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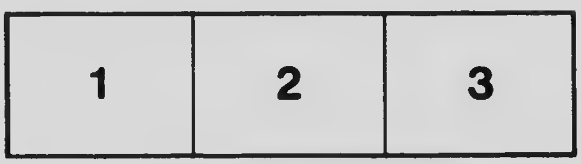
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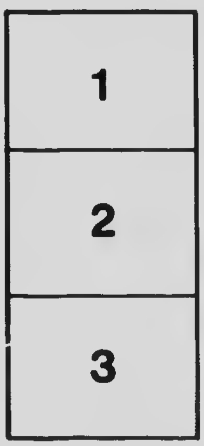
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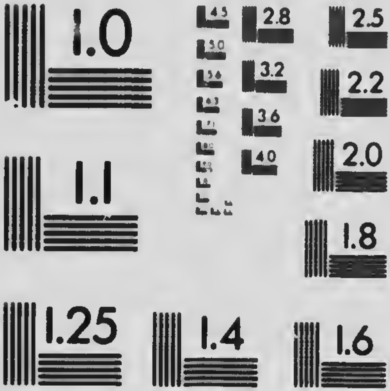

WITH THE AUTHOR'S COMPLIMENTS

Canadian Mining Institute

PETROLEUMS AND COALS

COMPARED IN THEIR NATURE, MODE OF OCCURRENCE AND ORIGIN

BY

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(Presented at the Annual Meeting, 3rd, 4th and 5th March 1909)

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PETROLEUMS AND COALS.

COMPARED IN THEIR NATURE, MODE OF OCCURRENCE AND ORIGIN.

By Eugene Coste, E.M., Toronto, Ont.

(Annual Meeting, Montreal, March, 1909).

There is found in nature a great variety of compounds of carbon, not only in the sedimentary strata of all ages, but also in crystalline rocks, in igneous and volcanic rocks, in seams and veins through all these, and even in meteorites.

All these carbon-compounds have been assigned by many geologists to the one and the same origin, namely:—an organic origin, from the decomposition or distillation of either animal or vegetable organic matter entombed in the strata, and they have all been grouped and classed in the one and the same series of compounds of carbon.

This organic origin cannot of course hold good for the natural carbon-compounds found in crystalline rocks, in igneous and volcanic rocks, in volcanic gaseous emanations, in metallic seams and veins where they are intimately associated with such minerals as quicksilver for instance, and also when they are found in meteorites. It has, therefore, always seemed to me that this idea of only one natural series of compounds of carbon with an organic origin, is so clearly at variance with so many well known geological facts and physical laws that I cannot cease to wonder how it is possible for such a huge error to have taken the firm root it has in the science of geology. In two papers which I read before this Institute, one nine years ago ([1]) and one six years ago ([2]),

1. Journ. Can. Min. Inst., Vol. III, 1900, pp. 68–89.
2. Journ. Can. Min. Inst., Vol. VI, 1903, pp. 73–128.

and in another paper which I read in 1904 before the American Institute of Mining Engineers ([3]), and before the Franklin Institute ([4]), I entered my strong protest against this fallacy. I pointed out in these papers the solfataric volcanic origin of the natural hydrocarbons or petroleums. Other geologists have also long ago given proofs of the inorganic origin of petroleums, especially Berthelot, Mendeléeff, Eli de Beaumont, De Lapparent, and a number of other writers mostly French and Russian.

But it evidently takes a long time to establish definitively even simple and palpable truths in science, as may be judged from some of the recent literature on the subject ([5]) in which the derivation of the natural hydrocarbons from organic matter is either again admitted without discussion or again sought to be proved. It appears, therefore, necessary that some of the facts in the case be once more presented, and I have adopted in this paper the comparative form between coals and petroleums, in the hope that it will bring out more forcibly and more clearly how entirely and absolutely different some of the natural carbon-compounds are to others in their nature, their mode of occurrence and their origin; and in the further hope that it will demonstrate that there are really two series of natural compounds of carbon, namely the Organic or the Coal Series, or Coals, and the Volcanic, or Petroleum Series or Petroleums.

NATURE.

Coal Series.—The coal series includes the natural carbon-compounds grading into one another from vegetation into peat, lignite, soft coal, semi-anthracite and anthracite. The exact chemical nature and proximate constitution of the members of this series are imperfectly known and are not yet fully made out, but they are nevertheless established to be complex oxidized carbon-compounds grading from definite carbo-hydrates into carbon-compounds richer and richer in carbon and poorer and poorer in oxygen as the natural carbonizing process of vegetation

3. Trans. Am. Inst. Min. Eng., Vol. XXXV, pp. 288–297.
4. Journ. Franklin Institute, Philadelphia, 1904.
5. The Data of Geochemistry, Bulletin No. 330, U.S. Geol. Survey, pp. 619–641. See also U.S. Geol. Surv. Bull. No. 250, 265, 282, 285, 300, 309, 317 318, and others.

proceeded, the end product, anthracite, still retaining, however, some 2½ per cent. to 3 per cent. oxygen.

One hydrocarbon, namely marsh gas or methane, is known to form, during the natural decomposition of vegetation, into coals; this is the only hydrocarbon thus formed. Many other gaseous or liquid hydrocarbons may be produced by the destructive distillation of carbonaceous matter or of coals, but these have nothing to do with the carbon-compounds formed in nature by the normal geological processes, as the destructive distillation of the sedimentary strata and of its carbonizing vegetation is not a normal geological process and never took place. This is conclusively proved by all the undistilled lignite and coal beds of the sedimentary strata all over the world and by the want of coke beds in these strata.

It may be well to point out here also that coal beds, being more or less porous strata, may and no doubt have been impregnated, in places, with gaseous and liquid petroleums from extraneous sources and hence these particular beds of coal, in these places, will be found really to contain natural hydrocarbons; but these are the result of a secondary enrichment by impregnation of the original coal deposit. These cases are, however, the exception and do not in any way affect the problem, save as exceptions to prove the rule.

Petroleum Series.—The petroleum series includes all the natural hydrocarbons with the exception of the marsh gas above mentioned. These petroleums grade from natural gas into fluid crude oil or petroleum proper, into semi-fluid maltha and into viscous or solid bitumen or asphalt in their many varieties, of which such minerals as grahamite, gilsonite, elaterite, napalite, ozokerite, albertite, anthraxolite, are only a few. As the end products of the petroleum series there are good reasons, as we will see, to include both graphite and diamond, whose deposits prove that they also have had a similar inorganic origin.

A good definition of the nature of petroleum is the one of Mabery ([6]) as follows: "petroleum, from whatever source, is one and the same substance, capable of a simple definition:—a mixture in variable proportion of a few series of hydrocarbons, the product

6. Journ. Am. Ch. Soc., 1906, XXVIII, p. 117.

of any particular field differing from that of any other field on' in the proportion of these series and the members of the series."

Mabery referred, I believe, in the above definition only to crude oil or petroleum proper, but it applies equally well to natural gas, to maltha and to viscous or brittle solid asphalts, and, it may be said, therefore, that all the members of the great petroleum series, as here understood and defined, are mixtures of different hydrocarbons in greater or less variety.

MODE OF OCCURRENCE.

Coals.—With regard to the mode of occurrence of the members of the coal series it is only necessary for the purpose of this paper to note that they are always found in regular beds of the sedimentary strata spreading uniformly far and wide, often over hundreds and even thousands of square miles. The marsh gas of the decomposing vegetation has partly escaped into the atmosphere in the early part of the process or possibly even later, if the folding, fissuring and faulting of the coal measures have been strong, as for instance in the anthracite fields of Pennsylvania. What marsh gas did not thus escape, however, has not mysteriously transformed itself into the mixture of the many varieties of hydrocarbons constituting petroleums, but it is still found as marsh gas directly in the coal from which it originated and where it becomes to-day the dreaded fire damp of the coal miner, often mixed with considerable choke damp or carbonic acid and with considerable nitrogen. This gaseous mixture is a very different gas from the mixture of hydrocarbons constituting natural gas; it is never, like natural gas, associated with liquid petroleum and with large quantities of very strong sal and sulphur waters and can only be confused with it by superficial observers.

There is only one more point which I think pertinent to make here with regard to the mode of occurrence of the coals, and that is that no coal beds are found below the Carboniferous period. A small amount of coal or carbonaceous matter is, however, found in some of the Devonian shales, but this never passes into pure coal beds and fewer and fewer of these carbonaceous shales are found in the Silurian and Cambrian. The science of geology has always interpreted and explained this fact—that so little coal is found below the Carboniferous—on the understanding that before Carboniferous time the conditions for the existence of considerable growth of vegetable matter were unfavourable and it is a geological heresy to speak of or to believe in coal beds existing in formations lower than the Carboniferous; geology teaches us that they cannot and do not exist there. How is it then that there are so many large deposits of petroleums below the Carboniferous? It could not be because there was so little vegetable or other organic matter entombed in these early strata, unless their origin is not in any way organic.

Petroleums.—If the mode of occurrence of coals is well understood, the mode of occurrence of petroleums certainly is not, and hence the great misunderstanding by so many concerning the origin of the latter. Instances are multiplying in which the natural hydrocarbons are found in emanations clearly volcanic and in igneous and volcanic rocks, that is, in places "where they have no business to be" ([7]) according to those who believe in and support the organic origin of petroleums. Nevertheless these petroleums are found often in such places and no well informed geologist can ignore this fact or refuse to take account of it. Some geologists have passed such, to them, unwelcome cases over with the remark that the petroleums in the igneous or volcanic rocks were no doubt due to the distillation of the bituminous shales cut through by the intrusions; but how can a hot rock distill or drive away a vapour into itself? Some new principles in physics would have to be discovered to permit of this explanation, which is simply a contradictory use of language and not a logical argument. It is also fallacious reasoning, a reasoning in a circle, to attribute the origin of oil to bituminous shales or to shales containing oil, that is to say to oil. In one of my previous papers ([8]) on this subject before this Institute I cited a good many instances of petroleums in volcanic emanations or in igneous or volcanic rocks, and for full particulars of these reference may be made to this publication, but I will recapitulate here what these instances prove beyond all doubt:

1st. The occurrence of graphite in igneous gneisses, granites, gabbros, pegmatite dykes and in a quartz-porphyry dyke.

7. G. R. Mickle, Journ. Can. Min. Inst., Vol. VI, p. 123.
8. Journ. Can. Min. Inst., Vol. VI, 1903, pp. 73–128.

2nd. The occurrences of hydrocarbons in the gaseous inclusions of the crystals of igneous rocks.

3rd. The occurrence of petroleums (liquid, semi-liquid and solid) in greenstone traps, in basalts, in trachytes, in dolorites and other volcanic rocks.

4th. The occurrence of diamond and gaseous hydrocarbons in volcanic necks and pipes.

5th. The occurrence of gaseous and liquid petroleums in the volcanic emanations of to-day.

6th. The occurrence of petroleum in freshly ejected scoriae from the volcano Vesuvius.

In confirmation of the above a few other direct proofs of the occurrence of petroleums in crystalline rocks, in volcanic or igneous rocks or in close connection with these, and in metalliferous veins, may be cited:—

1st. Oil in crystalline gneiss:—In Placerita Canyon, five miles east of Newhall, Los Angeles county, California, a very light oil, almost naphtha, of a gravity between 50° and 60° B., is produced from crystalline gneisses which overlay the San Gabriel granite (9). It was discovered in shafting for gold. There are seven wells there, producing from depths of between 400 and 1,100 feet, one of them yielding between five and six barrels per day of oil with 30 or 40 barrels of salt water, and another spouted high when the oil was first struck. The crystalline schist or gneiss in which the oil occurs is micaceous and granitic, conspicuously banded and greatly contorted.

2nd. Oil and bitumen in the quicksilver deposits of California:—The occurrence of petroleums in the Redington quicksilver mine, New Idria, Cal., and in the other quicksilver mines of that State, has been reported by Luther Wagoner (10), Prof. Egleston (11), Becker (12), Prof. Christy (13), and many others. It occurs abundantly as liquid oil, viscous tar, solid asphalt, and also in the gaseous state of natural gas intimately associated in the veins with the cinnabar and with metallic native mercury. Many other

9. Bull. U.S. Geol. Surv. No. 309, pp. 100–101.
10. Eng. and Min. Journ., Vol. XXXIV, p. 334.
11. Trans. Am. Inst. Min. Eng. III, p. 273.
12. U.S. Geol. Surv. Monograph, XIII, pp. 371–373.
13. Trans. Am. Inst. Min. Eng., XIII, pp. 547–548.

instances of petroleums found in quicksilver veins in Europe and in other metallic veins could be cited, in which the solfataric volcanic origin of not only the mercury or other metals, but also of the petroleum, is very apparent. The petroleum in such deposits cannot possibly have an origin different from that of the metals themselves.

3rd. Graphite and natural gas in the metalliferous vein of Silver Islet, and graphite in the veins at Cobalt and Ducktown, Tenn.:—The natural gas and graphite found in abundance at the Silver Islet mine has often been cited ([14]). Graphite was found there not only in the metalliferous vein intimately associated with rich native silver ores, but also in the norite or gabbro dyke accompanying the vein. At Cobalt graphite is also found in many of the complex cobalt-nickel arsenides and silver veins ([15]). Prof. J. F. Kemp in his paper on ([16]) "The Deposits of Copper Ores of Ducktown, Tenn.," says "graphite or some closely related carbon-mineral is met in occasional specimens of the ores of the Mary mine. It appears to specially favor the crushed masses and was probably of late introduction. It not only forms fine leaf-like aggregates but in thin section may be detected by the microscope as minute spheroids in the midst of other minerals, such as calcite and chalcopyrite. It must have been introduced as some gaseous or very mobile liquid hydrocarbon which has penetrated into minute cavities and filled larger cracks and has been subsequently changed to graphite."

4th. Solid petroleums in pegmatite dykes, and other veins, associated with uranium, radium and vanadium:—J. Obalski, in a very interesting paper ([17]) read before the Annual Meeting of this Institute, 1904, mentioned the fact that he found in a pegmatite dyke worked for mica a radio-active carbonaceous material burning quite easily and leaving ashes containing oxide of uranium, and also that he found in the same dyke some "eleveite," an ore of uranium strongly radio active and containing one tenth of a milligram of radium. Similar so-called "coals," which are, how-

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14. Eng. and Min. Journ., Vol. XXXIV, pp. 320, 323, 453. See also—Ore Deposits of the U.S. and Canada by J. F. Kemp, p. 283, and Eng. and Min. Journ., Vol. XXIII, pp. 54–55 and 70–71.
15. Prof. W. G. Miller, Bureau of Mines Report, Ontario, 1907, Pt. II.
16. Trans. Am. Inst. Min. Eng., XXXI, 261.
17. Journ. Can. Min. Inst., Vol. VII, pp. 245, 256.

ever, solid hydrocarbons or petroleums, are found in veins in Peru [18] and are mined for the vanadium they contain; these veins form lenses of "asphaltite" or solid petroleum from 0.5 inches to 22 feet wide and as much as 500 feet long, in a well-defined belt 15 miles long in the Yauli district, Peru; they are parallel and in close proximity to an obsidian intrusive dyke. In the Quespi district, Peru, there is another deposit of solid petroleum forming also a lens-shaped mass with a maximum width of 28 feet and length of 350 feet occupying one of the faults of a quartz-porphiry dyke. Similar occurrences of hydrocarbons containing vanadium and uranium have been cited by other writers [19].

5th. Graphite, diamond and hydrocarbons in meteorites:—It is well known that pure carbon in the form of graphite and diamond has often been found in meteorites [20], but it is not so well known that hydrocarbons have also been found in them as cited by N. V. Sokoloff [20]. G. Tschermak also reports 0.85% of hydrocarbon in the meteorite which fell at Goalpara, India [20].

6th. Oil and natural gas in volcanic rocks in Europe, Africa and Mexico:—O. Silvestry [21] has found both liquid oil and a solid paraffin in basaltic lavas near the volcano Etna. Similar occurrences have often been cited from other parts of Europe, as for instance in Hungary [22], where liquid petroleum, asphalt and bitumen are found in rhyolite tuffs, in a rhyolitic quartz-trachyte and in andesite. On the Elansdraai farm [23], Hopetown district, Cape Colony, South Africa, two dolerite intrusive sheets were traversed in a well between the depths of 121 and 137 feet and of 364 and 401 feet and both were found to be rich in oil in their cracks and crevices. Many other dykes and sheets of intrusive rocks in Central British South Africa are also found richly impregnated with oil.

I have myself examined similar occurrences in dolerite dykes and in calcite veins running across Upper Cretaceous strata in the State of Chihuahua, Mexico.

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18. Bull. Am. Inst. Min. Eng., No. 27, March, 1909, pp. 291–316.
19. See Bull. U.S. Geol. Surv., No. 330, pp. 611–616.
20. See Bull. U.S. Geol. Surv., No. 330, p. 632.
21. Gazz. Chim. ital. Vol. 7, p. 1, 1877; Vol. 12, p. 9, 1882.
22. Trans. of the Inst. of Min. Eng., Vol. XXXV, pt. 6, p. 721.
23. Trans. of the Inst. of Min. Eng., Vol. XXXV, pt. 4, pp. 545–558.

7th. Natural gas in serpentine ([24]), Asiatic Turkey:—"On the southwestern coast of Asia Minor, north of Cape Chelidonia is the famous Chimaera or 'stone that burns,' of the ancient Greeks. Here gases are continually disengaged from fissures, and are known to have been burning for at least 2,800 years, as the phenomenon was described by Hesiod before the time of Homer. According to the Russian geologist, Tchiatcheff, the gas is emitted from fissures in an altered igneous rock (serpentine) which is intrusive in limestone."

8th. The occurrence of oil around volcanic necks, Mexico:— As described by Ezequiel Ordonez ([25]), in the State of Tamaulipas, Mexico, in the Gulf-Coast lands, the oil deposits are found around vertical borings, chimneys or pipes drilled upward through undisturbed and almost horizontal shales by volcanic action during the Pliocene and perhaps Post-Pliocene times and forming small isolated cones ranging from a few feet to four or five hundred feet in height. These cones of volcanic origin spread over the coastal peneplain and consist either of solid basaltic lava or of basaltic tufa. At the base of these cones, or in their neighborhood, are to be found the greater number and more important seepages of oil. The Mexican Petroleum Company, at Ebano, near Tampico, have obtained their more productive wells at the base of the tufacious cones, such as the Cerro de la Pez, where from but very few wells around this hill they have secured a daily output of 6,000 barrels. In the more highly productive wells of this company the heavy oil, abundantly charged with gas, carries a sandy material consisting of small sharp pieces of shale, fine lapilli, and volcanic sand. The conditions above described as to the occurrence of oil prevail in an extensive zone of the Gulf-Coast lands and extend further south in Mexico to the northern half of the State of Vera-Cruz. Any number of cones, peaks and pyramids of volcanic origin are here also distributed over the coastal plain piercing through very slightly folded or undulated strata of shales, interbedded with limestones and sandstones in thin layers, the whole probably of Upper-Cretaceous age. The oil seepages are always found here also around the volcanic hills but more frequently near the isolated volcanic peaks than in

24. "Mineral Industry," New York, 1903, Vol. XI, p. 514, 515.
25. Mining and Scientific Press., Aug. 24, 1907, pp. 247–248.

places where such peaks are closely grouped and surmounted on large bases which are composed of lava streams preventing the oil from seeping out to the surface. Mr. Ezequiel Ordonez further says ([26]), "In the coastal plain lying between Tampico, Tuxpan and Papantla will be found the greater number of volcanic hills and the more important and densely distributed oil-seepages of Mexico. I shall name a few of them: near the Laguna de Tamiahua there exists a large pool of asphaltic oil, close to the twin volcanic hills known as Los Hermanos; not far from the Sierra de Tantima is another big, dry asphaltic lagoon; on the hacienda de Tiacohila we found two oil seepages, one on either side of the basaltic hill called Temaxcales. The large volcanic mountain near the hacienda de Tamatoco gives birth to several exudations of oil; on the eastern side and not very far from its base is found one of the larger seepages named La Chapopotera de Juan Felipe, having an extent of one-half mile. The Chapopotera de Cerro Viejo, those of the hacienda del Chapopote and others nearer Tuxpan are also extensive and important." It is along the Laguna de Tamiahua mentioned by Mr. Ordonez as affording a large seepage of asphaltum oil close to the twin volcanic hills known as Los Hermanos, that S. Pearson & Son's wonderful and uncontrollable oil gusher ([27]) has since been drilled in a property known as the San Diego de la Mar, at a point on the lagoon known as Dos Bocas. The first well drilled on this property by the firm of Pearson & Son came in at 2,005 feet with an estimated production of 5,000 barrels of oil daily. The second well came in on July 4th, 1908, at a depth of 1,824 feet and the oil flow was so enormous that it lifted the 1,283 feet of 8 inch casing in the hole and also the 43 feet of 11⅝ casing, and broke out in every direction on the outside of the casings catching fire from the boiler and burning, it is said, for a time at the rate of 100,000 barrels of oil daily, and for 57 days before it could be put out by pumping sand and gravel into the crater formed around the well. Three weeks after the fire was put out the diameter of the crater was 400 feet and soundings taken 30 feet from the sides showed a depth in places of 200 feet. Approximately two acres of earth dropped into the crater at one time from the sides. This crater later on became so

The Mining and Scientific Press, Aug. 24th, 1907, p. 248.
Eng. and Min. Journ., Jan. 2nd, 1909, pp. 7, 8 and 9.

big that the well was finally abandoned and it is now a veritable geyser of oil, mud and water, throwing out, it was estimated on November 1st last, 14,000,000 barrels of an emulsion of oil, mud and water.

Other instances could be given here of petroleum deposits directly connected with vulcanism, but the one just cited is enough to prove that oil fields are not "commonly remote from great indications of volcanic activity" as it has been contended ([28]), and that on the contrary enormous quantities of oil are obtained in the porous sediments or tufacious sands around volcanic necks. When the petroleums are found, however, in the igneous, volcanic or crystalline rocks themselves it is impossible to find more than small quantities, as the necessary porosity to store these products in large enough amounts to be economically valuable is, of course, wanting on account of the imperviousness of the crystalline texture of these rocks. These small quantities of hydrocarbons are nevertheless found in many regions all over the earth in whatever small cavities, cracks and seams is co-existent with the crystalline texture of the igneous, volcanic and crystalline rocks and even in microscopic inclusions inside of their crystals.

On the contrary, in the sedimentary strata of all ages some of the sediments, principally sandstones, conglomerates, limestones and sandy shales are occasionally quite porous rocks, and therefore may and do form catch basins, tanks or reservoirs for gaseous or liquid petroleums forcing their way under strong pressure through the fractures, fissures, seams and joints of the strata. These reservoirs when thus filled constitute the important petroleum deposits, the commercial oil—and natural gas-fields. They are found indiscriminately in hundreds and hundreds of horizons in the strata of all ages, from the oldest paleozoic to the alluvial gravels and sands of the Quaternary. The natural gas or gaseous petroleum in these reservoirs is always found to have a heavy pressure, sometimes as high as 1,500 pounds to the square inch and in this connection the most important fact to be noted is that this pressure increases in each particular field with the depth of the porous reservoir or "sand" containing the petroleums, indicating that its source is from below. It has been proven ([29]) be-

28. The Data of Geochemistry, U.S. Geol. Surv. Bulletin, No. 330, p. 633.
29. Journ. Can. Min. Inst., Vol. VI, pp. 96–99, and Vol. III, pp. 68–89.

yond a doubt that this pressure is not a descending artesian or hydrostatic water pressure, the main proof being the uniformly decreasing pressure of the gas as it is being taken out; nor is it a pressure exerted by the weight of the superincumbent strata since the gas is in the pores of firm coherent rocks not under crush. The origin of this pressure requires no explanation and becomes self-evident when the true volcanic origin of the petroleums is understood.

Far from forming, like the coals, uniform beds, spreading out uninterruptedly in every direction over wide regions, the petroleum reservoirs on the contrary are always found to form comparatively small, local, accidental and irregular pockets, pools or fields. In these pools or fields themselves extreme irregularity is often the characteristic of the reservoirs; patches and strips of barren and productive territory being intermixed in most intricate manners, leading often to productive wells being surrounded by dry holes, and vice versa. In many of these fields the oil and gas are obtained in a number of different sands or reservoirs, some of which are hundreds and thousands of feet lower than the upper one and again in that respect in some of the fields there is great irregularity as to what depth the producing reservoir will be found; in neighbouring wells the oil or gas may be tapped at entirely different depths. To any keen observer the above features at once demonstrate absolutely that the petroleums in all of their reservoirs are wanderers, not in their original home, and that all their deposits are deposits of secondary impregnation. This adventitious character of the petroleums in all their deposits is a self-evident proposition when the ever present strong pressure of their natural gas is remembered. Fluids so elusive, ready to gush out with such force the moment the drill pierces their reservoirs and evidently ever impelled upward through disturbed, faulted and fractured strata by the strong pressure of their gas, can never be in their original home and the evidence that they are not is most abundant. But there is another most important feature of the oil and gas fields, and that is they are generally very much elongated in one direction, and the different fields or pools of the same district are always arranged in lines along folded and fissured zones or belts parallel to the tectonic structure or to the orogenic uplifts of the region. The maps of the Appalachian oil-and gas-fields and of the Northwestern Ohio oil- and gas-fields published by the respective geological surveys of these States illustrate this last feature most eloquently and demonstrate that these fields form two parallel oil and gas belts to the Appalachian range of mountains, each belt being several hundred miles long. Many other illustrations of this may be found in the maps of the oil- and gas-districts of California, Galicia, Rumania, Russia and other regions. The oil- and gas-fields in these last mentioned countries are always found ranged in belts at the foot and on each side, respectively, of the Coast Range, of the Carpathian mountains and of the Caucasus mountains. It is most marked in Galicia and Rumania where the Carpathian mountains form, as is well known, a semi-circle and the oil- and gas-fields also form the same semi-circle on both sides of the mountains and along their foot hills or ranges. This reminds one of the metallogenetic provinces referred to and indicated by some geologists in regard to the incoming of particular metals into the strata at various periods of the earth's history in connection with certain volcanic manifestations and intrusions of that particular period, and along the great orogenic uplifts of that period. De Launay, Lindgren, Spurr and others have, in several of their writings, pointed out clearly some of these metallogenetic provinces. The alignment of the petroleum-fields in every region in parallel belts to the orogenic uplifts or to the tectonic fissuring of that region shows conclusively that there are also in nature "petroliferous provinces" or petroleum-bearing belts, no doubt due to causes similar to those which have given us the metallogenetic provinces, namely:—tectonic disturbances accompanied by volcanic emanations. As De Launay remarks, in his "Science of Geology" (30), "the dislocations of the earth are more and more observed to have taken place, not alone in mountainous regions but even in regions of plains;" he also remarks (31) that "all the regions of the earth, probably without exception, have been subjected to dynamic movements to which are connected igneous manifestations of internal origin." These remarks will explain how petroleum-fields even at long distances from mountainous ranges and in flat plains, such as the Northwestern Ohio, Ontario, Indiana,

30. La Science Géologique, L. De Launay, Paris, 1905, p. 229.
31. La Science Géologique, L. De Launay, Paris, 1905, p. 351.

Illinois, Texas and Louisiana fields, etc., can nevertheless be connected with the tectonic structural dislocations of this continent and to the volcanic emanations which have accompanied these structural dislocations during the different geological ages. For further proofs of the connection of oil- and gas-fields with the disturbances of their region, even in the States which I mentioned last where it is not at all apparent on the surface, I refer you to the following papers:—one by G. D. Harris [32] on the "Geological Occurrence of Rock Salt (associated with petroleum) in Louisiana and Eastern-Texas,"another by H. Foster Bain [33], State Geologist of Illinois, on the "Geology of Illinois Petroleum Fields," to the records of the late Edward Orton [34] on the Northwestern-Ohio fields, and to one of my previous papers [35] before this Institute.

In the California oil-fields a most obvious connection is to be seen in most of the fields, between the occurrences of oil and the very strong and profound disturbances of the strata occasioned by the orogenic uplifts of the hills and mountains of the Coast-Range. Contrary to many other oil-fields, the oil is here often found in highly disturbed and intensely crushed strata and in many cases along well defined and prominent structural faults. I refer you to Eldridge and Arnold's most interesting bulletin [36] on the Santa Clara Valley, Puente Hills and Los Angeles districts of Southern California, for many good proofs and examples of this. Briefly the evidence in this bulletin shows conclusively that the oil-fields follow, in narrow but long belts, the much disturbed and faulted zones at the foot of the higher mountain ranges of the Coast-Range, and that the oil is found to be stored in the porous reservoir-rocks or in the seams and joints of any and all the strata affected by these disturbances in a vertical geological scale of some 25,000 feet including at the bottom crystalline schists and gneisses resting on granite, then a great thickness of Tertiary resting unconformably on these crystalline schists, then an upper unconformable series, partly Tertiary and partly Quaternary, called the Fernando, and finally, overlying all,

32. Economic Geology, Vol. IV, No. 1, Jan. and Feb., 1909, pp. 12–34.
33. Economic Geology, Vol. III, No. 6, Aug. and Sept., 1908, pp. 487.
34. Geology of Ohio, Vol. VI, p. 46, et seq.
35. Journ. Can. Min. Inst., Vol. VI, pp. 102–108.
36. U.S. Geol. Surv., Bulletin No. 309.

unconformable beds of the Quaternary. To go into more details the oil is found in the Santa Clara Valley in ascending order in the following formations:—

In the crystalline schist and gneiss penetrated by the wells to a depth of 1,100 feet; above this there is a great unconformity but the oil is still found in the following strata in ascending order:—

Lower Eocene—Topatopa quartzites, sandstones and hard shales . . . . about 5,500 ft. thick

Upper Eocene—Sespe red sandstones and conglomerates . . . . about 3,500 ft. thick

Oligocene—Vaquerous shales, limestones and sandstones . . . . about 3,000 ft. thick

Miocene, Modalo sandstones and shales (probably equivalent to the Monteray formation) . . about 3,500 ft. thick

Here there is another distinct unconformity but above it we still find oil in the—

Miocene, Pliocene and Pleistocene—Fernando conglomerates, sandstones and arenaceous clays . . . . about 9,000 ft. thick

Here again is another distinct unconformity but above it we again find the oil in the Pleistocene gravels, sandstones, clays and conglomerates, of variable thicknesses.

The total thickness of the formations more or less impregnated with the oil is . . . . about 25,600 feet.

Although we have here three geological unconformities, meaning long lapses of time and erosion between the deposition of the different formations, yet the oil is in all of them, through a thickness of over 25,000 feet of strata, from and including the crystalline rocks to the most recent gravels, but only along great fault-lines and zones of disturbances. There are three conclusions to be drawn from this which are plain:—1st, the movements of the oil were vertical, not lateral; 2nd, some of these movements were of recent date, namely Post-Quaternary; 3rd, it cannot reasonably be supposed, as some geologists have, that this oil originated in any one of these formations (such as the Monterey which is often cited by Arnold as the source of the oil) as this would entirely fail to explain the oil in the formations below the Monterey and also the oil in unconformable formations above the Monterey. Oil formed from decomposition of organic remains in the Monterey, as supposed by Arnold, would either have remained in that formation if the Monterey shales were impervious enough to prevent its escape into the atmosphere, or, if they were not, would have exhausted out into the atmosphere long before the Fernando and Quaternary strata were deposited unconformably over it. There is only one possible explanation, namely:—solfataric volcanic emanations of hydrocarbons coming up from below the crystalline gneisses along the fault-lines and in the zones of disturbances at repeated periods of dynamic movements of the Coast-Range, and some of these movements must have been very recent to explain the oil in the gravels of the Quaternary. Even in the Monterey shales, as in all the so-called bituminous shales, it is plain that the petroleum is a secondary product of impregnation subsequent to the forming of the shales, as evidenced by the fact that these shales are bituminous only along the zones of disturbances and in local and irregular pools; in these, it is not in any way spread over uniformly in one or more beds but it is distributed in the shape of branching streaks, veins, patches and in the joints and cracks; in fact the portions impregnated with bitumen often look like a regular breccia, indicating plainly the injected nature of the bitumen ([37]).

In one of my former papers ([38]) on this subject before this Institute I have emphasized by other examples this well established geological fact with regard to the occurrence of petroleums illustrated grandly by the California example just cited above, namely: —that the petroleum deposits belong to no special horizon of the geological scale, and that they are found in any and all of them, including the crystalline rocks, and as we have seen, also in volcanic emanations, in volcanic and igneous rocks, in metalliferous veins and in meteorites. When to this consideration we add the further one that these petroleum deposits are found in great abundance in certain districts in the porous reservoir-rocks of thousands of feet of the geological scale but only when these are aligned in narrow long belts along certain structural lines, while neighboring districts outside of these lines but with the same

37 Bulletin Geol. Surv., No. 317, pp. 39–41.
38. Journ. Can. Min. Inst., Vol. VI, pp. 109–113.

geological sequence of formations are absolutely barren, we see that we must necessarily consider petroleums as secondary products of impregnation and replacement coming up along these structural channels from a source below the last formation in which it is found, namely the crystalline rocks. It must also necessarily be inferred that the latest incoming or emanations of these secondary petroleum products through all these strata are younger than the youngest impregnated formation.

The solid petroleums are also found in zones of great fracturing and of profound disturbance, in parallel vertical veins following the general direction of the orogenic uplifts of their particular district and cutting all the strata and in every way similar to mineral veins. This is well proven in California, Utah, Indian Territory, Galicia and other places, instances of which will be found in one of my other papers ([39]) on this subject. Arnold ([40]) and Ells ([41]) have both sho instances from California and from the Barbadoes Islands, res ectively, in which the solid petroleum was replaced in depth in t e same vein by liquid petroleum

In some of the more recently formed oil- and gas-dep as in Texas and Louisiana, where the oil and associated salt wa rs are often hot yet, the petroleums occur in vertical chimneys of salt, gypsum, sulphur, calcite, dolomite and silica replacing and uplifting Quaternary, Tertiary and Cretaceous clays and sands, and forming peculiar qua-qua-versal domes called salines, mounds or salt islands. The local uplifts in some of the salines of Louisiana and Texas is extraordinary, as much as one to two thousand feet in an elliptical area but a mile or so across, and these salines, as Capt. Lucas pointed out long ago, are ranged along straight lines ([42]). Mr. G. D. Harris, in an article just published ([43]), gives us an interesting map of the structural lines of dislocation of this region, and shows that they belong to two systems more or less at right angle one to the other, and parallel to the great Balcones fault for the northeast system and to the Red River and Alabama Landing fault for the northwest system; he also shows that the salines are

39. Journ. Can. Min. Inst., Vol. VI, pp. 101-108.
40. Bulletin No. 309 and 317, U.S. Geol. Surv.
41. The Geology and Mineral Resources of Trinidad and Barbadoes Islands.
42. Trans. Am. Inst. Min. Eng., Vol. XXIX, p. 463.
43. Economic Geology, Vol. IV, No. 1, Jan. and Feb., 1909, p. 12.

all located along these lines of weakness and he claims at the intersection of two of these lines where a still weaker point was determined "admitting the upward passage of fluids or gas under pressure from below;"—but Mr. Harris is still under a similar impression as Mr. Robert T. Hill was ([44]), namely:—that these gaseous and liquid substances are carried to these salines by artesian waters entering the pervious layers of the Mesozoic or Paleozoic far up country and going down to greater and greater depths as the latitude of the gulf border is approached to ascend under hydrostatic pressure at the above mentioned points of weakness. As I have pointed out twice before ([45]), several years ago, the pressure to which the fluids under the salines are subjected is not hydrostatic and it is also impossible for meteoric waters to gather and carry down from sediments the diversified products of these salines especially insoluble liquid hydrocarbons and such gases as natural gas and hydrogen sulphide. Permit me to recall here the explanation of the nature of these salines which I gave before this Institute six years ago ([46]):—"But, on this continent, in the newly discovered oil-fields of Texas and Louisiana, we have many no less direct evidences of vulcanism, though they do not appear to have been understood in their true light. These are the salt islands and the mounds of the Coast-Prairie such as the famous 'Spindletop' near Beaumont, which are clearly nothing else but 'suffionis' or 'salses' hardly extinct yet, grouped along fractured lines and marking in that region the dying out of vulcanicity, that is to say the dying, distant echo of that tremendous volcanic energy which, a little further south, in Mexico, Central America and in the islands and along the south coast of the Caribbean Sea, is to this day so powerfully active." When these occurrences of petroleum in the Texas-Louisiana salines are considered in the light of what is now being found a little further south along the gulf-coast plain in the new oil-fields of Mexico, where, as noticed above, the oil is found around volcanic necks, it can be seen that the view which I took six years ago that these salines were regular solfataric volcanic vents was the right one;—in the Mexican oil-fields the volcanic action has been a little more intense and instead

44. Trans. Am. Inst. Min. Eng., XXXIII, 363.
45. Journ. Can. Min. Inst., Vol. VI, p. 93 and Trans. Am. Inst. Min. Eng., Vol. XXXV, pp. 292, 293.
46. Journ. Can. Min. Inst., Vol. VI, p. 89.

of only the hot gases, vapors and waters piercing up more or less through the horizontal strata to form the salines, as in Texas and Louisiana, we see the volcanic lava cones themselves piercing up boldly through the plains. There is no doubt that these lava cores in Mexico surrounded with petroleum and other solfataric emanations are one and the same volcanic phenomenon as the vertical chimneys of salts, hot waters and hot petroleums of the Texas-Louisiana salines.

ORIGIN.

The opposite chemical nature of the members of the two series of natural carbon-compounds, namely, oxidized complex carbon-compounds for the coals and a mixture of reducing hydrocarbons for the petroleums, gives us the first hint of the surface or external origin of the coals and of the internal origin of the petroleums. Beneath the earth's surface, as is well known, there is a deficit of oxygen, and hence we find none in the natural hydrocarbons from the interior, except in the solid varieties which are the oxygenated and sulphureted residues of the other petroleums in places where they came near enough to the surface. The coals on the contrary obtained their oxygen from the atmosphere at first in their original state of vegetation, and have retained part of it during the carbonizing process to which they have been subjected.

Coal Series.—The origin of the members of the coal series from the natural decomposition of vegetable matter, either in place or drifted, is abundantly proven, and is now generally acknowledged and admitted among geologists.

Petroleum Series.—It is, however, very different in the case of the petroleums, the origin of which is still admitted by many, as a matter of fact requiring no demonstration, to be due to some unseen and unexplained decomposition of organic matter. Other geologists have discussed the subject at length and have tried to prove the organic origin of the petroleums, but not one has ever been able to point out to a single case where a petroleum production process coeval with the kingdoms of life could be witnessed in nature to-day. Some other geologists are discouraged and proclaim the origin of petroleums as a profound mystery not yet solved by science.

As I have long contended, I, for one, cannot understand how it is that the solfataric volcanic origin of the petroleums should be considered as any more doubtful and less proven than is the organic origin of the coals. It seems to me that the geological facts proving the one are just as clearly established scientifically to-day as are the facts proving the other. They are simple facts, the A. B. C., so to say, of geology, and yet strange to say they are every day ignored and set aside.

There can be only two kinds of organic matter in nature to which the derivation of petroleums might be attributed, namely:—*First*—The soft tissues of animals. *Second*—Vegetation.

1st.—But the soft tissues of animals always decompose, decay completely and disappear entirely before their entombment in the sedimentary strata can possibly take place. It leaves us, therefore, only the vegetation to deal with in the consideration of this problem. That the soft tissues of dead animals entirely disappear before the entombment of their hard part, even in the comparatively rare cases where the entombment of the latter takes place, is one of the best known and best proven facts in geology;—water, carbon dioxide and ammoniacal salts, are the chief products of the decomposition ([47]), no petroleum is formed. If it had been otherwise we would not find, as we do, even in recent Quaternary deposits, many beds composed entirely of ostreas, corals and shells of all kinds such for instance as the "coquina" beds of Florida, absolutely devoid of some carbon-compound to represent the supposed entombed soft tissues of the animals; while, in the fossil-shells and other hard parts of the animal life which we have collected in great abundance in our paleontological museums, from strata of every geological age, we would surely often see at least a modicum of some carbon-compound; but we may examine millions of these fossils and see nothing of the kind, even when these fossils were collected in impervious shales from which the decomposed products of the soft tissues of the animals, if they had been entombed and had decomposed there, could not possibly have escaped. In very rare cases we do find portions of

47. Bulletin U. S. Geol. Surv., No. 330, p. 116.

strata with shells or other fossils filled up with liquid petroleum, but in these cases we also find the seams, joints and other open or porous parts of these strata impregnated with the same fluid, showing plainly that it is a secondary product of infiltration and replacement. Many other substances have thus filtered through the strata and petrified or mineralized the fossils, such as calcite, silica, pyrites and a great many other, including such metals as copper and mercury. In all such cases there can be no implication of a community of origin between the infiltrated products and the organisms. Yet many geologists often quote some of these rare occurrences of petroleum in hard parts of organisms and use them as evidence bearing in favor of the derivation of it from these organisms, whether fish, mollusk or other organisms. For instance, in a recent memoir on the natural hydrocarbons by Frank Wigglesworth Clarke ([48]), I find the following:—"Dieulafait observed that the copper shales of Mansfield are strongly impregnated with bitumen and also rich in fossil fish. The petroleum of Galicia is always associated with menilitic schists in which fish remains are peculiarly abundant . . . . . G. A. Bertels, on the other hand attributes the Caucasian petroleum to the decomposition of mollusks. In the Kuban district, the oil, accompanied by salt water, exudes directly from beds of molluscan remains, which occur in enormous quantities." I wish to point out in answer, that in the great majority of cases even traces of fossils of any kind are impossible to find in the prolific oil- and gas-sands of the United States and of the other parts of the world at large, and therefore that one is arguing the rule from the exception when he relies on such rare cases as cited above for his proofs of the organic origin of the petroleums; also that in the copper shales of Mansfield, there is as much reason to attribute an organic origin to the copper as to the petroleum; also that in Galicia the petroleum is found in much greater quantities, than it is in the menilitic schists, in sands without any fossil fish, and that it is found also in very large quantities, as ozokerite, in parallels and branching veins cutting lower strata than the menilitic schists; and finally, that the salt water which exudes with the oil from the mollusks in the Kuban district must also have its

48. Bulletin U.S. Geol. Surv., No. 330, pp. 635.

origin in the decomposition of the mollusks, according to th reasoning used.

There are a few instances cited in geology of partially decom posed and preserved remains of animal bodies having been found,bu these are most exceptional cases, such as a few remains preserve in the antiseptic waters of peat bogs or a few frozen remains o Elephas. These exceptions of course only confirm the rule, whicl is, namely:—when there is anything left of animal life in th strata it is the shells or bones, or their moulds or casts, but ther is no trace of the flesh or soft tissues to be found, as none of i was entombed.

All that has been written, therefore, about petroleums being derived by distillation or otherwise from the soft remains o animal organisms, whether macroscopic or microscopic, entombed in the strata cannot possibly have taken place in the natural geological processes, since no such remains were ever entombed in the strata. C. Engler, C. M. Warren, F. H. Storer, S. P. Sadtler and others ([49]) have experimented and produced hydro-carbons by destructive distillation of organic animal matter, and these syntheses are often quoted by some geologists as very strong proofs in explaining the origin of the natural hydro-carbons in a similar way, but as it has been shown above it is impossible to suppose that there could be any similar normal process in nature, since not only the soft parts of the animal organ-isms were never entombed in the strata but the sediments in the oil-fields were also never subjected to the high temperature re-quired for the destructive distillation in such experiments, namely between 300° and 400°.

2nd.—Now as to the vegetation:—~~It is~~ Is it not also absolutely and most abundantly proven that vegetation decomposes naturally into the coal series of carbon-compounds, and are not all the members of this coal series found all there in the sedimentary strata? Nothing more can be asked from vegetation. Are not all the stages, the beginning, the middle and the end of its gradual carbonizing process into peat, lignite, soft coal, semi-anthracite and anthracite right there before us even since the very beginning of vegetation in Silurian or Cambrian times? Are we to disbelieve what we see to have taken place by the billions of tons during all

49. Bulletin U.S. Geol. Surv., No. 330, pp. 629, 630.

ages since these most ancient periods, namely, that vegetation carbonized into the coals, and are we to imagine instead that some other unobserved, unseen and mysterious transformation of vegetation into something else, namely petroleums, took place? This would be to lay aside an abundance of proven facts in order to adopt a mere supposition. The normal process of decomposition of vegetation into coals in nature is in active operation in the world today as it has always been, and it is the only one that we can see. It Is also the only one of which we have any record in the long history of the geological ages.

As to the other argument that by destructive distillation the petroleums can be obtained from the coals, that would be all very well if nature had distilled the sedimentary strata and the coals or other vegetation in it, but as a matter of absolute fact it has not; therefore this line of argument also falls to the ground at once and can be dismissed. If the sedimentary strata had been distilled and petroleum thus produced there would be no coals anywhere on the globe; we would have nothing but coke beds.

The belief in the organic origin of the petroleum leads also to chaos in the understanding of other geological facts and physical laws brought out clearly in the study of many petroleum occurrences or deposits, and no wonder that some geologists who are inclined to believe in this organic origin exclaim therefore that the genesis of petroleum is a profound mystery not yet solved by science. For instance:—

1st.—It cannot possibly explain the large petroleum fields below the Carboniferous.

2nd.—Neither can it explain the petroleums in the volcanic emanations of today.

3rd.—Nor in the volcanic or igneous rocks in all parts of the world.

4th.—Nor in crystalline rocks; in California and New Brunswick, for instance.

5th.—Nor in meteorites.

6th.—Nor in metalliferous veins.

7th.—It is also at a loss to explain why the petroleum fields in every district are found grouped along certain lines and why the petroleums are found there in many horizons, while outside of the lines in just the same strata and over much larger areas all the horizons are barren.

8th.—It cannot explain either how the petroleums can possibly travel out of their supposed organic-remain source in some impervious clay or shale to accumulate in a few porous receptacles far distant laterally and some times hundred and thousands of feet above, or even below as some assert, and this all through most impervious rocks and without any impelling force behind, or any cracks, joints or fissures to follow since the decomposed products of the organisms must naturally be supposed to come from the whole mass of the strata through which the organisms were and there could not be fissures, cracks and joints to all parts of the strata.

9th.—It cannot possibly explain why the petroleums, although found today in their reservoir-rocks under strong pressures, cannot by means of that pressure, return and disperse back to their original sources; they should be able to return the way they came, nothing is to prevent them and there is plenty of pressure for the return voyage if one admits the first voyage from the organic source.

10th.—It cannot possibly explain either how the petroleums from the organic remains in the Monterey formation for instance, in California, got out into the unconformable series above, such as the Fernando formation and the Quaternary, and why these petroleums did not all get out into the air during the long lapses of time marked by the unconformities, and how they were able to get into the lower Eocene and the still lower crystalline rocks, thus working their way against the pressure of their own natural gas which always increases with the depth.

11th.—It cannot possibly explain again, if the petroleums can travel so freely through the strata as to be able to accumulate under an anticline from organic remains deposited far and wide laterally (at least a mile or two or much more in order to allow for the quantities obtained in many fields), why they did not escape out into the free air only a few hundred or a few thousand feet away at most; the shales above the sands are not any more impervious than the shales below the sands, which on that theory are supposed to be the source of the petroleums, and if they can travel freely through the shales which are the most impervious rocks of the sedimentary series, I repeat, what is to prevent them from getting out into the atmosphere?

12th.—It cannot account for the continual absence of petroleums in the hard parts of organisms preserved in the sedimentary strata.

13th.—It cannot explain the evident non-connection of petroleum deposits with coal-beds.

14th.—It cannot account for the continual association of petroleums with strong salt and sulphur waters.

The origin of the petroleums, therefore, is not organic; that it is volcanic is absolutely proven by:—

1st.—The fact that volcanic emanations of hydrocarbons are the only natural geological process of petroleum production of today, abundantly verified and witnessed in actual operation in volcanic eruptions and phenomena all over the world.

2nd.—By the presence of petroleums in volcanic rocks, igneous rocks, metalliferous veins and meteorites.

3rd.—By the rock pressure of the natural gas in the petroleum deposits. This pressure always increases with depth in each field; it has been well proven that it is not an artesian water pressure from above, and it cannot be explained in any other way than as a remnant or spark of the volcanic energy forcing the petroleums through the crystalline rocks and all the sedimentary strata from below.

4th.—By the products associated with the petroleums in their reservoirs, principally salt, sulphur, hydrogen sulphide, gypsum, calcite, dolomite and silica, which are also the products associated with hydrocarbons in the volcanic emanations of today. This association is the unmistakable solfataric volcanic seal which I pointed out before (50).

5th.—By the hot oils, gases and waters in some of the more recently formed petroleum-fields.

6th.—By the fact that the petroleum deposits are located along the faulted and fissured zones of the crust of the earth,

50. Trans. Am. Inst. Min. Eng., Vol. XXXV, pp. 290–294.

parallel to the great tectonic, orogenic and volcanic dislocations and in "petroliferous provinces" analogous to the metallogenetic provinces of DeLaunay, Lindgren, Spurr and other writers. These petroleum deposits could not be inseparably and intimately connected with the tectonic structure of each particular region unless their source was as deep seated as the forces which have caused these profound dislocations of the crust. We have gradually come to this conclusion in geology in regard to ore deposits similarly connected with tectonic disturbances; and hydrocarbon gases and vapors must be added to this class of solfataric metalliferous emanations and receive their proper place in geology as solfataric "petroliferous" emanations. These "petroliferous" emanations have played a most important part in the deposition of ore bodies ([51]).

7th.—By the fact that petroleums are never indigenous to the strata in which they are found, and are clearly secondary products impregnating porous rocks of all ages. In all fields there is always a lower horizon in which the petroleum is found, until finally the crystalline rocks are reached, and they are even found in these. This adventitious nature of the petroleum deposits is further illustrated by the deposits of solid petroleums which cut through all rocks in veins exactly similar to mineral veins.

8th.—By the fact that petroleums are found in such abundance in certain small localities, while neighboring localities are found entirely barren; this forces one to the conclusion that they must originate from the volcanic tank below which is the only one adequate to furnish these enormous quantities to narrow long belts or to small isolated spots, such for instance as the one hundred acres of the Spindletop Mound, near Beaumont, Texas, which has already produced about 38 million barrels of oil; such as the one billion of barrels produced from a small area in the famous oil-field of the volcanic peninsula of Apcheron, near Bakou, Russia; and such as the millions of barrels produced in many other fields from very narrow long belts while areas many scores of times larger next to the producing strips are barren; this cannot be held to be an accumulation in the producing fields from vast surrounding areas of sediments, as if this was supposed

51. See Walter P. Jenney, The Chemistry of Ore-Deposition, Trans. Am. Inst. Min. Eng., Vol. XXXIII, p. 487.

one could not explain why the petroleums did not escape to the surface instead of travelling so far laterally.

9th.—By the fact that the sedimentary strata of the oil-fields are so highly impervious that the volcanic fracturing and fissuring and the volcanic force of the natural gas alone can explain how so many small porous receptacles at different horizons between these impervious strata, have been filled with petroleums, salt and sulphur waters, and how these small detached petroleum-reservoirs are found to-day under a gas pressure which increases with depth in each district but is nevertheless a stored energy which will dissipate gradually in the utilization of the oil-field, the volcanic energy which brought it there at one time being now dead and inactive.

Before concluding permit me to insist on the fact that the recognition of the solfataric volcanic origin of the petroleums not only removes every difficulty in the way of a full comprehension of all the chemical and geological facts established to-day with regard to the nature and mode of occurrence of these products, but it fully harmonizes also with the physical laws governing the circulation of gases and liquids through great thicknesses of very impervious strata before being able to reach to and accumulate in a few small separated receptacles in the midst of these. The volcanic origin of the petroleums forms, therefore, a complete chain of evidence, with none of the links weak or missing. The very reverse is the case, as I have shown above, when one attempts to explain the origin of the petroleums by means of organic sources;—in doing so, well known chemical and geological facts are set aside and ignored and physical laws are distorted and abused. The geologists who still hold these views should seriously reflect on this, and I am confident that if they do they will soon abandon and relegate to the past the old unsupported notion of the derivation of petroleums from organisms and that they will come to the conclusion that this idea is now unworthy of the progress made by the geological science of today.

When one considers that there were produced in the United States alone last year 184 million barrels of oil and fifty-three million dollars worth of natural gas, he can fully appreciate the great economical importance which petroleums have attained. It is essential, therefore, even leaving aside the purely scientific aspect of the question, that the origin of these products should be understood in order to afford a basis or guide for the intelligent exploration of the many new fields yet undiscovered and which are to supply the world with even vaster quantities of petroleums in the future. The correct understanding of the volcanic origin of the petroleums furnishes us at once, as a matter of fact, with the solution of this problem of how and where to look for new fields; we must follow, as I have pointed out before ([52]), the structural or tectonic lines of disturbances and fissuring or the fractured belts along which the solfataric hydrocarbon emanations came up from the interior. The outward manifestation of these tectonic disturbances may be a fissured anticline, as it often is, but the fissuring may also have occurred at any other part of the structural folding of the strata whether in the syncline, at a monocline, along a slope or terrace or at other parts of any form of structure. The so-called anticlinal theory, as heretofore explained and understood, namely, as a favorable place of accumulation under an arch of the supposed products of decomposition or distillation of organisms, is absolutely untenable and without any meaning. Such products cannot and do not travel through impervious strata as well demonstrated by the fire damp and choke damp of the coal mines which are always found today right in the beds of coal from which they originated. If hydrocarbon gases and fluids could travel through the shales below the producing sands which in this organic theory are supposed to be their source, these hydrocarbon fluids would also travel just as freely through the shales and other strata above the sands and therefore would have escaped out into the atmosphere long ago instead of stopping under the anticlines. There is absolutely no difference between the degree of perviousness of the strata above or below the "sands," in fact very often a shale which is above a producing sand is also below another producing sand. All these strata are highly impervious, including even the "sands" which are porous only in occasional comparatively small spots. It has been impossible, therefore, for gases and fluids to travel through the strata except when they were fissured by profound dynamic disturbances which permitted the tremendous volcanic

52. Trans. Am. Inst. Min. Eng., Vol. XXXV, p. 297.

pressure from below to exert itself, and even then the enormously pent up gases and vapors from the interior reached to or near the surface with great difficulty as exemplified by the great differences in pressures of the natural gas in different sands at various levels in a given field, by the fact that although natural gas pressures of 500 to 600 lbs. to the square inch are often obtained quite near the surface, at depths of only 800 to 1,000 feet, yet the gas did not escape, and, by the further fact that oil- and gas-fields are such small detached pools never extending but short distances away from the dynamic disturbances which formed their original channels. It is only as a part of this broader conception of the occurrence of the petroleum-fields along the profound structural disturbances that the so-called anticlinal theory has any merit. This conception alone explains why some fissured anticlines are "petroliferous," or petroleum-bearing, in several of their sands, at different horizons, while the great majority of anticlines are absolutely barren of hydrocarbons at all their horizons because they are not fissured folds in "petroliferous provinces."