifying the Nineveh sand over any considerable area. This horizon is regarded as the top of a series of red beds recognized beneath large areas in western Pennsylvania, and known to geologists as the Catskill beds, which attain a maximum thickness of 200 to 300 feet in eastern Greene and Washington counties, but die out toward the west, so that in western Greene County the horizon is marked only by the bed of red shale mentioned above and occasionally by one or two other thin red beds. The western limit of the Catskill beds, therefore, can be said to correspond approximately with the western boundary of the State of Pennsylvania.

Evidence from position of Bedford (?) red shale.—A second horizon of red shale—not one of the Catskill beds, but one which assists in correlations—is a bed which lies between the Thirty-foot and Gantz (or Fifty-foot) sands and which occurs rather extensively in western Greene and Washington counties and to the northwest. Toward the east it dies out. This fact was recognized by John F. Carll in the Seventh Report on the Oil and Gas Fields of Pennsylvania,[a] and he published a map showing the distribution of this bed and tracing it beneath the counties of Forest, southern Venango, and western Butler in Pennsylvania, and in eastern Ohio as far west as its outcrop along the Cincinnati anticline. By Carll the bed was provisionally correlated with one of the Bedford shales of Ohio. Since Carll's report was issued considerable drilling has been done in Washington and Greene counties, and the red shale is here found to be present considerably outside his southeastern boundary for it. In western Greene County this bed occurs from 30 to 80 feet above the top of the Fifty-foot sand and helps in the identification of this sand.

Evidence from the persistency of the Nineveh sand.—In Washington and Greene counties several sandstone horizons occur within the limits of the rocks designated as Catskill. These are generally not persistent over wide areas, owing to the fact that by nature they are lentils in the Catskill formation, dying out toward the east. The Gordon Stray, Gordon, and Fourth sands are such beds, and do not seem to be persistent. The next lower bed, or Fifth sand, and the next higher sand, the Nineveh, are much more regular, and can be traced for great distances.

Evidence from intervals.—As explained above, the interval of the Nineveh sand from the Pittsburg coal runs from 1,997 to 2,121 feet, and the distances of the Gordon sand from the coal vary between 2,023 feet and 2,287 feet. The figures for the Nineveh sand and their averages are given by townships in the following table:

Intervals from Pittsburg coal to Nineveh sand in western Greene County (in feet).

Township.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
Morris	2,028	2,110	2,055	6
Richhill	1,997	2,054	2,036	32
Center	2,005	2,120	2,039	8
Jackson	2,024	2,065	2,044	66
Aleppo	2,018	2,098	2,056	101
Wayne	2,033	2,045	2,039	2
Gilmore	2,065	2,113	2,089	2
Springhill	2,033	2,121	2,052	94
General average			2,051	

[a] Second Geol. Survey Pennsylvania, Rept. I, 1890, pp. 95-96, Pl. V.

The figures representing the interval of the Gordon sand below the coal are somewhat more variable in their extremes than these. They run in general as follows:

Intervals from Pittsburg coal to Gordon sand in western Greene County (in feet).

Township.	Least interval.	Greatest interval.	Average interval.	Number of records averaged.
Morris	2,100	2,141	2,133	6
Richhill	2,094	2,155	2,136	17
Center	2,083	2,170	2,127	8
Jackson	2,070	2,175	2,111	16
Aleppo	2,110	2,183	2,157	30
Wayne	2,133	2,287	2,213	13
Gilmore	2,177	2,189	2,181	3
Springhill	2,130	2,205	2,166	8
General average	....	....	2,153	....

From a comparison of the figures in the foregoing tables it will be seen that, while the Gordon sand in its averages for the various townships in this part of the county varies between 2,111 and 2,213 feet, amounting to a difference of 102 feet, the Nineveh sand, on the other hand, differs in its averages by only 53 feet. It will be noticed that none of the averages given in the table for the Gordon sand approach within 20 feet of the highest figures given in the Nineveh table, and the general averages of each table differ by over 100 feet. The overlapping of several of the figures in the maxima and minima columns is due to local variations or to inaccuracies in the drillers' measurements.

From the foregoing discussion it can be seen that there is little danger of confusing these two sands when proper care is taken in making interpretations.

SURVEY PUBLICATIONS ON PETROLEUM AND NATURAL GAS.

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