

(petroliferous provinces) they occur in many sands throughout all the sequence of the sediments from the earliest Cambrian to the latest Quaternary, entirely irrespective of the fossiliferous beds, and mostly in sharp sands without fossils—sometimes above great thicknesses of shale strata, sometimes below all shales, as, for instance, the petroleums in the Trenton limestone of Ohio and Indiana, while in other districts the same entire series of sediments is absolutely barren of petroleums.

It is also insufficient to say that because volcanic rocks are not everywhere to be seen in the petroliferous districts a solfataric volcanic origin cannot be attributed to the petroleums. As I have already quoted several times in other papers, De Launay in his *Science of Geology* remarks:

"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."

"All the regions of the earth, probably without exceptions, have been subjected to dynamic movements to which are connected igneous manifestations of internal origin."

These disturbances furnished the necessary fissuring of certain belts of strata, whether much disturbed and uplifted, as in California, Roumania, and Galicia, or sometimes lying still comparatively flat and apparently undisturbed, as along the Appalachian belt in Pennsylvania and West Virginia. In all cases, however, the imperviousness of the bulk of the strata, especially the shales, and the fact that these readily caved in and sealed the fissures, prevented the petroleums from entirely escaping to the surface. Through this fissuring of the strata the pent-up solfataric hydrocarbon emanations came up from the interior, losing some of their pressure as they forced their way up through the fine minute fissuring and the imperfectly porous sands. Hence the differences of pressures recorded in the different sands of the same field and the higher pressures recorded in all fields as the petroleums are found in deeper and deeper sands. Hence the fact that in every field or district, not one but a number of different sands belonging to a number of different geological formations, sometimes unconformable, are impregnated with the petroleums in irregular spots, here and there, along the structural lines in the neighboring districts are absolutely barren.

The distribution of the Mexican and of the Texas and Louisiana oil fields along lines of fault has already been referred to, as well as the evident connection of the oil of these fields with vulcanism.

Similarly the oil fields of California belong to much disturbed and fractured belts bordering the Coast Range on each side for many miles. There also the migratory ascent of the hydrocarbons through faults and fissures is most plainly attested by numerous asphalt veins, and by tar and gas springs. That these faults and disturbances, constantly referred to in the reports of Arnold and Anderson, have brought up the hydrocarbon emanations from below the crystalline gneisses and granite is evidenced by the fact that in Placerita canyon, 5 miles east of Newhall, Los Angeles county, a very light oil (between 50° and 60° B.) is produced from crystalline gneisses which overlie the San Gabriel granite. Above these crystalline rocks, the oil is found in California to be stored in the porous reservoir-rocks, or in the seams and joints of any and all the strata affected by these profound disturbances in a geological column of some 26,000 ft. of Cretaceous, Tertiary, Fernando, and Quaternary sediments,

those of each period lying unconformably on the next lower, and the lowest unconformably on the crystalline rocks. It cannot be imagined that the petroleums contained in any one of these rock series can have originated from organic remains in the underlying unconformable series, since they would have been lost at the surface, if they had migrated at all, during the long intervals marked by the unconformities, unless a still more improbable process be imagined; namely, that in each case the organic remains accommodately waited until the end of the long period marked by the unconformity, before beginning to be decomposed and transformed into petroleums, and to migrate upward. There is only one possible explanation: solfataric volcanic emanations of hydrocarbons coming up from below the crystalline rocks along the fault lines and in the zones of disturbance, at repeated periods of dynamic movements of the Coast Range. Some of these movements must have been very recent to explain the oil in the gravels of the Quaternary and the large seepages often found at the surface.

If the other oil districts of America are considered broadly it will be seen that the Appalachian fields, the Northwestern Ohio and Western Ontario fields, the Illinois fields and some of the Indiana fields, and the Mid-Continent fields, all show linear distribution of their petroleum deposits more or less parallel to the Appalachian uplift, except some of the Oklahoma pools, which follow the direction of the Arbuckle or Wichita Mountain uplifts. Along these oil belts the numerous petroleum-bearing rocks do not represent fixed geological horizons—the oil and gas rising from various beds of different ages; and outside of these oil belts, structurally favorable folds are barren of petroleums in the same geological horizons.

Following the Appalachian oil belts, for instance, from Tennessee and West Virginia through Pennsylvania to New York State, the petroleums are found in lower and lower rocks in the geological scale, until they are found right on the top of the Archaean in the Potsdam sandstone. The Archaean, therefore, or the igneous magma below it, must be the final source. It would be puerile indeed to assume one hundred different sources of this belt, since it must then be assumed also that every member of the sedimentary series separating two oil-bearing sands is the impervious cover, and cannot therefore be considered as the source, of the petroleums in the sand below; and since it has to be admitted, after all, that the Archaean rocks, or the igneous magma below the Potsdam, is one at least of the sources.

This peculiar occurrence of the petroleum deposits in the sedimentary strata of all ages, yet in certain districts only, along zones of tectonic structural disturbances of these strata, where they align themselves in "petroliferous provinces," as do the metals in "metallagenetic provinces," is exemplified not only in North America but all over the earth. In Russia the petroleum deposits follow the Caucasus uplift from the Tamansk peninsula in the northwest to the Apcheron peninsula in the southeast for a distance of 750 miles. In Galicia and Roumania they follow the Carpathian range and turn with it in a grand sweep of more than 500 miles from a northwest to southeast direction in Galicia to an east-and-west one in Roumania. The same association of naphtha to a dislocated zone along the Krudestan chain in Persia, has been well described by J. de Morgan. The Tertiary tectonic and igneous "girdles" around the Pacific and the Caribbean sea are followed by an immense Tertiary "petroliferous province," of which the oil fields of California, Alaska,