DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

STUDIES IN THE APPLICATION OF THE ANTI-CLINAL THEORY OF OIL AND GAS ACCUMULATION.

DISCUSSION OF A PAPER BY M. J. MUNN IN ECONOMIC GEOLOGY,
MARCH, 1909.

Sir:—As the “Application of the Anticlinal Theory of Oil and Gas Accumulation,” by M. J. Munn, in the March number of ECONOMIC GEOLOGY, is a subject to which I have given some thought, and as I am familiar with many pools in western Pennsylvania, eastern Ohio and northern West Virginia, where the formations he describes are productive or have been penetrated by the drill, I wish to accept the author’s invitation to discuss the hypotheses in question.

The term “anticlinal theory” is an unfortunate one in some respects, as it gives a non-geologist the idea that the adherents to this theory believe the distribution of oil and gas pools to be dependent on anticlinal structure and on nothing else. Such is not true, however. Personally, I have found it necessary scores of times, when questioned by well drillers or operators as to whether I believed in the “anticlinal theory,” to qualify my affirmative replies by informing them that the theory holds as an important factor in the accumulation of oil and gas, even in pools in which no definite relation to geologic structure is apparent, and in regions where there are no definite anticlinal or

synclinal axes. I have further found it necessary to qualify my replies by explaining that the structure of the rocks, and consequently the "anticlinal theory," is only *one* of the factors in the accumulation of oil and gas pools, and that a geologist, in order to locate a pool, even approximately, has to consider every other particle of evidence found in structure of the subsurface rocks, changes in intervals, texture of the "sands," character of the overlying beds, differences in pressure, relations to water in the rocks, shape of the surrounding pools, and character of the oil in the vicinity; and every factor must be given its due weight, before a recommendation can safely be made. After all other factors have been considered, it might seem as if the "anticlinal theory" had been lost sight of as unimportant; yet the fact remains that structure is the essential condition which finally determines the distribution and size of the pools when all other conditions are favorable.

Mr. Munn's paper is an admirable one, but some statements appear with which I cannot agree. The Hundred-foot sand, described by him, in the Sewickley quadrangle, underlies "thousands of square miles in western Pennsylvania and Ohio." It also extends southward into West Virginia. In southwestern Pennsylvania and in West Virginia it is broken up into the Gantz sand and the Fifty-foot sand, separated by a bed of shale. Both these sands may be productive of oil in a single well. Everywhere throughout the area in which the Hundred-foot sand, or its constituents, produces oil, it consists of a well-defined sandy group occurring at what is supposed to be the very bottom of the Carboniferous system. Directly below the Hundred-foot, or the Fifty-foot sand, are found the Catskill red shales, which are easily recognized by the drillers.

Scores of pools have produced, and are producing, oil from the Hundred-foot sand, but many times as many are producing from other sands, lying below and above the Hundred-foot. Whatever conditions affect the accumulations of oil in one sand must be factors of greater or less importance in all of them; but the differences in character of the sand and other rocks, and the oil, gas and water existing at different places in them, fre-

quently produce structural relations which might appear, at first thought, to be entirely contrary to conditions in other pools with which the operator may be familiar. The Berea, or Thirty-foot, sand, lying at an average distance of 150 feet above the Hundred-foot, is of much wider extent as a productive sand than is the Hundred-foot.

The Hundred-foot sand is the chief productive horizon in the Sewickley quadrangle, and is also productive a few miles west, in the eastern part of the Beaver quadrangle. In the western and northern parts of the Beaver quadrangle the Berea sand is productive, and the Hundred-foot, though present, has not yet been found to contain oil, although many holes have been drilled to it.

The oil pools in the Beaver quadrangle, and in the quadrangles north and west of it, occur in thin "pay-streaks," as in the Sewickley quadrangle, and certain features, including the general character and distribution of the "pay-streaks," agree with those described by Mr. Munn. As found elsewhere, there are some dry areas several miles in extent, which lie directly down-dip from important pools of oil or of salt water or of both. For instance, near the corner of Brighton, Chippewa and South Beaver townships, in Beaver County, is a small pool in which the production of the wells is so light that they are not worth pumping, producing at best only a barrel or two a day. This pool is bordered on the northeast, southeast and south by a number of strong salt water wells. Contrary to the expectation of the operators, this pool was not found to lead to a stronger one near by, the dips of the rocks being too gentle to form any strong accumulation. The "pay" here, as in most pools of the Berea sand, is near the top of the sand. The salt water in close proximity to the pool occupies a definite structural position with reference to it, occurring on all sides of the pool except on the up-dip side. However, this water was not found to extend far southeast of the pool, several wells between there and Ohio River, four miles southeast, having been dry of water and oil. Similar occurrences are found repeatedly in the Berea sand in the Beaver and Newcastle quadrangles in Pennsylvania

and in the Steubenville and Wellsville quadrangles in West Virginia and Ohio, where dry sands occur on the down-dip sides of pools of oil and of salt water.

I can not agree with Mr. Munn that "the evidence as a whole is decidedly against the idea that the pools could have been accumulated by difference in gravity of oil and salt water." Everywhere, within a particular pool, where gas, oil and salt water are present, the gas occurs *above* the oil, and everywhere the main pool of salt water occurs *below* the oil, not directly underneath, but at right angles or at an acute angle down-dip. Although "lateral movement through difference in gravity alone," may, during historical time, have been "so limited as to be of no consequence," I have been obliged to dismiss all assumptions of the oil having been accumulated without regard to structure, and consequently gravity.

A point to be noted in pools a short distance west of those described by Mr. Munn is that the lowest oil pool in the Berea sand in a given group of pools is successively higher above sea-level going from southwest to northeast parallel with the Ohio River. Near Steubenville and Mingo, in Jefferson County, Ohio, the lowermost elevation of the oil yet discovered in this sand is 600 feet below sea-level; at Holliday's Cove, West Virginia, it is about 400 feet below sea-level; on the West Virginia-Pennsylvania line near the southwestern corner of Beaver County it is 250 feet below; at Hookstown and Smiths Ferry, Beaver County, it is at sea-level; while near the corner of Brighton, Chippewa and South Beaver townships it is 200 feet *above* sea-level. This progressive rise is not explained by Mr. Munn's theory, but it is explained in part by the greater general height of the anticlinal folds and the lesser depth of the adjacent synclinal depressions toward the northeast.

At the time the oil sands and intervening strata were deposited as sediments in the sea, the pores of all sandstones and other porous rocks must have been saturated with salt water. Through some cause, most of the water seems to have dissappeared, leaving only scattering pools of it still present. We may fairly question, however, whether the harder and closer-grained por-

tions of the Berea and Hundred-foot sands, where they are reported by drillers as dry, are in reality as dry as they appear to be, or whether they seem so owing to their lack of porosity. The fact that the still deeper oil sands, below the Hundred-foot, yield troublesome water much less frequently than do the upper ones, that they require no casing, and that the drillers seldom report water from them, indicates that most parts of these sands, whatever their texture, are really dry, and this view is in accord with the best data in deep mines, *i. e.*, that rocks below 1,000 feet or so are commonly dry of water. Whatever the cause of the real or apparent dryness of portions of the upper sands, the salt water, accompanied by whatever oil may have been present in any beds, was concentrated by rock pressure, molecular attraction, seepage, hydraulic pressure and other causes, and accumulated to a great extent in the more porous portions of the sandstones (in the "pays"). In deeply-buried sands the pressure alone would account for the segregation of the oil and salt water in the "pay-streaks."

Most of the "pays" in which the oil and salt water are found are many miles in extent, and the accumulations could not have been sufficient for economic development at any particular point in a sand or "pay," were it not that the rocks were subsequently tilted. The truth of this statement is manifested particularly by an area covering large portions of several counties fronting on Ohio River in southwestern West Virginia, in which conditions are otherwise favorable, where the dips are so slight that only shows of oil and gas have been obtained by drilling. Where the oil was concentrated into pools it was assisted by tilting of the rocks, which gave a partial or entire anticlinal structure. In each individual porous lentil, or "pay-streak," the oil, water and gas occupying it and the closer-grained rock in proximity to it, were arranged according to their specific gravities at the lowest point on the down-dip side of the "pay-streak." The deposits could not be arranged in any other way. The fact that a so-called "pay-streak" lying down-dip from a known pool may be dry of both water and oil does not disprove the anticlinal theory in its proper application; but its position is due to the

fact that whatever water and oil may once have occupied the "pay-streak" have been drained out or segregated elsewhere, naturally or artificially, or that the streak is not in reality so porous as would seem from the size of grains in the sand-pumpings. The arrangement of the grains, and the proportions of different relative sizes, are more important in determining a "pay" than is their absolute size.

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