*NATURAL GAS.**

BY EMERSON McMILLIN.

After the publication in the MINING JOURNAL last August, of the very interesting and instructive paper by Dr. Orton, Chief Geologist of the Ohio Survey, it may very naturally occur to the readers of the JOURNAL that there is no call for another paper bearing upon the same subject. The question, however, is one of so much interest that it will bear frequent discussion, and while I shall present no original ideas or startling developments, I may be able to give enough facts, as ascertained by others, to make the paper at least readable. Perhaps all of your present readers may not have been fortunate enough to have seen Dr. Orton's article in print, and I must therefore cover, hurriedly, at least, a portion of the ground covered by his paper.

We are told that the Chinese have for hundreds of years utilized the natural gas issuing from the crevices of the earth's surface in some portions of the Flowery Kingdom, and that they now drill, in some instances, 3,000 feet deep to obtain the gas. Perhaps the oldest historical instance of which we have a record of the discovery and use of natural gas is that of the Appollo Oracle, at Delphi, Greece. The gas was used there a thousand years before the Christian Era. It has been used in many places in Europe and in Asia for hundreds of years. There are traditions that the Red man smoked his pipe in the lurid light of burning springs before the advent of the White man to the American Continent. It was used at a very early day in the Kanawha Valley for the evaporation of salt water. In a letter recently received from the proprietor of the Gas Works at Fredonia, N., Y., he tells me that the gas has been in use there for more than sixty years; that it is necessary to drill only 100 to 300 feet in order to obtain it; that some fifteen wells, mostly of recent date, are in use, and that increasing the number of new, did not appear to diminish the supply in any of the old wells. A gas well was struck in boring for salt at

*In the preparation of this paper I have received valuable suggestions from Col. T. P. Roberts, of Pittsburgh, Prof. J. C. White, of West Virginia University, and Prof. Edward Orton, Chief Geologist of the Ohio Survey. I have drawn largely from the 10th volume of U. S. Census, the petroleum industry prepared by Prof. Peckham, of Pennsylvania, and from Newberry's Ohio Reports.

Olive, Noble county, Ohio, in 1814. Residences in Lorain county, Ohio, have been lighted for fifteen or twenty years with natural gas. At East Liverpool the gas has been flowing for more than twenty years. At New Cumberland, W. Va., the gas has been utilized for twenty-five years, and the supply is still good. In scores of other places in this and other States, gas has been utilized for the past twenty-five or fifty years, yet apparently the interest has not been great nor general in this question until very recently.

To enumerate all the places and locations where gas has been found would require a volume itself. The records in this respect are not so complete as are the records respecting oil geographical locations and geological horizons. I would assume, however, that wherever oil is found gas must almost of necessity be near. The following are a few of these locations and horizons: Oils and bitumen of the Pacific slope, of Mexico, West Indies and South America are Tertiary, in California Miocene, and Eocene in Trinidad. Nearly all far East productions may be, as far as known, accredited to the Eocene epoch. The greatest part of the world's supply of petroleum comes from horizons in the rocks, older than the Carboniferous period, though the greatest number of localities and largest extent of oil bearing strata are of much more recent date, Eocene rocks being the greatest reservoirs.

Gas has been found in quantities possessing economic value in or directly over the Utica Shales of the Lower Silurian, as at Burkesville, Ky., at Collingwood, Canada, and in the lower gas veins of Findlay and Bowling Green, Ohio; in the Niagara shales of the Upper Silurian, as found in the upper gas veins at Findlay and Bowling Green; and in the Huron Shales of the Devonian age, as found in hundreds of places in Ohio, West Virginia, and at some points in Kentucky. In Pennsylvania the greatest gas horizon is in the Catskill rocks, while the greatest oil reservoir of Pennsylvania is in the Upper Chemung, 300 feet below the Catskill. That part of the Ohio Shale, designated "The Cleveland Shale," is the gas and oil producer of Northern Ohio, along the Lake region, as at Mecca, Grafton, etc. The gas and oil of Washington county, Ohio, are obtained, some of it at least, at the top of the lower coal measures, and even the lower oil rock of that locality, while being 300 or 400 feet below the first "sand" or oil rock, is still reported with a thin seam of coal a few feet above it. (See 2nd Vol. Ohio Geol. Survey, page 497.)

The territory in the United States in which we may expect, with some show of reason, to find gas, is quite large, and it has had its borders, so far as Ohio is concerned, materially extended during the past year. Western New York, Western Pennsylvania, Northeastern Ohio, much of West Virginia, limited parts of Kentucky and Indiana, are now producing gas. There is a *possibility* of finding it in any part of Ohio where the Huron Shale exists with sufficient covering. The same remark probably applies to other States. It is said a good supply of gas is obtained in the neighborhood of Kansas City at a depth of not over 300 feet. Harrison county, Indiana, seems to be a fairly good gas territory. The successful borings at Findlay and Bowling Green, Ohio, indicate that we may reasonably expect to find gas in the Trenton lime or Utica Shales of the Lower Silurian, especially along the crest of the Cincinnati arch. The apparently favorable conditions for finding gas at this horizon extend across the western half of the State from North to South. The developments at Findlay are very encouraging, and are now sufficiently numerous to warrant predictions that success may reasonably be expected in a search for gas in the territory and at the horizon mentioned.

The southern part of our State possesses all the apparent requisites for finding gas in abundance in the Huron Shale, (aside from the absence of folds in the strata), and yet no wells put down in that territory have ever yielded gas in quantity to possess much, if any, economic value. A well drilled in the year 1865, at Rio Grande, Gallia county, starting at about the horizon, if I remember rightly, of the Upper Freeport coal, and going down 850 feet, struck gas which flowed for some years, and, for aught I know, is flowing yet. The quantity was not large, though this possibly might have been in a measure accounted for by the pressure of the water which flowed constantly from the salt rock up over the top of the tubing. A well has been drilled during the past year by the Belfont Iron Works Company, at Ironton, Ohio. The well starts 160 feet below the horizon of the ferriferous limestone, and was driven more than 2,000 feet. But little gas and no oil of consequence was obtained. The parties ceased drilling when they could no longer keep out a vein of water struck at a depth of 2,000 feet, which water rose up some 800 feet in the hole, and emitted such a disagreeable odor that the workman claimed they could no longer endure the smell, and quit work. Just what stratum constitutes the bottom of the well is not quite clear. There were many indications that they were down into the Niagara, and the same indications would apply to the supposition that they were just through the corniferous and into the Helderberg. A sandstone was pierced, just before reaching the vein of water, saturated with sulphuretted hydrogen. Columbus is located on the horizon of the corniferous limestone, and by going down 90 feet and passing through a sand rock, a vein of sulphur water, strongly impregnated with sulphuretted hydrogen, is struck, and the water flows to the surface in great quantities. To my mind the similarity is something more than a coincidence.

Some excitement prevails at Middleport, in Meigs county, at this date, over the finding of oil in that locality. A well put down for gas across the river in West Virginia failed to find oil or gas in quantity to possess much value.

The fact that the four gas wells at Findlay and the three at Bowling Green have developed new territory, causes more than ordinary interest to attach to them. On page 366 of the 2nd volume of Ohio Geology is published an interesting letter from Dr. Carr, written in 1872, in which he says that his house had then been lighted for nine or ten years from a well sunk but seven feet from the surface. Afterwards a well was drilled 135 feet into limestone, but the drill getting fast the enterprise was abandoned, though the flow of gas was stronger than from the shallow wells. Gas was struck in small quantities in other parts of the town. In digging sewers through the town gas is struck, very foul with sulphretted hydrogen. In drilling the second deep well at Findlay three veins of gas were struck in the gray slate, the first at 527 feet, the second at 623, and the third at 640 feet below the surface. These shales I have assumed are in the Upper Silurian, and belong to the Niagara group. Another and lower vein was struck at a depth of 1,200 feet, and while drilling in limestone. I assume that this is in the Lower Silurian, and that the gas comes from the Utica Shales, or more probably from the Trenton limestones.

Many regard a good flow of gas from a well located in the vicinity of a manufacturing town as equal in value, as an investment, to a first-class gold mine. A demand is readily created for the gas at prices which must pay enormous profits upon the money expended. Nevertheless, if one company was paying all the losses and reaping all the profits, up to this date it is a question upon which side of their ledger the profit and loss balance would appear.

During the year ending May 30th, 1880, there were oil and gas wells drilled to the number of 3,696. Of this number, 3,541 were drilled in Pennsylvania, and 155 in Ohio and West Virginia. The total cost of these wells, as reported to the Census Bureau, was $9,149,907.00, or an average cost of $2,475.00 for each hole put down. It is very probable that, under the impetus given to the business by the utilization of natural gas and the greatly increased demand for it, many more holes were drilled during the year 1884. The outlay for that year doubtless exceeded $10,000,000.00. The total expense of putting down these wells is proportioned about as follows: Rigs, 15 per cent.; engines and boilers, 8 per cent.; drive pipes, 6 per cent.; casing, 8 per cent.; tubing, 11 per cent.; torpedoes, 10 per cent.; labor, 27 per cent. This leaves 15 per cent for incidentals.

Col. T. P. Roberts, of Pittsburgh, a gentleman who has given the subject much thought and investigation, estimates that there have been 50,000 wells drilled in Pennsylvania alone; that thousands and perhaps tens of thousands of these wells have been unproductive, failing to get oil in paying quantities when oil was sought, and finding no gas when gas was desired, will not be questioned. Can this enormous expenditure be curtailed without interfering or checking the development of the industry? Prof. I. C. White, of the University of West Virginia, a gentleman of much experience and possessing rare scientific attainments in the field of Geology, answers the question affirmatively.

The writer having understood that Prof. White was meeting with almost phenomenal success, both in accurately locating gas wells and in condemning territory, asked him to give the readers of the JOURNAL the benefit of his knowledge and experience, to which request he kindly assented. Not having time to prepare an article for publication, he gave me the facts in a private letter, from which I shall quote liberally. He says: "In 1883 I was engaged by Pittsburgh parties interested in natural gas to study up the question as to whether the presence or absence of gas could be determined by any geological features with a reasonable degree of certainty. In order to do this, I visited the Murraysville, Tarentum, Butler, Washington, Wellsburg, and every other district that had been accidentally developed in drilling for oil. To my astonishment I found that every great gas well in the region I was investigating was situated near or on the crown of a gentle uplift of the rocks, or on what we geologists term an anticlinal; while only a short distance (one-half to one mile) on either side, in the synclines, only salt water was found, and no gas to amount to anything. For instance, the famous Murraysville well was exactly on the crest of the Pin-Hook anticlinal of Stevenson's Pennsylvania Report "K." The Tarentum wells were near the line of the Bull Creek axis. The conditions for the presence or absence of gas then seemed to resolve itself into one of structural geology. The tension of the arch of the anticline would, of course, in a loose, coarse, porous sand-rock, open many fissures near the crest, and thus still farther increase the capacity of the rock as a reservoir for gas, whether escaping upwards from beneath or from the generation of gas within the rock itself, out of buried organic material. Of course the reasons why the gas should seek the crown of the arch, and the salt water be found in the trough, are self-evident, from the nature of the two substances. Hence, so far, the theory and facts all agree ; but before practical men would take hold of the question, the theory must be submitted to a practical test. To do this, I traced the Murraysville arch southwestward to the Youghiogheny River, and located a test well on its crown more than ten miles from Murraysville, and where it was surrounded with water wells, one of which was one-fourth mile distant. Here, certainly, were the conditions for a satisfactory test. This well struck a large flow of gas (200 pounds pressure) in March of last year. On January 1st, 1884, I located gas territory for the Washington (Pa.) Heat & Light Co., along the crest of the Washington anticlinal, and the three wells they have since put down on my locations have all been good, though a well located by other parties, and bored off my line, got no gas, but a small flow of oil.

As yet I have made no failures, though some wells are much more productive than others, apparently depending both on the strength of the anticlinal and the thickness of the sand, or, in other words, the size of the reservoir."

The success in condemning territory by Prof. White has been quite as marked. He condemned the territory at Wheeling, Pittsburgh, Martin's Ferry and other places, and in none of this condemned territory has subsequent drilling developed gas. Prof. White says the idea of finding gas at the crest of anticlines was suggested to him by some one else. Of course gas cannot always be found, even where conditions appear to be favorable.

The over-lying material may not be porous enough to constitute a store-house, or fissures in the rock may permit the escape of gas as generated; but Prof. White has certainly demonstrated that vast sums of money may be saved by intelligent investigation and by the employment of persons with scientific knowledge —geologists—to make selections of locations for gas wells. As will be seen in another part of this paper, Dr. Newberry was governed ten years ago by the same rule in the location of oil wells. To my mind, however, the rule will not apply with the same probability of success to the location of oil as to the location of gas wells. Many writers mention the fact of the oils being located at the crest of the anticlinals. Prof. Minchell, in writing of the "oil break" of the volcano region of West Virginia, says: "Whether you strike gas, oil or water, depends upon the comparative level of the point at which you strike the fissure." Dr. Orton says he has taught that idea to his classes for many years. Yet credit is due to Prof. White for making practical, thorough, and positive demonstration of the correctness of the theory, at least as applies to the location of gas wells.

It is generally conceded that natural gas, as well as petroleum, is generated from the carbonaceous material of the deeply buried shales. There are many, however, whose opinions are worthy of consideration, who believe that the oil sands are the real producers, and still others who believe that the oil and gas come from the limestones. I think incontestable proof can be offered that all are right. I believe that the gases of the Devonian system come chiefly from the shales, but not exclusively. The Corniferous lime at Chicago and Terre Haute are producers. Dr. T. Sterry Hunt estimates that the Chicago lime contains 7,750,000 barrels of petroleum to the square mile. The frequent occurrence of oil and bitumen found enclosed in geodes of limestone seems to establish the fact of its being indigenous.

The advocates of the idea that the sand rocks are not only the store-houses but the generators of the natural gases and oils have many facts to back up their theory, yet I am not sure that they have made out a clear case. To determine this point definitely, it will be necessary to particularize a little more as to the real origin of the carbonaceous matter. What was it? Was it vegetable, similar to that which produced coal, or was it seaweed debris? Or was it animal and not vegetable? Or was it both animal and vegetable? Or was it neither animal nor vegetable, but chemical? Instances may be cited in which an affirmative answer might be given to each of the inquiries. That the gases obtained from the Trenton, Niagara and Corniferous limestones are animal, admits no room for doubt in my mind. That the gases of the Utica Shales, the Huron Shales, and of the sand-stones of the Coal Measures are partly animal and partly vegetable seems equally probable. That the gases of the volcanic regions are chemical may readily be believed. The writer has until recently supposed that Dr. Newberry (who was the first to suggest that the natural gases of Ohio and Pennsylvania were generated from the carbonaceous matter of the Huron Shale), believed that the oils and gases were wholly of vegetable origin. A careful reading, however, of his second volume of Ohio Geology will show that he doubted that, even at the date of that report. Speaking of the Cuyahoga Shale, Dr. Newberry, in the second volume of the Ohio Survey, page 88, says it "is crowded with its characteristic mollusks, and with the bones, teeth, scales and spines of fishes." The shale is described as dark gray or nearly black. On the same page he says, speaking of this same shale, that it is "literally made up of shells." On page 90, second volume, referring to the Berea grit, which is the oil sand of Grafton, Liverpool and Mecca, of Ohio, and the same rock is the oil sand of Oil Creek, Penn., he says "it contains in large numbers the spine and teeth of fishes. Of these the most conspicuous are the spines of a species of Ctenacanthus (Ct. triangularis) of which more than *two dozen* were found upon a surface not larger than a square yard." Hundreds of quotations could be made from Newberry's Ohio Reports that would in a measure sustain the theory that the oils and gases are largely from animal matter, and many of these quotations would sustain the argument that at least some of the sand-stones are producers as well as store-houses. In a paper read in February, 1882, Dr. Newberry says that the oils of the Niagara limestone are indigenous in that rock, and believes they are of animal origin. In this same paper he says the gases of the Hamilton Shales are from the carbonaceous matter, apparently produced from the decomposition of sea-weed, these being abundant and nearly all other fossils absent.

Very many eminent authorities may be quoted in maintenance of the claim that the natural oils and gases of some horizons at least are of animal origin. Peckham says Ohio and Pennsylvania oils are undoubtedly of vegetable origin, but thinks the Kentucky oils from the Trenton limestone are of animal origin. This statement was made, however, before the development of the new gas and oil field of Northwestern Ohio. Prof. T. Sterry Hunt attributes the origin to animal matter. There are others that reason that it is possible that they are neither of animal nor vegetable, but that the origin is purely chemical, that is, the result of chemical action upon inorganic matter. Byasson, of France, by experiment in 1871, produced petroleum from water and carbonic acid in contact with white hot iron. A possible theory is suggested that sea water invades greatly heated portions of the earth and comes into contact with unoxidized highly heated metals. Berthelot, in 1866, suggested nearly the same theory, viz., the formation of acetyline by contact of carbonic acid with alkaline metals in the bowels of the earth, and then, through action of steam, carbides of hydrogen are formed. M. Mendeljeff, of Russia, in 1877, suggested that the law of gravity must put metals nearest the center of the earth. Water has reached the metallic carbides through crevices, and carburetted hydrogen is formed. In 1877, Mr. Cloez obtained oil by action of sulphuric acid on speigeleisen.

It seems evident to me that gases are found in rocks to which they are indigenous, and in rocks where they have only been stored; that they are of animal, vegetable and chemical origin; that the oils and gases of the older rocks are almost exclusively of animal origin; that the oils and gases of the shales are animal and vegetable,—those of Devonian age in Ohio and Pennsylvania mostly vegetable; that the gases of the volcanic regions, issuing from the fumaroles, mostly chemical, with probably an intermingling of atmospheric gases or air, drawn into the earth by the chimney-like action of the volcanoes and of the fumaroles. That the oils of Ohio and Pennsylvania are not wholly derived from vegetable matter may be easily believed when attention is called to the fact that the products of destructive distillation of coal have but few things in common with the products of oil distillation. Gas Works that make gas from oil do not get a coal tar residual. I believe that neither alizarine nor anthracine, nor in fact any of the coloring matter of coal tar, are produced in the manufacture of oil gas. I am also under the impression that carbolic acid and erysilic acid are not found in the condensed liquids of oil gas. Little or no ammonia is produced. The heavy hydrocarbons belong to different series, and are in greater abundance. The percentage of free Hydrogen is much less in oil than in coal gas. The advocates of the theory of vegetable origin may truthfully claim, however, that the valuable coloring matter obtained in the distillation of coal comes from the *coal tar*; that in the manufacture of oil gas the oil is really undergoing a second distillation; that the *tar* was left in the earth, and that the difference in quantity of ammonia present may be due to the modes of distillation. Pelouse, of France, obtained the same series of hydrocarbons from lime soap, made from fish oil, that are found in petroleum.

The distillation of the oils and gases from the fossils of the shales and limestones is a question that has not been so much discussed. The question is one that may be regarded by some as having no practical interest, and yet I am persuaded that if we had a more thorough knowledge of all these matters we would doubtless be able to reap some practical benefit from it. The temperature of the earth has been the principal factor in the distillation of the fossils. The pressure of the over-lying strata has probably been a prominent feature in the production of the oils. Could we ascertain the exact condition of the compounds when in the earth before the drill releases the pressure, it might assist us to guess what brings about liquefaction and gasification. It is the opinion of many that the natural gases of Pennsylvania exist in the earth as either solids or liquids, and that gasification occurs when the pressure is removed by the drill. Much may be said in support of this opinion, and something against it. If the gas was originally driven off from the fossils as marsh gas, does sufficient pressure exist in any of the gas wells, and especially the more shallow ones, to liquefy that gas? If the gas is compressed or distilled as an oil from the mass of fossiliferous material and remains a liquid until the drill releases the pressure, would the gas go off so uniformly as marsh gas, or would there be vaporized the benzine series of carbon compounds and the gases not be so permanent? It is easy to ask, but not to answer. Dr. Newberry evidently believes that the distillation of the carbonaceous matter results in the direct production of gas, and that the liquid is produced by the condensation of the gases in the crevices of the over-lying strata, as he uniformly advised searches for oil to be made at the crest of the anticlines. He says in Vol. 2, page 504, Ohio Geology, that the correctness of his ideas as to the proper place to drill for oil has been abundantly verified in practice. Had this statement been made by a less eminent authority, I would have believed he was mistaken. Whether the gas is given off originally from solid matter, or escapes from the volatilization of the oil,—in either event it will seek the highest point, and will occupy the interstices at the crest of the anticlines, and, if in abundance, must crowd the oil to a lower level. To bore for and obtain oil at the top of the fold would, in my opinion, be to invite the expense of a pumping well, (by letting the gases escape), while to drill to one side of the fold would be to utilize the pressure and tension of the gases in forcing the oil to the surface. The Pennsylvania oils are not found at the crest of anticlines, but the gases are.

To my mind, the distillate of the shales was mostly a liquid; that the gases were vaporized by the long continued warmth of the earth; that the marsh gas naturally sought the highest storehouse and was constantly leaving behind the richer hydrocarbons that were no longer able to maintain a gaseous state after the lighter gas had escaped from them, and that this accounts, in a large measure, for the great variation in the illuminating power of the gases from different wells,—the almost pure CH_4 being found furthest from, while the richest and best gas is found in close proximity to, the oil; that by constant distillation and condensation, new oil and gas "sands" are being created. The gases are doubtless becoming poorer in carbon as the pressure increases, by reason of the condensation of the compounds richest in heavy hydrocarbons.

It seems hard to believe that the marsh gas exists in the earth either as a solid or liquid, and yet it must of necessity be greatly reduced in bulk. By the law of the compression of gases, the bulk of marsh gas that measures 1000 feet at atmospheric pressure must have been reduced to only about 70 feet, when under 200 pounds pressure in the fissues and pores of the sand rocks, and estimates of pressure many times greater are common. The idea that the gas exists as a liquid or solid is borne out, in some instances, by the great reduction of temperature resulting from the escape of gas from some of the Pennsylvania wells. A cold so intense is sometimes produced that solidification occurs of everything in the vicinity whence the gas escapes, so that, in one instance, at least a hundred feet of ice had to be drilled through to again open a frozen well.

The chemical feature of the natural gas question is one of great interest and importance. The composition of gases from different wells varies greatly, and, as before suggested, their composition, so far as the absence or presence of illuminants is concerned, is governed by the immediate presence or absence of oil. For other features of distinction, however, we cannot so easily account. The following table gives the analysis from a number of wells in different sections of the country, chiefly, however, from wells in Pennsylvania. The figures are taken from the report of a committee of the Engineers' Society of Western Pennsylvania, excepting only Nos. 10 and 11, (Findlay Wells):

NUMBERS.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Hydrogen	......	......	6.10	13.50	22.56	19.56	......	......	......	......	......
Marsh Gas	82.41	96.50	75.44	80.11	60.27	78.24	......	47.37	93.09	96.49	85.690
Ethane	......	......	18.12	5.72	6.80	......	......	......	......	......	......
Carbonic Acid	10.11	......	0.34	0.66	2.28	......	15.86	3.10	2.18	0.88	0.150
Carbonic Oxide	......	0.50	......	......	......	......	......	......	......	1.00	3.375
Nitrogen	4.31	......	......	......	7.32	......	......	49.39	0.49	......	10.260
Oxygen	4.23	2.00	......	......	0.83	2.20	......	0.17	......	......	2.700
Illuminating Hydrocarbons	2.94	1.00	......	......	......	......	......	......	3.26	0.50	......
Sulphuretted Hydrogen	......	......	......	......	......	......	......	......	......	0.88	0.363
Carbon Bisulphide	......	......	......	......	......	......	......	......	......	0.25	0.110

Copies of numerous other anlayses might be given, but the above table is sufficiently extensive to give a fair idea of the various qualities of natural gas. These analyses would furnish a theme for a long discussion. Marsh gas largely predominates in all, with one exception, that of No. 8, and this was gas from marsh ground. In this the quantity of nitrogen exceeds 49 per cent., and yet there is shown but 0.17 per cent. of oxygen, which is positive proof that the large per cent. of nitrogen was not due to an admixture of air. Whence came it? It will not do to assume that it is only air robbed of its oxygen, as upon that hypothesis there should be 14 per cent. of oxygen present in other combinations, while there is but 2.25 per cent. present in combination with carbon as carbonic acid. No. 7 was from Rogers' Gulch, Wirt County, West Va. By reason of the very large per cent. of carbonic acid in that gas, it would be worthless as an illuminant, and its calorific value would also be low as compared with most of the other samples. No. 1, from West Bloomfield, N. Y., shows more than 10 per cent. of carbonic acid. This carbonic acid gas probably comes from the partial calcination of the carbonates of lime and magnesia, or from the oxidation of the carbonates of the protoxide of iron.

The sulphur compounds are shown in but two samples, numbers 10 and 11. While the per cent. of sulphuretted hydrogen is inconveniently large, (especially in number 10) still its presence adds an element of safety to the use of the gas, and possibly imparts to them a value that none of the other samples possess.

It seems probable that the gases that shall hereafter be found —in our State, at least—at the horizon of the Findlay and Bowling Green wells will contain sulphuretted hydrogen. The very strong odor from the Ironton well on the Ohio River, the artesian wells at Columbus, flowing water strongly impregnated with sulphuretted hydrogen, the sulphur springs of Delaware, and the gas wells at Findlay and Bowling Green complete the chain across the State, all in about the same strata, and all giving off sulphuretted hydrogen. When going still lower down into the lower Silurian as developed by artesian wells at Cincinnati, the sulphur is still found strongly impregnating the water.

The following shows the composition of natural gas from Lago di Naftia, in the Val del Bove, of Etna:

	NO. 1.	NO. 2.
Carbonic acid	94.20	84.58
Sulphuretted hydrogen		6.17
Nitrogen	1.82	2.42
Oxygen	0.28	4.52
Loss	3.70	2.31

Gas evolved from the fumaroles on the Island of Saint Paul, (temperature 78 to 80 degrees Fahr.), shows the following composition :

Carbonic acid..................	14.24	Absolutely non-combustible.
Oxygen..............................	17.01	
Nitrogen...........................	68.75	

The presenee of free oxygen and nitrogen in this gas, and the proportions in which they are present, indicate to my mind that these gases are the result of air being drawn in by some unobserved means. A portion of the oxygen so drawn in has united with carbonaceous matter to increase the per cent. of carbonic acid. The natural gases from Campi Flegri, Vesuvius, is found to be mainly carbonic oxide; sometimes as high as five per cent. of sulphuretted hydrogen is present. The gas is changeable in its composition, at times containing as high as 50 to 60 per cent. of nitrogen. Nearly all of the gases of the volcanic regions are composed of carbonic acid, sulphuretted hydrogen and nitrogen. None possess hydrocarbon compounds in large quantities. This possibly may be the natural result of the free admission of air, and the conversion of hydrocarbons to carbonic oxide, carbonic acid and water.

The pressure of the natural gas in the ground occasionally reaches a high figure—in some instances, in the wells of Pennsylvania, to that of more than thirty atmospheres. Prof. Peckham says it is even estimated at as high as two thousand to four thousand pounds per square inch. This, however, is with pipes closed. With a free escape the pressure, of course, is greatly reduced. The Committee of Engineers' Report, before referred to, says that in no instance was the pressure found in the wells examined to be more than two pounds per square inch with the pipe full open. That report was made a year ago. The Chairman of that Committee now writes me that there are authenticated instances of twenty five pounds pressure at some wells. He describes the noise of the gas escaping from the Westinghouse well near Pittsburgh as exceeding that made by fifty locomotives blowing off steam.

The temperature of the gases as they escape from the well is usually about 41 to 45 degrees Fahr.

One question of paramount interest is, will the wells continue to flow, and will the supply be as inexhaustible as has been our coal? Sufficient data have not yet been furnished upon which to even base a good guess. The experience of Fredonia would lead us to expect the supply to last a long time. On the other hand the experience in Pennsylvania tends to show that there is a "gradual diminution" of the flow from a well, "tending ultimately to total extinction."

"The following historical facts in regard to wells drilled by Spang, Chalfant & Co., are of interest in this connection:

No. 1, has been in use nine years and is still a good well.

No. 2, four years in use, still flowing, though with diminished force. Its location is three miles distant from any other gas belt.

No. 3, yield insignificant.

No. 4, pressure diminished from one and one-half pounds to zero in one week.

No. 5, failed after four years' use.

No. 6, in use six years, gradually failing.

No. 8, good yet. Drilled in 1883.

No. 9, dry hole.

No. 10, was a small well.

No. 11, good well. Gas struck within the past few days." These are Butler county, Pennsylvania, wells.

It is claimed (the grounds of the claim I do not know) that the average life of a Pennsylvania well is about eleven years. However, recent investigation presents this question in a more favorable light. It has been discovered that at least some wells that had been considered exhausted were only obstructed with deposits of paraffine, and that when the obstruction was removed the gas again flowed in paying quantities. It is not only possible, but altogether probable, that many of the abandoned wells may be obstructed with paraffine deposit, and with lime, magnesia, and common salt.

Some interesting experiments were made by the committee from whose report I have quoted so freely, in connection with the velocity of the gas and pressure in the pipes. A well giving three and one-quarter ounces pressure with a free escape, gave fifteen pounds pressure when connected to 16,000 feet of pipe, and it took the gas four and one-quarter minutes to travel the length of the pipe. Gas with ninety pounds initial pressure was two and one-quarter minutes in traversing 16,000 feet of pipe. Gas from a well having a pressure of twenty ounces had a velocity of 23,400 feet per minute; a rubber ball was driven through three miles of five and five-eighths casing pipe in two and one-half minutes. The great variation in the velocities here recorded are doubtless due to the different sizes of conductors and perhaps to angles and bends in the pipes.

The great problem for solution now seems to be, "how can the natural gases be transported economically and safely to consumers?"

The most intense excitement has prevailed in and about Pittsburgh at times during the past winter, growing out of the accidents that have occurred through the defective system of transporting natural gases. The escape of the gases, which there possess no odor, caused houses to be blown up and many persons to be dangerously injured, and in some instances causing loss of life. The dangers became so great that the matter was taken into Court and an effort made to correct the evil. In the equity proceedings between the City of Pittsburgh and the Fuel Gas Company, et. al., the Court appointed a Commission of five intelligent persons, skilled in the various branches of science and mechanics, to make a thorough and exhaustive investigation of the questions involved. Occasionally the testimony given before this commission has been made public. The full report is expected to be given to the public soon, and it will doubtless impart to the world much valuable information. The parties giving testimony are experts, engineers, pipe-layers, chemists and mechanics, and the testimony given has been of the most confusing and conflicting character. While there are many questions of detail to be settled by the investigation, there are two principal questions to be determined that transcend all others. First, how high a pressure can be carried in the pipes without endangering life and property, and second, to how low a pressure may the gas be reduced without increasing its cost beyond the point where a profit commensurate with the risk of the business can be made on the money invested.

It is now estimated that about 60,000,000 feet of natural gas is being used in Pittsburgh every twenty-four hours. This equals 2,500,000 feet every hour. The consumption, however, will not be regular, and the capacity of the supply pipes must be equal to a maximum delivery of 5,000,000 feet per hour.

The testimony before the Commission, so far as it has been made public, indicates that experts are inclined to believe that the old established practice of companies supplying manufactured gas ought to be taken as the rule, guide and government of the natural gas companies. Should this rule be accepted, and assuming that 5,000,000 feet is now being delivered at an average of 40 pounds pressure, the present capacity of the mains would have to be increased about sixteen times in order to supply the desired quantity at the maximum *night* pressure of the old gas companies, and would needs be increased about thirty-two times to supply the gas at the average *day* pressure carried in the pipes of the companies supplying illuminating gas. This would so enormously increase the cost and consequent capital employed as to greatly curtail its use in competition with the cheap and good coal of Pittsburgh. Experience, however, has demonstrated that the best results in combustion are obtained by the consumption of the gas at a pressure that does not exceed three ounces per square inch.

One gentleman gave testimony before the Court Commission, who claims to have submitted a report to the city of Chicago, showing that two parallel pipes, seven feet in diameter, would convey gas enough, *at an initial pressure of four ounces per square inch*, from the Murraysville well above Pittsburgh to the city of Chicago, so that when the gas was sold at only one cent per 1,000 feet, it would give a revenue sufficient to pay interest on a capital of $35.000,000. It was proposed, however, to have intermediate storage points, and, I presume, would use exhausters. The rate of interest not being stated, we cannot accurately calculate the quantity of gas required to be delivered; but, assuming the rate to be four and one-half per cent. per annum, the daily interest would be more than $4,000, and to equal this sum 400,000,000 feet must be sold every twenty-four hours of the year. We cannot imagine how it could take less than one-fourth of a cent per 1,000 feet to send this gas from Pennsylvania to Chicago, distribute it to consumers, do the office work, make collections and pay the necessary expenses incident to the maintenance of an organization employing a capital of $35,000,000; and if this estimate is not too high, an additional 200,000,000 feet per day must be sold, or a total of 600,000,000 feet per day must be sent a distance of several hundred miles through two pipes, each seven feet in diameter. To the average gas man the scheme does not present a feasible aspect, neither in its practical working nor in its probable ultimate financial success.

The pipes that have heretofore been laid for transporting natural gas in and about Pittsburgh have not been laid much, if any, below a depth of three feet. The past winter was one of unusually low temperature, and the result was constant disturbance of the pipes by frost, with resulting enormous leakage and frightful destruction of property and life. The apparent absolute necessity for a better and safer system for transporting this dangerous fluid set inventors to work, and scores and hundreds of plans and devices have been suggested, but unfortunately, so far, none seem to entirely meet all phases of the demand. Some governors of great value have been invented. They control the pressure of the gas, preventing its rising above the desired point in the pipes, and if from any cause the gas ceases to flow, and the fires or lights are extinguished, the gas cannot again pass into the premises without its being turned on by hand. This is probably the most useful invention yet brought out in connection with the natural gas question.

To prevent leaking at joints, innumerable plans have been suggested. The ends of the wrought pipes have been faced, and the threads made long enough so that the pipes can be butted together in the middle of the socket, practically making a ground joint. Another plan was to chamfer the ends of the pipes and screw them in against a gasket of lead in the center of the socket. Either of these plans would doubtless have given a tight joint, had the temperature of the pipe always remained the same as when put down, but at the shallow depth at which the pipes were laid the joints were failures. Screw joints, calked with copper wire, also failed for the same reason. Had these joints been made with the pipe at about 40 degrees temperature, and the pipe buried seven or eight feet in the earth, it is my opinion that they would have been practically tight, even at 100 pounds pressure. Pipe should not be laid in long straight lines, but should form, when down, a slightly wavy line, to give room for contraction without destruction of joints. Much of the trouble from leaky joints has been attributed to the variation of the pressure. The registering sheets show a constantly varying pressure, the variations generally being slight, but occasionally it drops down to five pounds and then suddenly leaps to 90 or 100 pounds per square inch. Now, I do not believe that this change of pressure causes leakage to any great extent with the screw joints. The increase of pressure must give an increase of temperature, and that in turn give expansion of the pipes and a consequent tightening of the joints.

It has been suggested that all high pressure pipes should be brought into Pittsburgh over-head, when the leaking gas would be diffused into the atmosphere. That possibly might prevent accidents, though I doubt it, and it would greatly add to the quantity of gas lost by leakage, from the constant change of temperature. One company has laid some lines of pipe the usual depth in the ground, and then laid a clay pipe along on the top of this pipe, with an occasional outlet leading to and up through a lamp post, where a light is kept constantly burning; the idea being to have the gas leaking from the iron pipes to follow along in the terra cotta pipe and escape at the lamp post and there be consumed. This, of course, does not prevent leakage, but prevents accidents from leakage. Opinions differ as to whether this plan will prove successful, the weight of opinion seeming to be against it. Another plan is suggested by Col Roberts, of laying the main below frost, then putting a sleeve over each joint of the main, and this sleeve to be tapped for, say a three quarter inch pipe, and this pipe to be attached to a two inch pipe running parallel to and lying over the main pipe, the upper pipe being buried just under the street pavement. The gas leaking from the joint would enter the sleeve surrounding it, pass up the small pipe into the two-inch, which pipe shall have stopcocks or valves between the joints, and by the aid of these valves the leaky joint can be located with but little trouble and little disturbance to the street. The objects sought to be accomplished are, first, to prevent the escape of gas into cellars, and, second, to be able to locate the leaks with rapidity and certainty, with the minimum disturbance of the streets. Owing to the difference in the composition of the gases, that found in the vicinity of Pittsburgh is much more difficult to transport without leakage than is that of the oil regions. In the first place, its specific gravity is much less, and, second, the absence of oily residuals, which in the gas of the oil regions aids in closing up the small interstices of the pipes and joints. The specific gravity of the Pittsburgh gas is given as .557, and that of Bradford as .850, air being 1.000.

Many strange ideas have been given out through the Court investigation at Pittsburgh. It is said that chemists differ greatly respecting the characteristics of natural gas. It is possible, however, that some are classed as chemists by the newspapers who do not class themselves as such, and perhaps some style themselves chemists who would not be given that rating by competent judges. One of the claims set forth by "a chemist" was that natural gas has a great affinity for water, and it seeks low levels in consequence, hence the penetration of gas to the cellars of buildings. One party will claim the absence of salt water, and another finds it in abundance. One says the gas has a strong ordor and another say it has no odor. To my mind the gas may or may not carry a strong odor, depending, first, upon the locality from which it comes, and second, the distance and velocity of travel. If the gas is permitted to become motionless, it will doubtless drop the salt water and the solid particles or condensable vapors that impart odor to the gas from some well.

The uses to which natural gas can be put are very numerous. It can be used for any purpose for which coal is or can be used, with perhaps the exception of smelting iron ores, and it fails in this respect through no inherent defect, but for want of proper apparatus. It is used for puddling and heating iron, melting steel, raising steam, for melting crude material in glass works, and for annealing glass, for domestic heating and cooking, and in lighting residences, offices and factories. For the latter purpose it is not well adapted, especially when the gas does not flow from the vicinity of oil pools. It is said that a light of twenty-four candles may be obtained from the gas at Bradford, Pa., by the use of argand burners, but not more than eight or ten candles can be obtained with open burners. This looks much like the intensity of light depended largely upon intensity of temperature. I have before suggested that an admixture of water gas, CO and H, would probably add to the illuminating power of natural gas, especially when consumed in an open burner. The Bradford gas contains a large per cent. of heavy hydrocarbons; gases in other sections contain very little.

In a series of practical experiments made at Pittsburgh, it was found that one pound of the natural gas, (23.5ft.), would evaporate 20.31 pounds of water, or, in practice, it gave 83.40 per cent. of its theoretical value. While the best Youghiogheny coal, under the same boiler and with similar conditions, evaporating nine pounds of water, giving only 60.90 per cent. of its theoretical value. The result shows that 1,000 feet of natural gas will do about 25 per cent more work, in practice, than one bushel of the best Youghiogheny coal. If there were no other advantages, such as perfect control of temperature, absence of ashes and clinker, saving of stokers' wages, cost of hauling coal, etc., gas would have to be sold at a very low figure to compete with coal. The price now charged in Pittsburgh varies from 12 to 20 cents per 1000 feet. One concern in Pittsburgh more than one year ago was paying $8,000 per month for gas.

The natural gas interest is yet in its infancy, and I predict for it rapid growth in the near future. To the readers of the JOURNAL who have followed me through this long and disconnected dissertation, I can offer a little comfort and possible compensation by informing them of the fact that, barring accidents, Dr. Edward Orton will issue another, or supplemental, volume of Economic Geology during this year, in which this question wil be given a very prominent place. His volume will be the latest and unquestionably the best publication on the subject of natural gas.