RUSSIAN AND AMERICAN PETROLEUM.

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American petroleum, or, more exactly, Pennsylvania petroleum, has, I am aware, been taken as a subject for lecture before this institution on several occasions already, notably in recent years by Mr. Chas. A. Ashburner, of the Second Geological Survey of Pennsylvania, and its geology and conditions of production as well as its refining and varied utilizations have been ably described. I am not aware, however, that it has been discussed in comparison with that equally wonderful and more recent production, Russian petroleum. It is my purpose then to describe briefly the conditions of occurrence of these two most important natural products, to note the chemical differences between the two "crudes," the differences of treatment made necessary in consequence, the characters of the respective products, and lastly the present and prospective commercial values of these two gifts of Nature. In speaking of the American field I shall speak, of course, essentially of the Pennsylvania production, for although we have Canadian oil, West Virginia oil, California oil and, prospectively of still greater importance, Ohio oil, the great bulk of the crude oil which is refined for illuminating and lubricating purposes, comes from what is called the Pennsylvania field. The extent and distribution of this oil-producing area is seen on the map (*projected on the screen*), taken from Mr. Ashburner's paper on the oil regions of Pennsylvania and New York, read before the Halifax Meeting of the American Institute of Mining Engineers, in September, 1885. Since the issue of this map, however, a considerable development has taken place in the neighborhood of Washington, Pa., so that an additional district, centring about the town of Washington, would have to be added. The combined area shown on Carll and Ashburner's map, as underlaid by oil-producing sands, is 369 square miles, stretching southwesterly from Alleghany County, N. Y., to Beaver County, Pa., on the Ohio River, the development centring about Bradford, McKean County, Pa.

The geological character of the oil-bearing strata has been very thoroughly studied by Messrs. Carll and Ashburner, of the Pennsylvania Geological Survey, and Prof. Peckham in his census report on petroleum. Mr. Carll has in his several reports, made to the Geological Survey, very clearly defined and described not only the groups of producing sand rocks, beginning with the three Venango County sands, the earliest producing rocks, but the different geological horizons, such as, to begin with the lowest, the Smethport sand, the Bradford and Alleghany group of sand rocks, the Warren and Clarendon sands, the Venango group before referred to, producing in Venango, Butler and Clarion Counties, and the Smith's Ferry heavy oil rock of Beaver County.

This sand rock of Western Pennsylvania varies in character from a coarse-grained uncemented sandstone, as in the Bradford district, to a pebble conglomerate of white or slightly colored opaque quartz, as in the Butler and Venango districts, overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. These formations, according to Prof. Peckham, "lie far beneath the influence of the superficial erosion, like sand bars in a flowing stream or detritus on a beach." "Taken as whole members of the geological series, the deposits lie conformably with the enclosing rocks and slope gently towards the southwest." The Bradford field, in particular, says Prof. Peckham, "resembles a sheet of coarse-grained sandstone, 100 square miles in extent, by from 20 to 80 feet deep, lying with its southwestern edge deepest and submerged in salt water, and its northeastern edge highest and filled with gas under an extremely high pressure."

While the oils found in this district may differ considerably in gravity, color, and undoubtedly somewhat in chemical composition, the differences are not fundamental, and with certain special exceptions, the crude oils from various localities are all brought together by the pipe lines and become mixed before going to the refineries. None of these Pennsylvania and New York oils contain any appreciable amount of sulphur or other impurity which would require a modification of the general refining methods. The heavy oils of Franklin and Smith's Ferry, Pa., and some few other localities, are so valuable for the manufacture of lubricating oils that they are collected and worked separately. The Pennsylvania crude oil has in general a dark greenish-black color, appearing claret-red by

transmitted light, and varies ordinarily in specific gravity from 0.782 to 0.850, or as it is frequently expressed, from 49° B. to 34° B. Exceptions to this general statement are the Washington County amber oil, the light colored oil of Smith's Ferry and some other natural yellow or amber oils. In chemical composition it is essentially composed of hydrocarbons of the paraffin series $C_n H_{2n+2}$, the gaseous and the solid members of the series being alike held dissolved in the liquid ones and smaller amounts of the olefine series $C_n H_{2n}$ and the benzene series $C_n H_{2n-6}$. According to Markownikow, as confirmed by Krämer, Pennsylvania petroleum also contains hydrocarbons of a series $C_n H_{2n-2}$ which he terms "naphthenes."

The crude oil of the Pennsylvania field is mostly refined in the three large cities of Pittsburgh, Pa.; Cleveland, O., and Buffalo, N. Y., or on the Atlantic seaboard, in close proximity to the point of shipment. The transportation of the crude oil to these points is at first effected exclusively by railway tank cars, is now very largely effected by means of pipe lines. Most of these are now controlled by the National Transit Company, and a map, showing their main pipe line connections, is here given. Their lines include a line from Olean, N. Y., to New York, Bayonne and Hunter's Point, 300 miles in length, and consisting of two six-inch pipes for the entire distance, and a third six-inch pipe for a portion of the way, with a transporting capacity of 28,000 barrels per day; a line from Colegrove, Pa., to Philadelphia, 280 miles in length, consisting of one six-inch pipe; a branch line connecting with this at Midway, Pa., and running to Baltimore, Md., seventy miles in length, consisting of one five-inch pipe; a line from Hilliards, Pa., to Cleveland, O., 100 miles in length, of five-inch pipe; a line from Farmville, Cattaraugus County, N. Y., to Buffalo, N. Y., seventy miles in length, of four-inch pipe, and a line from Carbon Centre, Butler County, Pa., to Pittsburgh, Pa., sixty miles in length, of four-inch pipe. The New York line has eleven pumping stations, about twenty-eight miles apart; the Philadelphia line has six stations; the Baltimore line is one line without a break; the Cleveland line has four stations, and the Buffalo and Pittsburgh lines each have four stations.

Still another trunk line is that of the Tidewater Pipe Company, which is a six-inch pipe extending from Rixford, in the Bradford

To New York, 1-6 inch, 2-4 inch & 3-6 inch Pipes.
 Philadelphia 1-5 "
 Baltimore 1-5 "
 Cleveland 1-4 "
 Buffalo 1-4 "
 Pittsburgh 1-4 "

⊙ = Pumping Stations and Terminals

Scale of Miles
 0 10 20 30

MAP SHOWING NOBEL BROTHERS' NETWORK OF PETROLEUM DEPOSITS IN RUSSIA.

OIL FOUNTAIN. BAKU OIL REGION.

field, to Tamanend, in Schuylkill County, where it connects with the Reading Railroad, by which the oil is transported to the seaboard in tank cars. The distance is 170 miles, and there are in this interval five pumping stations. The capacity of the line is 10,000 barrels per twenty-four hours.

If we turn now to the question of foreign petroleum production, we will find that only one locality deserves to be mentioned in comparison with our Pennsylvania production, viz: Baku, on the Caspian, in the Russian province of the Caucasus. The map (*projected on the screen*) will show the several known petroleum deposits of Europe and their geographical relation to each other, and to some extent the transportation facilities, as far as illustrated by the railway connections. The second or special map of the immediate Baku district will show the producing points and the refining centre on the outskirts of the town of Baku. As seen on this last map, there are two great groups of wells, the Surakhani and the Balakhani groups. The former exists on the site of the old fire worshippers' temple, where the petroleum gas has been issuing from the ground from the prehistoric period, 2,500 years ago, to the present. Only two or three companies carry on operations here. The majority are gathered at Balakhani, as a more copious supply was discovered here, and drilling operations were found to be more easily carried on.

The geology of this Baku district is not very definitely known. Vasilieff, in an article in the *Russian Mining Journal*, of September, 1886, states that the petroleum-bearing strata of the Caucasus belong to the Lower Miocene series of the Tertiary epoch, the deposits extending in a northeasterly to southwesterly direction, and the dip ranging apparently between 20° and 40° . The petroleum-bearing beds are composed of sand, calcareous clays, marls, and, in places, compact sandstones, often of great thickness, penetrated by bands of pyrites. The theory of Ludwig Nobel, based on numerous oil-well records made by his company, is that "the oil-bearing strata, originally running regularly in an almost diagonal direction, became dislocated and thrust hither and thither horizontally during some volcanic disturbance, and a sort of irregular cellular character given to the petroleum deposits." The peninsula of Apsheron is probably honeycombed with thousands of these oil cells, which seem to be for the greater part independent of each

other. They are found at all depths down to 825 feet, the extreme depth yet reached. The great Droobja oil fountain, which, in six months of 1883, poured forth about 55,000,000 gallons of oil, had reached a depth of 574 feet only, and while this was flowing at the rate of 2,000,000 gallons per diem, wells a stone's throw off and of lesser depth, were giving their daily supply of petroleum totally unaffected by it. Many of my audience have, perhaps, read newspaper items with regard to the terrific power and prolific character of some of these Baku oil wells, and may have put down much of the account to exaggeration. But numerous reliable and unbiased witnesses have united in giving figures that we must therefore accept. The largest flowing well we have had in Pennsylvania (the Armstrong No. 2) flowed for a time at the rate of over 6,000 barrels (or 260,000 gallons) per twenty-four hours. When Bover-ton Redwood, the Secretary of the British Petroleum Association, visited Baku in the fall of 1884, one of Nobel's capped fountains was opened for his benefit, and the sight then displayed is represented in the accompanying illustration. A solid column of oil, more than a foot in diameter, shot up to a height exceeding 100 feet, and continued to flow without diminution of violence as long as the valve remained open, forming a lake of oil to leeward of the well. The derrick was seventy feet high, and the oil column occasionally rose to at least double this height. This well (Nobel's No. 18) yields at the rate of 1,125,000 gallons per twenty-four hours whenever opened. It was, however, exceeded by the Droobja well before referred to, and Nobel's No. 9, each of which for a time having yielded double that quantity, or over 2,000,000 gallons per twenty-four hours, about eight times the amount yielded by the strongest Pennsylvania oil well known. The Nobel No. 9 was promptly capped, 1,000,000 gallons of oil being the total loss, but the Droobja well could not be gotten under control for over four months, and it is supposed that 100,000,000 gallons of oil were lost during this period. Not only this, however, but this Droobja fountain, which was from 200 to 300 feet high, threw out so much sand that neighboring engine houses and derricks were partly buried by it. The company owning it not only lost their oil, but were ruined by the damages they had to pay the surrounding well owners for flooding them with sand and oil. The maximum pressure previous to the discovery of these two fountains, had been

four atmospheres, but in the case of Nobel's No. 9 and the Droobja well the pressure exceeded thirteen atmospheres, or nearly 200 pounds pressure to the square inch. Of the 400 wells in the Baku district only about 100 are producing at present, and of these 100 some twenty are flowing wells. These twenty, however, would for a time yield more than enough crude oil to suffice for the manufacture of the 2,000,000 gallons of refined petroleum that the world consumes daily. Nobel Brothers had, moreover, at a recent date, fourteen oil fountains plugged up and held as a reserve.

Wells in the Baku district which do not flow, cannot be pumped in the ordinary way, in consequence of the large quantity of the sand present (sometimes as much as thirty to forty per cent.), and the oil is raised to the surface in cylinders resembling the sand pump. About two minutes are required to lower and lift the tubes, which bring about fifty gallons of oil to the surface each stroke. "Torpedoing" is so far unknown, as a well requires only to be bored a little deeper in order to bring fresh quantities of oil. The oil on issuing from the well is always allowed to stand for a time in reservoirs (which are frequently only shallow ponds in the surrounding soil) in order to deposit the sand, and is then pumped through the pipe lines to the refineries at the Blacktown on the coast some eight miles off.

The Baku petroleum has a higher gravity than the American, averaging 0.873, or 31° B., and has been found to be entirely different in its chemical composition, consisting for the most part of hydrocarbons of the series C_nH_{2n} , isomeric with the olefine series and called "naphthenes." As will be seen later, this difference in chemical composition involves a difference in the refining methods and results.

The processes of distilling Pennsylvania petroleum are in a general way at least familiar to most of my audience, so I shall not take the time to go over them in detail. It is sufficient to say that although a normally conducted fractional distillation would give from thirty-five to fifty-five per cent. only of illuminating oil, by the process of "cracking," or destructive distillation, the percentage of illuminating oil may be increased to seventy-five to eighty per cent., the benzine fraction being from ten to fifteen and the residuum from five to ten per cent. On the other hand, the Russian petroleum does not yield over about twenty-seven to thirty

per cent. of illuminating oil of satisfactory quality, but will yield fifty per cent. of a very superior lubricating oil. Nobel Brothers, who are by far the most scientific and progressive in their methods, obtain about the following result: Benzine, 1 per cent.; gasoline, 3 per cent.; illuminating oil (32°C . or 89°F . Abel flash point), 27 per cent.; Soliarovi lubricating oil, sp. gr. 0.87, 12 per cent.; Veregenni lubricating oil, sp. gr. 0.89, 10 per cent.; lubricating oil, sp. gr. 0.905, 17 per cent.; cylinder lubricating oil, sp. gr. 0.915, 5 per cent.; vaseline, sp. gr. 0.925, 1 per cent.; liquid fuel, 14 per cent., and loss, 10 per cent; total, 100.

It is true that more illuminating oil than this twenty-seven per cent. is sometimes gotten by some of the Baku refiners, but it is of lower flash test. Prof. Beilstein, of St. Petersburg, has also proposed a method of cracking by which the yield of illuminating oil can be raised to fifty per cent., but it is not adopted as yet to any considerable extent. With regard to the character of the best Russian illuminating oil as compared with the best American oil, it is claimed by English and German experimenters that, while the Russian oil gives less light at the beginning of the burning when the lamp is full of oil and freshly trimmed, it affords a flame of somewhat greater permanence as the level of oil in the reservoir becomes lower, the difference being supposed to be due to the greater power which the Russian oil has of ascending the wick. In a comparison of the lubricating oils, there seems but little doubt that the Russian product has a distinct advantage. These lubricating oils from Baku petroleum contain little or no solid hydrocarbons, the greatest quantity obtainable amounting to only a quarter of one per cent. of the crude oil. They will show, therefore, exceptionally low cold tests. At the same time they have a remarkably high viscosity in relation to their specific gravity. This characteristic is exhibited in the following tabular statement, prepared by Boverton Redwood:

	Viscosity at 70°F .	Viscosity at 120°F .	Loss per cent. in Viscosity.
Russian oil (sp. gr. 0.913),	1400	166	88
American oil (sp. gr. 0.914),	231	66	71
Russian oil (sp. gr. 0.907),	649	135	79
American oil (sp. gr. 0.907),	171	58	66
Russian oil (sp. gr. 0.898),	173	56	67
American oil (sp. gr. 0.891),	81	40	50
Refined rape oil (for comparison),	321	112	65

It is true that the disproportion is chiefly at lower temperatures, the Russian oil losing its body relatively faster than the less viscous American oil. One distinctive feature of the Baku refining is the successful use they make of continuous distillation processes which are especially suited to Baku petroleums, as the quantity of burning oil separated being comparatively small the residuum is not very much less fluid than the crude oil. The stills, each of the capacity of 4,400 gallons, are arranged in groups or series of not more than twenty-five, and a stream of oil is kept continuously flowing through the entire number. The crude oil entering the first still parts with its most volatile constituents, passing into the next still has rather less volatile hydrocarbons distilled from it, and finally flows from the last still in the condition of residuum, which in Russia is termed *astatki*, or *masut*. The several stills are maintained at temperatures corresponding with the boiling points of the products to be volatilized. Superheated steam is used for all the stills, the steam being delivered partly under the oil and partly above the level of the oil; that is, in the vapor space above. The fuel used under all the stills in Baku is petroleum residuum, or "astatki." At many of the smaller works, the liquid fuel is simply allowed to flow upon the hearth of the furnace, and in thus using it, a very dense black smoke is evolved, whence the refining suburb of Baku has come to be known as the Blacktown. At Nobel's refinery, however, arrangements are adopted for burning the fuel with a proper admixture of air, and smokeless combustion is thus obtained. The part the *astatki*, or liquid fuel, now plays in the Caucasian district and in Russia is something not to be overlooked. It is the only fuel for locomotives, steamers and factory engines throughout this part of Russia. It has replaced wood and coal, and the use of it is now extending as far as Moscow to the north, Teheran to the south, Merv and Khiva to the east and Batoum to the west. In 1883, the aggregate export of *astatki* to Russia by all the Baku firms was 281,000 tons. On the other hand, the production was estimated as exceeding 500,000 tons, leaving, after making allowance for consumption in refineries, perhaps as much as 200,000 tons, or 50,000,000 gallons undisposed of. Enormous quantities are therefore allowed to go to waste. It is found in practice that with a good hydrocarbon furnace one ton of *astatki* goes as far as three tons of mineral fuel. Nobel Brothers alone are now turning out 450,000 tons of this fuel per year.

It remains now to glance at the methods of transportation and commercial development of Russian petroleum fields as compared with those of America. Our American system of pipe lines, extending to the seaboard, has already been illustrated. With the oil once at the Atlantic seaboard, its shipment either as crude or as refined is readily effected to any part of the habitable globe. Here, the Russians are at a disadvantage. Baku is on the Caspian Sea, on the border line between Europe and Asia, but with very imperfect means of communication. What there is may be said to have grown principally out of the wonderful energy and engineering ability of one man, Ludwig Nobel, a Swede by birth, although resident in Russia since his twelfth year. In 1875, his elder brother, Robert Nobel, began refining at Baku in a small way, with capital furnished by Ludwig, who had extensive engineering works at St. Petersburg. The Nobel Brothers found all the oil that was refined at Blacktown transported from Balakhani in barrels slung in two-wheeled Persian carts, termed "arbas." They laid down a pipe line eight miles long and paid its expenses the first season. They imported American oil-well borers and revolutionized the method of sinking wells. Then it was that, finding the transportation facilities too limited to allow them to ship their oil, Ludwig Nobel, the engineer, designed and had built the first of the oil-tank steamers that allowed him to ship his oil on the Caspian from Baku to the mouth of the Volga, a distance of 460 miles. This first liquid transport, or "cistern steamer," appeared on the Caspian in 1879. There is now a fleet of forty of them, the Nobel's owning twelve, carrying about 5,500 barrels apiece each trip. As the Volga at its wide mouth is very shallow, the tank steamers can proceed no farther than a locality termed "nine-feet sounding," about twenty miles from land, where the oil is transferred to oil barges, in which it is conveyed to Tsaritzin, the first railway point on the river Volga, 400 miles distant, where Nobel Brothers have established one of their great distributing centres for Russia. They have twenty barges on the Volga, and from Tsaritzin they distribute the oil by trains of oil-tank wagons. Of these, the Nobel's own 1,500, holding 2,600 gallons, or about ten tons of refined oil each. These are made up into trains of twenty-five wagons, so that the firm runs sixty such trains continuously in their distributing work. The accompanying map

shows the network of storage depots and distributing stations that the Nobel's have established throughout Russia and the adjacent countries. This system of storage depots is not merely a matter of convenience to them, but is to a large degree a matter of necessity. During at least four months in the year, the Volga is frozen over solidly, so that the oil needed for consumption during this winter term has to be accumulated at points accessible by rail connection. The oil trains of the Nobel's, therefore, are occupied during part of the year in collecting the oil in their storage depots, and during the winter in distributing it for consumption. This work is all directed from St. Petersburg, where Ludwig Nobel, the President of the company, resides. They are beginning also to ship their oil by tank steamers from Libau on the Baltic, where they bring it by tank cars, to Stettin, Hamburg and even to London. At Stettin, they have begun to erect storage tanks for the supply of the German trade.

In 1883, the Trans-Caucasian Railroad was finished, and oil is now shipped from Batoum on the Black Sea in quite considerable amounts to Mediterranean ports. A pipe line from Baku to Batoum has also been surveyed, and the Government concession having been obtained, it will likely be built in the near future.

The successful introduction of transportation of oil in bulk by means of oil-tank steamers on the Caspian, of course, led oil shippers to consider the question of using similar tank steamers for the transportation of American oil in bulk to Europe. Indeed, some slight experimenting in this line had preceded the adoption of the tank steamers on the Caspian, but the engineering difficulties connected with the shipment of oil in bulk for the voyage across the Atlantic were far greater, and hence greater precautions against danger had to be devised. Two large tank steamers, however, have been running this last year successfully, the *Crusader* and the *Andromeda*, the former to London and the latter to Bremen. The most important feature of their construction is the provision of auxiliary tanks above the level of the storage tanks and in communication with them. The storage tanks can thus always be kept quite full of oil, the auxiliary tanks serving to hold the surplus when the storage tanks become expanded by heat and supplying the deficiency when contraction takes place. The *Crusader* is provided with forty-five tanks, with an average capacity

of 125 barrels each, the *Andromeda* with seventy-two tanks, and carried in its first trip to Bremen 684,641 gallons of refined oil.

The statistics of production of both American and Russian oil and of exportations of the two, as far as statistics are attainable, are given in the tables in the Appendix.

I would, in conclusion, express my indebtedness for information on Russian petroleum matters to Boverton Redwood's lectures and articles in the *Journal of the Society of Chemical Industry*, to Dr. C. Engler's "Das Erdoel von Baku," reprinted from *Dingler's Polytechnisches Journal*, and especially to Chas. Marvin's work, "The Region of Eternal Fire," London, 1884. I am also indebted for personal favors to Mr. H. M. B. Bary, to Messrs. Fuller Brothers, and to the Atlantic Refining Company, of this city.

APPENDIX.

TABLE I.

Annual Production and Value of Petroleum in the United States, according to the Bureau of Mining Statistics, U. S. Department of the Interior.

Production.		
1882,	39,053,500 barrels, valued at \$23,705,698	
1883,	23,400,229 " "	25,740,252
1884,	24,089,758 " "	20,476,294
1885,	21,842,041 " "	19,193,694
1886,	28,110,115 " "	20,028,457

TABLE II.

Annual Production of Crude Oil in the Baku District, according to Engler.

1881,	4,900,000 hundred kilos, or 3,500,000 barrels.	
1882,	6,800,000 " "	4,857,143 "
1883,	8,000,000 " "	5,714,286 "
1884,	11,300,000 " "	8,071,428 "
1885,	16,360,000 " "	11,685,714 "

TABLE III.

Exports of Crude and Refined Petroleum from the United States for the Years 1884-85 and '86, according to the U. S. Bureau of Statistics.

	1884.	1885.	1886.
Crude petroleum exported,	79,679,395 gallons.	81,435,609 gallons.	76,346,480 gallons.
Valued at,	\$6,102,810	\$6,040,685	\$5,068,409
Naphthas and light distillates,	13,676,421 gallons.	14,739,469 gallons.	14,474,961 gallons.
Illuminating oils,	433,851,275 "	445,886,518 "	485,120,686 "
Lubricating oils,	11,985,219 "	12,978,955 "	13,948,367 "
Residium and tar,	126,369 barrels.	136,474 barrels.	47,474 barrels.
Value of the refined products,	\$43,354,306	\$43,631,058	\$43,076,795

TABLE IV.

The Shipments of Baku Petroleum for the Years 1885 and 1886 are thus given in the U. S. Consular Reports:

(1) From Batoum via Trans-Caucasian Railway—	1885.	1886.
Illuminating oil,	26,865,325 gallons.	39,321,005 gallons.
Crude, lubricating and residuums,	4,774,600 "	14,915,315 "
Total,	31,639,925 "	54,236,320 "

(2) Via Astrachan on the Caspian Sea—

	First Six Months of 1886.
Illuminating oil,	44,428,325 gallons.
Crude, naphthas and residuums,	79,866,200 "
Other products,	8,851,960 "
Total,	133,146,495 "