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X

SOURCES OF MATERIAL FROM WHICH PETROLEUM MAY HAVE BEEN DERIVED

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In discussing the testimony of a witness a New York court once said: "The testimony of this witness is important, if true. We do not deem it important." That is just the way some of us feel about the theory that "practically the entire source of petroleum has been certain disintegrated and decomposed constituents of fishes."[1]

This is not a purely academic question. It has a very practical bearing upon such questions as why, when and how far oil migrates, in what kinds of formations it is likely to be found, in what kinds of beds it originates, and many others. That the theory is bearing unfortunate fruit is evident from certain speeches recently made before commercial organizations by inexperiened geologists.

We may accept certain important facts presented by Professor Macfarlane, without accepting his sweeping conclusion. Undoubtedly some species of fishes do live in enormous schools and are very rich in oil, and it would be quite possible for such schools to be caught by showers of volcanic ash or in other unusual and catastrophic ways and buried, so that the

[1] Macfarlane, Fishes, the Source of Petroleum, 1923, pp. 5, 77, 384.

oil derived from the breaking down of the protoplasmic mass would not be dissipated. Indeed, there are indications that something of the sort has actually happened in some instances, though that is not by any means the only possible interpretation of "fish-bone beds,"[2] nor are such occurrences as numerous as one may be led to believe.

On the other hand, other organisms are and always have been much more abundant than fishes, contain the essential chemical elements for the formation of oil, and are much better adapted to rapid burial. There seems to be no *a priori* reason why they, instead of fishes, may not have furnished much or most of the material from which petroleum has been derived, especially in those highly petroliferous formations rich in lower organisms and practically free from fish remains. It is asserted in support of the fish-oil theory that fishes are the only possible adequate source for all the petroleum and that fish remains are actually abundant almost wherever petroleum is found. Neither assertion is correct.

The inorganic origin of oil does not seem to be well founded. Assuming that it is of organic origin, in order to produce petroleum in great quantity the organic material in the rocks must not only have been abundant, but it must have been incorporated in the sediments under conditions which prevented the dissipation of the oil as it formed. Also, as Goldman has said, the rate of accumulation of the organic material must bear proper relation to the rate of decomposition.

One amateur geologist, in a recent pamphlet, has explained that the great weight of salt water would hold the oil down and prevent it from rising to the surface. It is unfortunate that he did not have a brief elementary course in physics before writing his pamphlet. I have forgotten whether he is the one who, mistaking oolite and pisolite grains for fossil fish eggs, declared that the oil in the Green River shales was derived entirely from fish eggs.

Fine sediments have a marked tendency to trap and hold oil. If dead organisms of any sort accumulate in sufficient quantities, under conditions providing the proper ratio be-

[2] Compare Goldman, Bull. Amer. Assn. Petroleum Geol., VIII, pp. 195-200, 1924.

tween accumulation and decomposition and a proper ratio between organic and inorganic sediments, a petroleum-bearing formation should be the result. These complex and varying conditions are much more likely to occur frequently and for prolonged periods in case of the lower organisms than in case of fishes.

True, algæ, diatoms, bacteria and other low plants, and protozoans and other invertebrates are not usually so rich in oil as some fishes, but their composition is such as to make them a quite possible source of petroleum under favorable circumstances, their size is such that they are easily buried by ordinary processes of sedimentation, their prodigious numbers compensate for their small size, and they are actually found to enter largely into the composition of certain formations rich in petroleum, in which fish remains are uncommon. Why, then, should we call into play wholly problematical catastrophies to overwhelm repeatedly great schools of fishes, when there are processes that have been in continuous operation from the dawn of life to the present time, daily burying vast quantities of organic material in sediments suitable for the retention of the oil derived therefrom?

Adequate, accurate statistics are not at hand to prove the assertion, but it may be safely said that the total bulk of low orders of aquatic plants and aquatic invertebrates now living very greatly exceeds the aggregate bulk of fishes now living, and that this has always been true. Furthermore, the rate of increase of some low organisms under favorable circumstances is almost unbelievable. A generation of certain species may represent only a few hours, or days, or at most weeks. A generation of fishes usually represents several years. A great many generations of the lower organisms die and their remains accumulate during a single generation of fishes.

It is difficult to make an accurate estimate of the average life period of fishes. Some species are known to be very long-lived. Jordan says most of them "apparently live until they fall victims to some stronger species." On the other hand, the Pacific red salmon has a rather definite life span of about four years, limited by its peculiar spawning habit.

In order to estimate the proportionate amounts of organic matter furnished by lower organisms and by fishes during a given year, we must indulge in multiplication and division. To ascertain the amount provided by protozoans, for example, we must multiply the quantity in the water at a given time by the number of generations which live and die during the year. To ascertain the quantity of fish material we must divide the amount in the water at a given time by a number equal to the years of the average life of fishes.

Experienced biologists assure me that there is little danger of exaggerating the excess of the total bulk of lower organisms over the total bulk of fishes. One unfamiliar with microscopic life can have but little idea of the abundance and aggregate quantity of minute organisms in the water, though one may vaguely recall having read or heard of a drop of water "swarming with animalculæ." One may, however, obtain a slight conception of the quantity in the ocean where certain species are present, by watching the flashes of phosphorescent light displayed as the water is disturbed by the dip of oars or the revolution of steamship propellers on a dark night, keeping in mind the fact that the species which produce these flashes constitute but a small fraction of all the minute life present.

Some conception of the vast quantity of organic matter furnished by minute organisms in the course of geological ages may be derived from a study of certain deposits, sometimes reaching a thickness of hundreds of feet, composed almost entirely of the siliceous skeletons of diatoms or the calcareous tests of foraminifera. No deposits of fish remains have been found at all comparable to the sometimes highly petroliferous diatomaceous and foraminiferal formations. Even that evidence, however, is wholly inadequate. A very large proportion of low organisms possess no hard parts suitable for preservation in recognizable condition as fossils in the rocks, and many others can only be so preserved under very exceptionable conditions. In view of the general presence of such organisms in water, surely no biologist or geologist will assume that they were absent from the water in which a formation

was deposited, simply because their remains cannot be recognized in the rocks.

Now let us consider whether it is true that petroleum has originated only where fish remains are abundant. In the first place, it is interesting to note the artful dodging by which the leading exponent of that theory seeks to avoid the consequences of facts inconsistent with the hypothesis. Murchison's report that in the early Paleozoic rocks of Sweden "graptolites and fucoids so abound as to have given a highly bituminous character to the lower strata," is set aside as valueless because the same geologist also found bitumen disseminated through a "matted mass of bony fragments" of fishes at another horizon in England, the inference being that the presence of fish remains in the one locality proves that the bituminous material at the other locality also came from fish remains, notwithstanding their absence from the formation and the presence of the other organisms in quantity. He causes fish oil to float long distances in the sea and then to be carried down by showers of volcanic ash, in order to get it from regions in which fish remains are common to localities where none are found. He admits that petroleum occurs in formations rich in diatoms and foraminifera, but refuses to believe that the latter organisms had anything to do with the origin of oil. He explains these facts away by declaring that the geologists have overlooked or ignored the fish remains, which will ultimately be discovered. This, in face of the fact that many geologists believe fishes to have been an important source of oil in certain formations, and would have been on the lookout for such fossils. It is presumptuous to assert that numerous competent geologists and paleontologists who have examined such formations with such thoroughness as to have discovered many species of microscopic organisms and numerous small mollusks have all overlooked or ignored such an important item as fishes.

The Mowry formation is cited as a good example of the derivation of petroleum from fishes, but perhaps some writers personally unfamiliar with the formation may have obtained from the literature an exaggerated idea of the abundance of

fish remains therein. Such phrases as the "widespread and often wholesale destruction of fish life over many thousands of square miles" by "powerful volcanic activity," and the "tremendous and comparatively sudden destruction of fish life," which have been applied to this formation, are not justified by the facts. There is no evidence of such destruction. Fish scales are very abundant, as compared with most formations, but after all they are so scattered that the scales from one good-sized fish would account for all found on a slab many yards square at most localities. They are not more common than might be expected in any marine shales deposited under ideal conditions for their preservation, without assuming wholesale and repeated destruction of fishes in schools. Indeed, the wonder is not that they are so abundant in the Mowry, but that they are so few in other formations of the region. The scales are seldom or never found very close together or arranged in natural order. This is important. It shows that the fishes were not overwhelmed by volcanic ashes and quickly buried, but that they were thoroughly decomposed and their scales scattered before burial, a condition favorable for the dissipation of the hydrocarbons, rather than for their retention. However, we are told by the advocate of the fish-oil theory that the oil floated until carried down by showers of volcanic ash, for which no proof is offered.

Another very significant fact is that, though the scales are from bony fishes, their bones and teeth are exceedingly rare in this formation and apparently totally absent from many localities. No theory of Mowry sedimentation or of the origin of petroleum in this or adjacent strata can be complete and satisfactory that does not account for the scarcity of bones. The most reasonable explanation seems to be that they were dissolved by solvents in the water, probably before burial, or their casts should be common. If this be true, it indicates even more thorough decomposition of the flesh than is suggested by the scattering of the scales, which were superficial.

What were the solvents? A correct answer to that question is imperative. It does not seem likely that there could have been in the water, mineral solvents which would thoroughly

dissolve the calcium carbonates and phosphates over thousands of square miles of territory. Decomposing animal matter under certain conditions may produce solvents, but is more likely to produce an alkaline condition unfavorable to the solution of the bones. On the other hand, decomposition of plants in great quantity would have produced just the acid condition which would result in the destruction of the bones and of the shells of mollusks, which are also rare in the scale-bearing strata. The fish scales, on the other hand, would be immune to the attacks of such acids.

The most likely plants which could occur in sufficient quantity to produce enough acids to do so thorough a job for so long a period over so large an area are low forms of algæ, etc., which as a rule are not recognizable in a fossil state. Here, then, we have a suggestion of a quite possible plant source of a considerable part of the Mowry petroleum, which cannot be ignored unless some other equally satisfactory explanation of the absence of bones be forthcoming.

In the discussion of the Green River shales also there is gross exaggeration of the abundance of fish remains, perhaps due partly to misinterpretation of portions of the literature of the subject. Their abundance is confined to a limited area in western Wyoming. The great majority of the fine Green River fish skeletons exhibited in the museums of the world have been obtained in one thin stratum at one locality. Considering the formation as a whole, in both its vertical and horizontal dimensions, the fossil fishes are abundant in only a very small fraction of the formation. They are exceedingly scarce in the much richer oil shales far to the south of the fish localities, in Colorado. If fishes were the sole or even the principal source of the shale oil, the richest shale should be somewhere near the region where fish remains are abundant. A thorough search for fossils over one hundred square miles of the richest oil shales in Colorado, during which fish scales, bones and teeth were especially sought, yielded only a very few, widely scattered examples, though leaves and insects were found in abundance. Investigators in other parts of Colorado, Utah and Wyoming have reported similar results,

though some skeletons were found in the Cathedral Bluffs region, I believe, according to a personal communication from Dean E. Winchester.

On the other hand, the oil shales at the richest localities in Colorado, where fish remains are very rare, are found by microscopic examination to be filled with plant remains of various kinds, chiefly algæ and algæ-like forms, in a ground-mass of material believed by investigators to have resulted from the decomposition of vegetable material. There is no evidence that it came from fishes. This plant material certainly furnished an enormous quantity of organic compounds in the very beds which are rich in oil. Why, then, should anyone attribute the oil of these shales to fishes, rather than to the abundant plant remains? Furthermore, at the type locality of the Tipton member of this formation, referred to by Schultz as "rich in bituminous strata," myriads of fresh water mollusk shells occur, with few, if any, fish remains.

Again, Macfarlane, after quoting Schultz to the effect that oil shale in the Rock Springs district "contains an *abundance* of vegetable and animal remains and *some* well-preserved fossil leaves and small fishes," asserts that "the only group that would again explain the origin of the enormous quantities of oil sealed up in the rocks" is the fishes, thus ignoring the other abundant organisms. Such loose reasoning concerning formations with which we are familiar has made some of us fear that similar statements concerning the relation of fishes to petroleum in more remote regions are equally unreliable.

It has been strongly urged that showers of volcanic dust have been responsible for the destruction of the fishes of the Green River shales. A careful examination of many slabs from Wyoming containing fish skeletons has disclosed no evidence of such material. All samples we have tested chemically almost completely dissolved in hydrochloric acid, leaving scarcely a trace of residue.

Some writers have suggested that the hydrocarbons of the oil shales may have existed in the water in a sort of colloidal condition that prevented its dissipation until buried by sediments. During the summer of 1925 I found the water of

Hasty Lake, on Whidby Island, Puget Sound, to be just such a mass of decomposed vegetation of the consistency of thin liquid glue to a depth of from two to four feet, greatly retarding the rowing of the boat. At one end of Lake Erie, on the same island, decomposed vegetation of nearly the same consistency occurred to such a depth that an oar thrust into it failed to reach the bottom, covered by a foot or two of clear water.

Macfarlane says that the "Fort Pierre and Laramie strata were in large part laid down in fresh water" and that they "are rich in fresh water fishes and in petroleum products." Such unfounded statements do not inspire confidence in statements concerning other formations.

The arguments concerning the fish-oil origin of early Paleozoic bituminous and petroliferous formations may be left for those more experienced in dealing with formations and faunas of those ages; pausing first to say that the definitely known fish remains of the Ordovician are confined to two or three localities which have not thus far yielded oil. Macfarlane's argument for fish-origin of the Ordovician oil of the eastern United States is based upon his belief that conodonts are teeth of cyclostomous fishes, not of annelids or other invertebrates, and that they are abundant enough to account for all the oil found in rocks of that age. He also declares that the conodont beds, as well as the Devonian fish beds, are all of fresh water origin, quite distinct from and alternating with the highly fossiliferous marine beds, and that the oil has all originated in the fresh water fish beds, not in the marine beds so rich in invertebrates. Are these statements correct? One might also ask how much evidence is there of abundant fish remains in the highly petroliferous formations of Texas and Oklahoma? Here again, perhaps, the geologists have overlooked or ignored the abundant fish remains which must be there.

In conclusion: (1) The arguments for the inorganic origin of petroleum are not convincing. (2) The arguments in support of the exclusive fish-origin of petroleum are in part based upon incorrect information, in part upon misinterpretation of

facts, in part upon conclusions which may be doubted concerning early Paleozoic teeth, and in part upon illogical reasoning. (3) The supposition that petroleum has originated only in strata which contain abundant fish remains is contradicted by very definite evidence. (4) All organisms contain more or less hydrocarbons essential to the formation of petroleum. (5) The total quantity of aquatic plant and invertebrate animal matter available for this purpose vastly exceeds the total amount of fish material, and much of it is better suited for deposition under conditions favorable to the formation of oil. (6) It is quite probable that different materials in different formations have provided hydrocarbons from which petroleum has been derived, including particularly swamp plants, aquatic plants such as algæ (which include diatoms), and aquatic animals such as fishes, protozoans, mollusks, and perhaps to a less extent in some formations the bryozoans, coelenterates, echinoderms, crustaceans and so forth, microscopic forms being especially important in some formations.

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