Art. LIV.—*On the Origin of Bitumens. A Retrospect;* by S. F. Peckham.

It is now nearly thirty years since I first directed my attention to this subject, and during this long period of time the discussion of the question has proceeded along the same lines that were quite clearly outlined in 1868.*

The chemical theories, notwithstanding the ability with which Mendeljeff treated this aspect of the question in 1877,† are at present receiving very little attention and will be passed by without further notice. In this connection may properly

* Proc. American Phil. Soc., x, 445; Rep. Geol. Sur. Cal., Geology, II; Appendix, pp. 73–90.

† Bull. Soc. Chem. de Paris, i, 501; Buer. d. Deut. Chem. Ges., 1877, p. 229; Wag. Ber., 1877, p. 1037.

be included the idea that polymerization has played any important part in the formation of natural bitumens; an idea that has lately been so ably discussed by Prof. Henry Wurtz.*

The organic origin of bitumens may therefore at present be accepted as practically undisputed. The question then recurs, are bitumens distillates or are they indigenous in the rock formations in which they are found—in other words, have they been produced *in situ?*

Twelve years ago, when preparing the essay on the Origin of Bitumens which forms a part of my report to the 10th Census of the United States, I wrote, that the derivation of bitumens had not in my judgment been uniform. That opinion took form in my own mind as a growth which was determined by many years of thought and a wide experience. This experience began with a very careful study of all the phenomena attending the occurrence of bitumen in Southern California during 1865–6, and the preparation of a report upon the same for the Geological Survey of California. I left California fully convinced that petroleum was of animal origin and formed *in situ.* Soon after I had returned to the Atlantic coast, I met Dr. J. S. Newberry in his office in New York and with Baron v. Koschkull held a long conversation upon Russian and American petroleum and incidentally upon their origin. Dr. Newberry then for the first time awakened my interest in the distillation hypothesis and based his argument upon the results that had been obtained in technical operations in Ohio in the distillation of coals and shales prior to the discovery of petroleum in Pennsylvania. The argument is all to be found in his celebrated paper on "The Rock Oils of Ohio";† but no one could resist the persuasive eloquence with which he developed the idea of that vast Sargossa sea that, gathered in the Devonian ocean, produced the Devonian shales from which the petroleum of eastern Ohio and western Pennsylvania was distilled. His speculation stopped at this point, with the idea that the oils were distillates.

Later, I was for a time in frequent intercourse with Cyrus M. Warren, whom we all remember with so much affection. He described to me in great detail the experiments he had made by saponifying menhaden oil with lime and distilling the lime soap. The amount employed was several tons, and he obtained the distillate in such quantity that a part was refined into illuminating oil, and the remainder was fractionated in Warren's apparatus. In fact, the experiment was made for technical purposes: but the results are only of

* Engineering, various dates.

† Ohio Agricultural Report, 1859, p. 605.

interest since the discovery of petroleum, for scientific purposes. This distillation yielded the hydrides of the monatomic alcohol radicals, and benzole and its homologues.

Later, Luther Atwood constructed a sort of kiln in the form of a tobacco pipe. The bowl held several tons of Cannelton cannel coal. A fire was kindled on top of the coal and the draft was urged by a jet of steam. In this apparatus distillation proceeded of necessity at the lowest possible temperature, the products of combustion expelling all the volatile matter as the combustion proceeded downward. The distillates more nearly resembled petroleum than any that had been produced by methods of distillation previously employed, apparently, *because* the distillation proceeded at the lowest possible temperature.

While this subject engrossed my thoughts I was led to consider the occurrence of bitumen in veins. I read reports on Grahamite and Albertite and Cuban asphalt and they all seemed to me to be distillates that were injected into crevices that resulted from an upheaval of the crust of the earth. At that time I had never visited the locality where Grahamite occurs, but I had seen the masses of asphaltum of vast extent that occur on the Pacific coast.* No one who has seen them doubts that they were injected into earthquake crevices. I made this question the subject of a communication to this Journal and years after, I had the pleasure of a careful inspection of the locality in which the Grahamite was obtained and talked with the men who mined it out. I saw nothing there that led me to question for an instant the relation of the Grahamite and Albertite veins to the other veins of bitumen and also to petroleum.

But distillation requires heat and the source of heat occasionally occupied my thoughts. No satisfactory conclusion was reached upon this point until one afternoon I met two of the men who helped drill Jonathan Watson's deep well. They told me their story all unconscious of what it meant to me. They said they drilled through all of the oil sands and struck the soapstone (Devonian shale) and kept on with the intention of reaching the limestone (corniferous limestone) which they believed they struck at the bottom of the well, just as, for some reason, the work was suspended and never resumed. They said the "soapstone" became harder as they went down and was redder in color, in fact had been burnt like brick. Their language at once recalled the metamorphosed shales that are so abundant in Santa Barbara (now Ventura) county, Cal., that are often as sonorous as porcelain. One day not long after, to wile away a few moments while waiting for a friend,

* This Journal, II, xlviii, p. 362: Am. Journal of Gas Lighting, xi, p. 164.

I took from a library shelf Prof. James Hall's report on The Geology of New York, and glancing at the introduction, my eye fell upon his clear description of the trend of the currents in the Silurian ocean.* First came Newberry's Sargossa Sea, which formed, when buried, one thousand feet of shale, so filled with fucoids that where the shales outcrop at Erie, Pa., it is impossible to obtain a piece of appreciable size that does not contain a seaweed. On visiting Erie and talking the matter over, I found that, at the time the distillations of coal were made in southern Ohio with which Dr. Newberry was familiar, attempts had also been made to utilize the Erie shale as a source of illuminating oil, and fifty gallons of distillate to the ton had been obtained.

The idea of metamorphism as a source of heat grew apace —heat, steam and pressure and unlimited quantities—cubic miles—of material on which to act. I had been familiar with the anthracite of Rhode Island from boyhood, and with the crystalline schists of eastern New England. I had been down in the coal mine at Portsmouth on the island of Rhode Island, and had seen the immense chambers from which the coal had been mined. All traces of bedding had disappeared, and the coal, almost graphite, had been seggregated into masses almost spherical and connected only by a thread, by which the miners traced the coal from one mass to another.

At the Palisades the molten interior mass has punctured the surface. Through eastern Pennsylvania the coal is metamorphosed into anthracite. At Saint Mary's, where the Philadelphia and Erie railroad crosses the summit of the Alleghanies, the coal is semi-anthracite. In the most easterly county of Pennsylvania in which petroleum is obtained—McKean county —the petroleum occurs at a depth of two thousand feet under a pressure estimated at four thousand pounds to the square inch and filled with paraffine, just as it ought to be if produced by metamorphism. Farther west, the petroleum becomes lighter, until, at Smith's Ferry, it is almost burning oil in its natural state. The products of distillation are all present in proper sequence along the entire line from Point Gaspè to Lookout Mt., and the porous sand bars and pebbly riffles, formed by the currents of the primeval ocean, are now filled with the oil because they afford a receptacle adequate to receive and store the vast accumulations of distillate.

Now, while I have received many very pleasant and favorable comments upon the provisional hypothesis which I ventured to propose in my Report, to the 10th Census, I have for some time had a critic who seems to partly disagree with me.†

* Nat. Hist. New York, Paleontology, iii, 45–60.

† Rep. 10th Census U. S., x, p. 59. This Journal, 1885 (?)

My friend, Prof. Orton, has in the kindest manner shown that in Ohio there is no evidence that any rocks are changed by metamorphic action. While I do not for a moment think Prof. Orton ever intended to be unjust to any one, I do think he has hardly given either Dr. Newberry or myself the position that belongs to us.*

Wise men hold any theory tentatively, no matter what it may be. When Dr. Newberry, in 1859, proposed to account for the origin of petroleum by considering it to be a distillate, very little was known concerning the occurrence of rock oil compared with our present knowledge. When I prepared my essay for the Census Report the Trenton limestone was almost an unknown factor in the production of petroleum; yet, enough was known concerning its occurrence with oil in the cavities of its fossils, to lead Dr. T. Sterry Hunt, in the same manner as other local observers; to conclude that all petroleum originated in limestone, *in situ*, and that the Trenton limestone was *par excellence* the home of petroleum.† As I have said before, when I left California in 1865, with the positiveness born of observation within a limited horizon, I was ready to declare that petroleum was formed by the decomposition of fossil animals. I first wrote the paper read at the meeting of the National Academy of Sciences at Northampton, in 1867, maintaining that narrow view; but I afterwards included vegetable remains as a precaution.‡ It has been many times demonstrated that each observer may be correct as to his own locality and wrong as to others; yet, when the consensus of opinion has been reached, the symposium may have presented a many-sided question from many points of observation, and truth may be discerned in the midst.

I therefore repeat, that in my judgment the derivation of petroleum has not been uniform. Let it be admitted that the earliest horizon of petroleum is the Trenton Limestone, in which petroleum is indigenous, having been formed by some peculiar sort of decomposition from animal remains at the bottom of a deep, excessively hot, and saline sea. If any one can prove that the Trenton Limestone extends beneath eastern Ohio and western Pennsylvania, lying beneath the Devonian shales, I am not prepared to dispute the assertion that the different varieties of petroleum found in that region have been fractionally distilled from the content of the limestone rocks, buried from three to four thousand feet beneath the present surface. I am confident that the heat required was to be found in the gradual dying out of the heated area which involved the Appalachian System. Accompanying this distillation, and a

* Rep. Geol. Surv. Ohio, vi, p. 60–83.
† This Journal, II, xxxv, p. 157–168; xlvi, p. 361. ‡ See note 1.

consequence of it, was an immense accumulation of gas. Some of it escaped into the air during the upheaval that produced the White Oak anticlinal of West Virginia, including the Grahamite vein near by, and some of it remained enclosed. There is little reason to doubt, that whether or no the oil found north of the Ohio and Kanawha rivers is distilled from the Trenton Limestones, the oils of eastern Kentucky have been. Therefore, admitting that Prof. Orton is correct in his conclusions that the sporangites of the shales are a source of oil, and that the Trenton Limestone still contains petroleum *in situ*, I still maintain my thesis, that the metamorphic action to which the Appalachian system has been subjected furnished the heat that has fractionally distilled all of the different varieties of Appalachian petroleum, either from their original source in the Trenton Limestone or through the decomposition of the shales. And further, that any consideration of the chemical constitution of these oils must show, that the oils found east of Central Ohio and north of the Ohio and Kanawha rivers are nearly pure paraffines, and that the western Ohio and Indiana oils—the Trenton Limestone oils—are mainly paraffines containing sulphur compounds from which the other oils are free; and still further, that the oils of southeastern Kentucky and Tennessee partake of the characteristics of both the Appalachian and Trenton oils.

I have lately returned to the region in Ventura County, Cal., that I visited in 1865, and that is so rich in all the phenomena that attends the occurrence of bitumen. During the years that have intervened between these visits, large quantities of petroleum have been brought to the surface, much of which has been burned as fuel. The refining of these oils still presents many interesting and involved problems. Of chief scientific importance is the discovery, lately made, and which I discussed in the paper that I read at the Mid-Winter Fair Congress of Chemists, of the manner in which the nitrogen content of these oils is chemically combined with the hydrocarbons.*

While this subject is of great interest to chemistry and technology, it is of supreme interest as related to the study of the origin of bitumens, and it is with some satisfaction that I note the sign boards that I have set up along the path that led to this discovery. While Warren produced the paraffines from menhaden oil soap, Dippel had a hundred years before produced pyridin by the destructive distillation of the gelatine of bones and the tissue of highly organized animals; but nowhere in nature had Dippel's oil been discovered until within the last two years it has been extracted from all the different varieties of bitumen found in Ventura county and its vicinity and from their distillates. These bitumens occur

* This Journal, Oct., 1894

in vast quantities in rocks that are filled with the remains of the marine mammalia that swarmed in the Miocene Ocean.*

Shall we apply Hunt's theory, and regard these wonderful compounds that appear nowhere else in nature as the product of some sort of ill-defined, inexplicable decomposition to which the animal remains have been subjected; or shall we believe that the metamorphic action which has converted into gneiss the sandstones and shales that flank the low mountains of that region, which gradually passes by insensible degrees into the granite core of the same hills in which the bitumens occur, has distilled the mixture of benzoles and Dippel's oil of which they apparently consist? To my mind the latter hypothesis alone conforms to the experience of technology and the demands of a logical scientific enquiry.

I do not wish to enter here upon any intricate inquiry concerning the nature and origin of metamorphism. I would, however, note by the way, that in addition to that unknown quantity, the internal heat of the earth, the spontaneous generation of heat by chemical action within the influence of the atmosphere has played an important part in the metamorphosis of shales in the region in which the bitumens of Ventura county occur. Locally such action has often been very recent, while, at the same time, the major portion of it belongs to a very remote past. I do not consider it necessary to represent in terms of Fahrenheit's thermometer the temperature at which any particular sample of petroleum was produced, nor do I intend to produce the coke that resulted from the distillation. The coke, if there is any, is where the distillation left it. It is not possible to furnish the details of a natural process the conditions of which are unknown to us. Nor can we reason from the processes of technology, bounded as they are by time and space, to the infinity of nature, which it is impossible to imitate. In order to establish the hypothesis that anthracite was once bituminous coal, it is not required that the distilled gases, and possibly petroleum, shall be produced, nor that it be stated where they now are. Let it be constantly borne in mind that time has always entered into the operations of nature, in sufficient quantity, and that heat, steam and pressure have invaded immense areas of the crust of the earth through vast cycles of the infinite past and the vision becomes clear:

"For a thousand years in thy sight are but as yesterday when it is past, and a watch in the night."

University of Michigan, Ann Arbor, Michigan, July 12th, 1894.

* In the course of an afternoon ramble in one of the small cañons of the mountains on the south side of the Santa Clara Valley near Bardsdale, Ventura Co., Cal., portions of three whales' vertebræ were found, one of them quite perfect. Also in one mass of rock, three vertebræ were found in contact that appeared to be those of a saurian. Besides these were innumerable fragments of ribs and other bones, in a stratum about 18 in. in thickness.