
**PETROLEUM AND NATURAL GAS
IN IOWA**

BY •

JESSE V. HOWELL

CONTENTS

	PAGE
PART I. Geology of oil and gas.....	5
Origin of oil and gas.....	5
Accumulation of oil and gas.....	5
Character of the rocks.....	6
Age of the rock.....	7
Degree of metamorphism.....	10
Movement of oil and gas through rocks.....	12
Structure	13
Anticlines	14
Synclines	14
Domes	14
Noses	15
Faults	15
Lenticular sands on monoclines.....	16
Other structural types.....	16
Relation of ground water to accumulation.....	16
Surface indications of oil and gas.....	17
Oil seeps and springs.....	17
Bituminous rocks.....	17
Oil shales.....	17
Coal beds.....	18
Artesian wells.....	18
False indications.....	18
Geological conditions in Iowa.....	22
The geologic section.....	22
Possible petroliferous horizons.....	22
Geological Structure in Iowa.....	23
Metamorphism in Iowa rocks.....	24
Occurrences of oil and gas in Iowa.....	26
Ground water in Iowa.....	28
Stratigraphic considerations.....	28
Pre-Cambrian rocks.....	29
Cambrian system.....	29
Ordovician system.....	29
Prairie du Chien formation.....	29
St. Peter formation.....	30
Platteville formation.....	30
Decorah formation.....	30
Galena formation.....	30
Maquoketa formation.....	31
Summary of the Ordovician.....	32
Silurian system.....	33
Devonian system.....	33

	PAGE
Mississippian system.....	33
Pennsylvanian system.....	34
Des Moines formation.....	34
Missouri formation.....	35
Summary of the Pennsylvanian.....	35
Permian system.....	36
Cretaceous system.....	36
Pleistocene series.....	36
Summary—Are oil and gas present in Iowa?.....	36
Unfavorable areas in the state.....	38
Conclusion	39
PART II. Oil and gas promotion.....	40
Losses by Iowa people in fraudulent oil companies.....	40
What an oil and gas company is.....	40
The oil business.....	41
The purchase of stocks in promotion companies.....	42
What constitutes an honest geological report.....	45
Stock selling methods.....	46
How to determine the value of an oil stock.....	47
Investments and speculation.....	48

PETROLEUM AND NATURAL GAS IN IOWA

PART I.

GEOLOGY OF OIL AND GAS

The enormous increase in the use of the products of petroleum during the past few years, with its attendant rise in the price of these commodities, has stimulated a world-wide search for new oil fields. No part of the inhabited globe seems to have escaped the efforts of the prospector and Iowa, too, has had her share of them. At the present time there are being drilled within the confines of the state no less than a half dozen tests for oil and gas. In view of the very general interest in these matters, it seems advisable to sum up all available information which has a bearing on the problem of whether or not the rocks of Iowa contain workable deposits of the natural hydrocarbons.

ORIGIN OF OIL AND GAS

The theory that oil and gas are of organic origin, and have resulted from the exceedingly slow decomposition or distillation of organic matter buried in the rocks, is now almost universally accepted by geologists. Field evidence is overwhelmingly opposed to the idea that the natural hydrocarbons are of volcanic origin, or that they have been developed chemically from some inorganic materials.

Evidence now at hand indicates that petroleum has been formed in marine sediments from the remains of animals and plants, deposited in the quiet waters outside of the littoral zone, where they have been prevented from rapid decay by the presence of salt in the sea water. Anerobic bacteria probably have been effective agents in producing the decomposition of the buried organic material, and they, together with dynamic metamorphism, have produced a change into hydrocarbons.

ACCUMULATION OF OIL AND GAS

The factors which seem to have the greatest influence on the presence or absence of oil in a given region are treated briefly below.

Character of the Rocks:

1. Marine or brackish water deposits. Oil and gas are known to be indigenous only to beds which can be shown to have been laid down in the sea or in brackish water lagoons near the coast.
2. Black, blue, brown, green shales with interbedded porous beds. It is only in the darker colored shales that sufficient organic material is present to provide a source of hydrocarbons.
3. Rocks deposited roughly within 100 miles of former* land areas. It seems improbable that organic material would be likely to drift beyond this distance.
4. Presence of a suitable reservoir. Contrary to the popular conception, oil and gas do not accumulate in underground caverns, but rather in porous beds of limestone or sandstone. It is necessary, therefore, that the strata include such a porous bed to retain the oil.

In order to seal this bed against the escape of the hydrocarbons, it is necessary also that above the reservoir there be an impervious layer, of either shale or dense limestone. Or in some cases a very tightly cemented sandstone may suffice.

Finally, the porous reservoir must not outcrop at the surface within a reasonable distance. This may vary from a few hundred yards to several miles, dependent upon the nature of the reservoir rock and the attitude of the beds.

Dolomites sometimes act as reservoirs of oil and gas in localities where their porosity is sufficiently high. This is especially true in the fields of Ohio and Indiana, where it has been determined that, no matter how favorable the structure may be, oil will not accumulate in the Trenton formation unless the dolomite (MgCO_3) content reaches 25 per cent. Rocks in which the amount of MgCO_3 present is below this quantity do not have the requisite porosity which will enable them to act as reservoirs.

The thickness of either a sandstone or porous dolomite may also be a factor which must be taken into consideration. Extremely thick horizons, though having the requisite porosity,

*This statement, together with much of the accompanying discussion, has been taken from an article by Schuchert, Amer. Inst. Min. Eng. Bull. 155, pp. 3059-60, 1919.

may fail of being good reservoirs by reason of their great thickness. Thick and porous horizons afford excellent opportunity for movements of both water and hydrocarbons, and may thus prevent accumulation.

Sandstones are the most common reservoirs of oil and gas. This is true for many reasons, of which the most pertinent are (a) their high porosity, and (b) their frequent occurrence in association with the shales which presumably give rise to hydrocarbons and which also seal the sands against loss of oil and gas which find their way into them. Sandstones are the important reservoir rocks in a majority of the great oil fields of the world.

Age of the Rock.—Oil and gas have been found in rocks of all ages from the Cambrian to the Pleistocene. The oil in Europe and Asia comes almost wholly from beds of Cenozoic age, and in South America, Central America and Mexico from Mesozoic and Cenozoic beds. In North America both oil and gas occur in Paleozoic, Mesozoic and Cenozoic beds in various parts of the continent.

No important production has ever been recorded from the Cambrian, the only known occurrences in this series being a little gas in New York. The Ordovician rocks are important producers in Ohio, Kentucky, Tennessee, Illinois, Indiana, Kansas and Oklahoma. The Silurian is productive in the Appalachian field, in Ontario and in a few wells in Garvin county, Oklahoma. Oil occurs in the Devonian in the Appalachian fields, Indiana, Ohio and Ontario.

The Mississippian is productive in the Appalachian district, Kentucky, Illinois, Oklahoma and northern Texas. The Pennsylvanian series constitute the most important producing horizon in the great Mid-Continent fields of North Texas, Oklahoma and Kansas. They are productive also in Illinois, Wyoming and the Appalachian region. The Permian produces important amounts of oil and gas in Oklahoma.

The Lower Cretaceous (Comanche) is not an important producing series, but has been found to contain small amounts of oil in a few places in southern Oklahoma. The Upper Cretaceous contains large amounts of oil in east Texas, Louisiana and Wyoming.

The Tertiary beds furnish the oil in the great fields along the Gulf Coast of Texas and Louisiana, and those of California.

Small amounts of gas have been reported from Pleistocene deposits in various parts of the country, notably in Utah, Illinois and Iowa. In none of these localities does it occur in important amounts.

The accompanying table (adapted from Emmons) shows graphically the geologic distribution of oil and gas:

AGE OF PRINCIPAL PETROLEUM RESERVOIRS IN THE UNITED STATES.
(Modified after Emmons.)

[illegible]

Degree of Metamorphism.—The heat and pressure attending dynamic metamorphism cause marked alteration of the rocks on which they act. Hydrocarbon compounds are particularly sensitive to such forces. By these means organic matter may be changed into solid, liquid or gaseous hydrocarbons, and the hydrocarbons themselves be greatly modified.

Recent work by White¹ and others has shown that a close relationship exists between intensity of regional metamorphism, measured by the extent of devolatilization of organic matter, and the occurrence of oil and gas in rocks which have been so metamorphosed. White has shown that where metamorphism has so far proceeded that the coals present contain more than sixty-five per cent of fixed carbon (pure coal basis), commercial deposits of oil have not been, and probably will not be found. A majority of the oil fields of this country occur in regions where the fixed carbon percentage is between forty-five and fifty-five.

Studies of the fields of North Texas and Oklahoma by Fuller², and of West Virginia by Reger³ have substantiated White's views and have served to place the carbon ratio as a valuable indicator of petroleum possibilities in regions where the presence of coal renders it applicable.

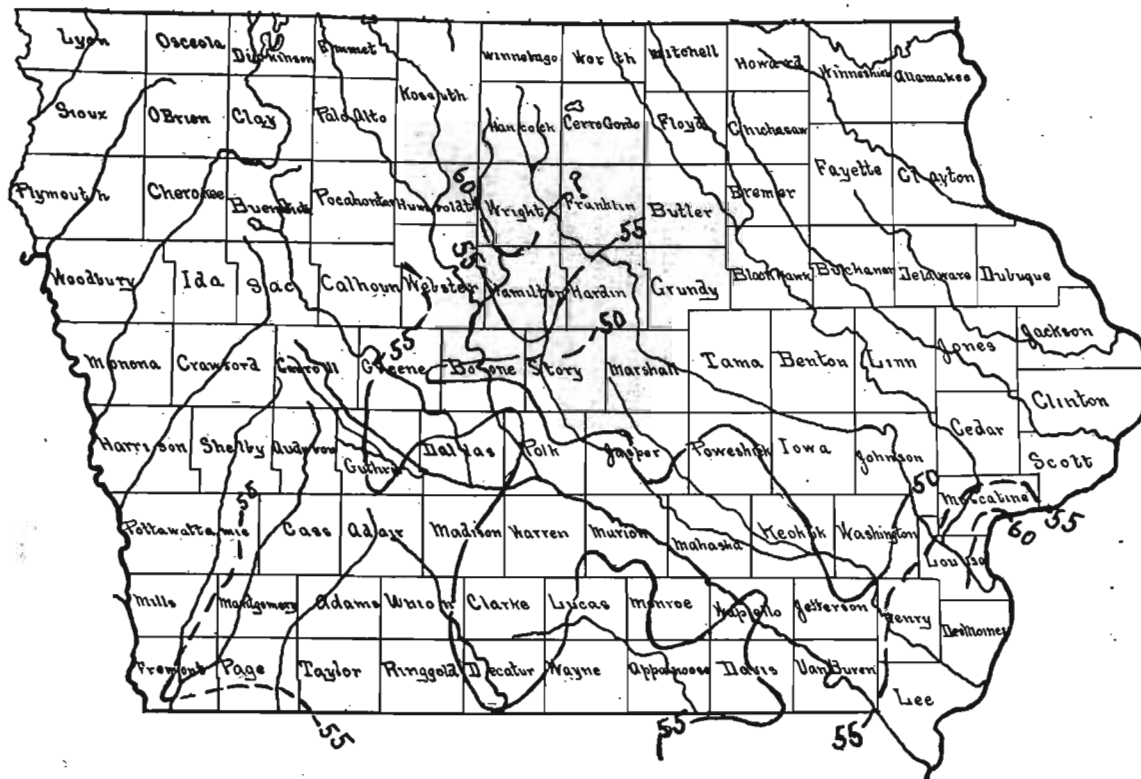
Examination of some eighteen hundred analyses of Iowa coals, from nearly every producing county in the state have resulted in the map (Plate I) on which have been drawn "isovols", or lines indicating equal percentages of fixed carbon. Inasmuch as Iowa lies well out in the great Pennsylvanian "Prairie Syncline", and is remote from any important area of crustal disturbance, the results of such a study are less satisfactory than had been hoped. This very fact may, however, be of great importance, as will be shown later. Superficially the analyses of Iowa coals show that the entire Pennsylvanian area of the state lies between the isovols of forty-five and sixty, therefore being possibly petroliferous, according to this theory.

Examination of the carbon ratio charts for Texas, Okla-

¹David White, Bull. Geol. Soc. Amer., Vol. 28, pp. 727-734, 1917. Jnl. Wash. Acad. Sci., Vol. 6, pp. 189-212, 1915.

²Myron L. Fuller, Econ. Geol., Vol. 14, pp. 536-542. 1919.

³Reger, David B., Trans. Amer. Inst. Min. Eng.



Map of Iowa showing carbon ratios of Pennsylvanian coals

homa and West Virginia (cited above) shows, however, that the productive areas in those states lie between the isovols of forty-five and sixty, but in proximity to areas whose ratios are very much higher. Such a relationship seems to have been overlooked hitherto, but it appears that it is more than mere accident. In any event, such contiguous areas of high metamorphism are lacking in Iowa.

In summary it may be said that in Iowa the evidence of the carbon ratio is rather favorable than otherwise, but owing to lack of any marked deformation which can be called on to account for the metamorphism which is indicated, it may be suspected that some important factor, operative in the Mid-Continent and Appalachian fields, may be lacking here. So far as the carbon ratio can be taken as a criterion, oil may be present in the rocks of Iowa.

MOVEMENT OF OIL AND GAS THROUGH ROCKS.

If the theory be accepted that oil and gas are of organic origin, and formed by the almost infinitely slow distillation of the animal and vegetable remains deposited in marine sedimentary rocks, the question arises as to how they become concentrated in the great pools from which they are produced. Certainly the enormous quantities of oil found in a comparatively small area in such pools as Cushing, Eldorado, Burkburnett, Salt Creek and others, are not now found in the place where they originated.

It has long been known that water moves with considerable freedom through the more porous rocks, such as sandstone and dolomite, and with greater difficulty through the more impervious ones, such as shales, quartzite, and granite. It is in this way that the water of springs and wells finds its way from the point where it falls on the surface, to that at which we utilize it. In similar manner, oil and gas have migrated through the rocks, seeking always the easiest channels through the more porous beds, where movement is freest. Three forces seem to have been effective in producing movement of the hydrocarbons; capillarity, hydrostatic pressure, and differing specific gravity of oil and water. The exact role of each

of these is yet a matter of dispute among geologists, but the fact that movement has been effected does not admit of doubt.

Inasmuch as the surface tension of oil is but one-third that of water, the latter tends to fill the smaller openings in rocks, thus forcing the oil into the larger ones, such as the pore spaces in sands and porous dolomites. It is in these coarser rocks, too, that ground water circulation is most rapid, and that the oil can move most readily. Hence the oil as it is formed, tends to move from shales and other fine-grained rocks into the easier channels, through which it may be impelled upward, downward, or laterally by the agencies mentioned above. The migration may follow a single porous bed, or by means of faults, joints or fissures may cut across from one bed to another. But when oil has once left the shale in which it was formed, it finds insurmountable difficulties in the way of a return, and the shales thereafter form barriers to its passage.

Structure.—Marine sedimentary rocks were originally deposited in layers which were nearly horizontal, or had only a slight dip seaward. Subsequent movements have modified this original simple structure to a greater or less extent, the rocks being in many places wrinkled or folded, and in others fractured and faulted. The structural relations of the beds are of great importance to the oil geologist, for it has been found that nearly all oil and gas pools have accumulated in their present places as a result of favorable structural conditions.

It has been shown that oil tends to migrate through porous beds and along larger openings, such as fissures. Due largely to the lower specific gravity of the oil, it tends to move upward rather than downward, and its migration, therefore, is up the dip. This movement continues until the outcrop has been reached, unless the movement is interrupted by some barrier. Of these barriers the most common is the anticline, a form of trap which is responsible for at least 75 per cent of the oil pools in the Mid-Continent fields.

The various types of structural conditions which may cause oil and gas to accumulate are shown in the accompanying figures (figs. 1-5).

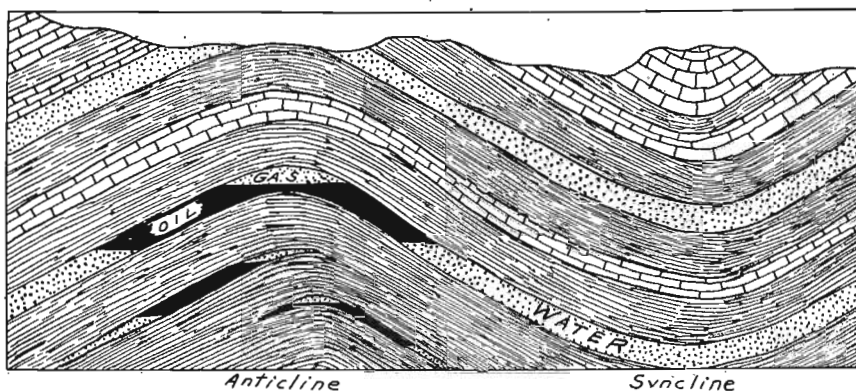


FIG. 1.—Cross section showing the occurrence of oil and gas in an anticline.

Anticlines.—An anticline is an upfold in the rocks (fig. 1) and is the commonest form of trap. On geological maps it is represented by contours, drawn on some selected bed, as in figure 2. As a rule the gas accumulates in the highest part of the fold with the oil immediately below.

Synclines.—A syncline is complementary to an anticline, and is the reverse of it. Oil accumulates in synclines only in the absence of water, or under some other special condition. Very few pools are found in synclines.

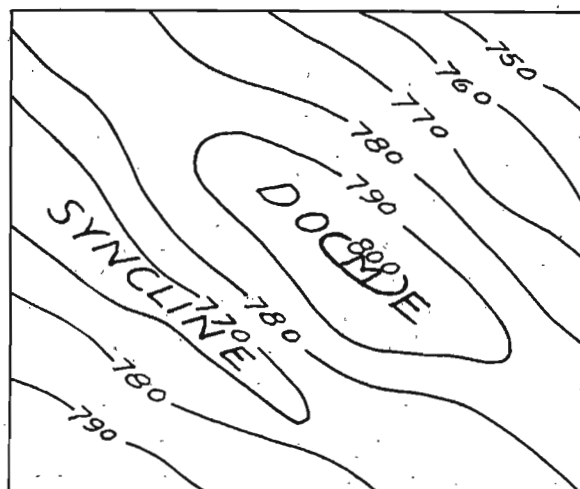


FIG. 2.—Structure contour map of a dome and a syncline.

Domes.—Anticlinal structures in which the strata dip away from the center in all directions are called domes, and con-

stitute ideal traps. Such folds are common in Wyoming and in Osage county, Oklahoma (fig. 2).

Noses.—A plunging anticline or nose is the term applied to the structure shown in figure 3.

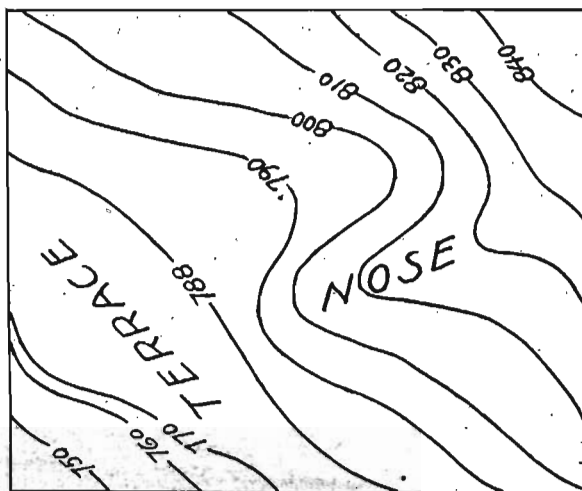


FIG. 3.—Structure contour map of a nose and a terrace.

Noses have caused accumulation in parts of Kansas and Oklahoma.

Faults.—A fault may cause accumulation when the porous bed along which the oil is moving, has been faulted against

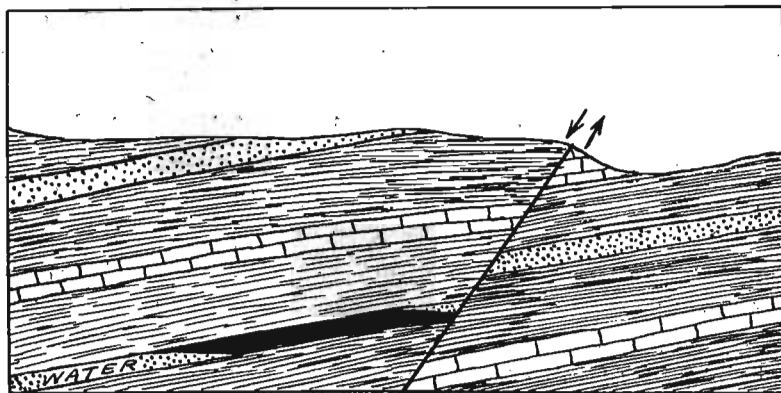


FIG. 4.—Sketch showing how faulting of the strata may cause accumulation of petroleum.

an impervious bed and sealed. Also in the case of large

faults where a thick band of gouge has been produced along the fault plane, accumulation may occur (fig. 4).

Lenticular Sands on Monoclines.—In certain formations, notably the Cherokee shale, conditions of sedimentation were very irregular and it thus happened that while sand was being deposited in one place, shale was deposited on all sides. As a result lenticular masses of sandstone, often of great extent, are completely surrounded by impervious shales. Such a lens may act as a trap (fig. 5).

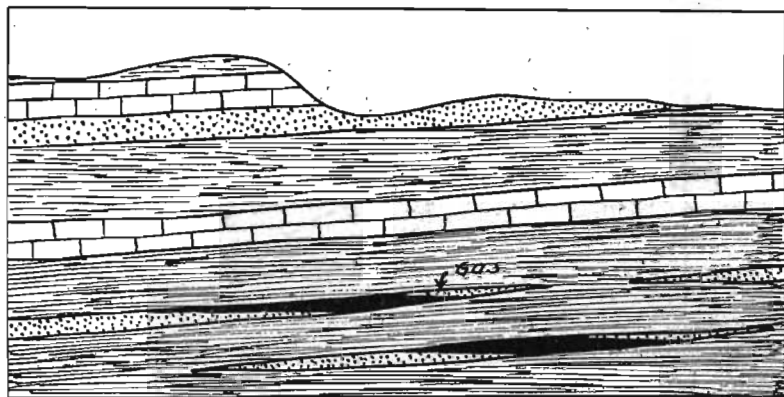


FIG. 5.—Section showing how oil and gas may accumulate in lenses on a monocline.

Other Structural Types.—Less common, and unlikely to occur in Iowa, are accumulations of hydrocarbons in salt domes, as a result of sealing by igneous dikes, in the vicinity of volcanic plugs, and along unconformities. These will not be discussed here.

Relation of Ground Water to Accumulation.—Rocks of all geologic ages contain water in greater or less amounts, and this has been termed "ground water". Its movements through the rocks and its immiscibility with oil and gas have combined to render it an important accumulative agent. If the rocks of a given region contain no water, one must search for oil in the synclines. If the rocks are saturated, the oil can be expected in structures of anticlinal type.

The direction of movement of ground water also may be a matter of great importance, for in some cases the direction

of movement of the migrating hydrocarbons has been thus governed.

The mineralization of the waters also is related to the presence or absence of oil and gas. While fresh water sands occur in all oil fields, it is not unusual to find slightly mineralized water directly associated with oil. The water which lies below and behind the accumulated oil and gas in the Mid-Continent field is almost all highly mineralized, its most prominent constituent being sodium chloride, or common salt. Whether these saline waters are "fossil sea water", enclosed since the deposition of the rocks themselves, or are the product of some reaction related to the formation of the oil, is not definitely known. The almost universal association of the two is, however, a matter of common and sad knowledge to all oil operators.

SURFACE INDICATIONS OF OIL AND GAS.

Oil Seeps and Springs.—The most common and noticeable indications of oil in many fields are the seepages and oil springs. These indications have led to the discovery of important pools in Mexico, South America, Russia and Wyoming. Such indications, however, are not prominent in the fields of North America, and in the Mid-Continent fields they are almost wholly lacking. While oil springs are in most cases favorable indications, they may be in other instances, unfavorable. Sometimes they are merely evidences that oil has been present, but has made its escape.

Bituminous Rocks.—Outcrops of rocks carrying tarry and bituminous materials are often considered favorable indications, but more often indicate that hydrocarbons have been present, and have been largely lost through evaporation, leaving only the heavy residue.

Oil Shales.—Oil shales, as the term is generally used, are a clayey material, containing a greater or less quantity of a complex substance known as Kerogen, which is not itself oily. When it is heated Kerogen is changed into a mixture of various hydrocarbons of the petroleum series. Oil shales differ from Bituminous shales in that they contain no substances which are soluble in chloroform and ether.

Oil shales are not, in themselves, indications of the presence of oil. In fact they usually indicate that the processes which produce oil from organic material have not progressed sufficiently to form petroleum.

Coal Beds.—It is commonly believed that the presence of coal indicates also the presence of oil at a greater depth. This belief, no doubt, arises from the fact that in the Appalachian fields the producing oil sands are reached by drilling through the beds which produce coal. Between the coal beds and oil beds, however, there is a great thickness of barren rock. There is no relationship in origin between oil and coal, and in fact the presence of one usually is evidence that the other is absent.

Artesian Wells.—The conditions necessary to produce artesian and flowing wells are such that oil and gas can not be expected in proximity to them. Artesian wells are located in synclines, and owe their tendency to flow to hydrostatic pressure. Hydrostatic pressure is effective only in rocks which are completely filled with water.

False Indications.—There are many phenomena which in themselves are in no way related to oil and gas, but which have been associated in the minds of many people with the presence of deposits of these substances. Among the most common of these is the escape from stagnant ponds of certain gases which may result from decomposition of materials buried there. The two commonest gases produced in this way are carbon dioxide and methane (CH_4). If one stirs with a stick the sediment on the bottom of almost any marsh, bubbles of gas will rise to the surface. This gas will be found to originate from decaying leaves on the bottom of the marsh, and has no other significance.

Another common mistake is that of assuming the iridescent scum on certain springs and pools to be oil. Such films are especially common in the vicinity of coal mines and coal outcrops. In most cases the films are composed of iron oxide and limonite, which have been formed by oxidation of iron salts contained in the water. An easy method of determining whether a scum is oil or iron oxide is to stir it gently with a stick. If the scum is oil it can not be broken up, whereas if it is iron oxide it will be broken in every direction and the

pieces will not again join when the stirring ceases. Another test is to wet the fingers with the scum, and then wash them in water. The iron oxide washes off readily, while the oil leaves the fingers greasy.

Within the past few years a number of embryo oil booms have been started in various parts of the country by the finding of oil in water wells. In nearly every case the oil is found to be a clear, almost colorless substance and is found to have the odor of gasoline or kerosene. Upon investigation such oils are always found to have leaked out from some nearby storage tank, and to have found their way into the wells through the porous surface beds. Any oil which has a marked odor of gasoline or kerosene and which is nearly colorless, should be viewed with suspicion, especially if it be found in wells near where refined oil is stored. Natural petroleum is usually dark in color, and in no way resembles refined oil.

Few wells have ever been drilled in which there were no showings of oil, if one may credit the uninformed observers who may have watched them. Many dark colored shales contain sufficient organic materials to cause a slight greasy appearing scum to form on the mud which comes out of the hole. This is so called "Farmers Oil", which never is mistaken for petroleum by any except a novice. Another source of error is the presence in mud bailed out of the test wells of a considerable amount of oil used originally to lubricate the drilling machinery and which has accidentally found its way into the well. Such oil may be dark in color and at first glance resemble true petroleum, but it can be readily distinguished by the expert. Where a well is being drilled by the rotary method, especially large quantities of lubricating oils are used on the machinery, and the mud discharged seldom is free from a little grease.

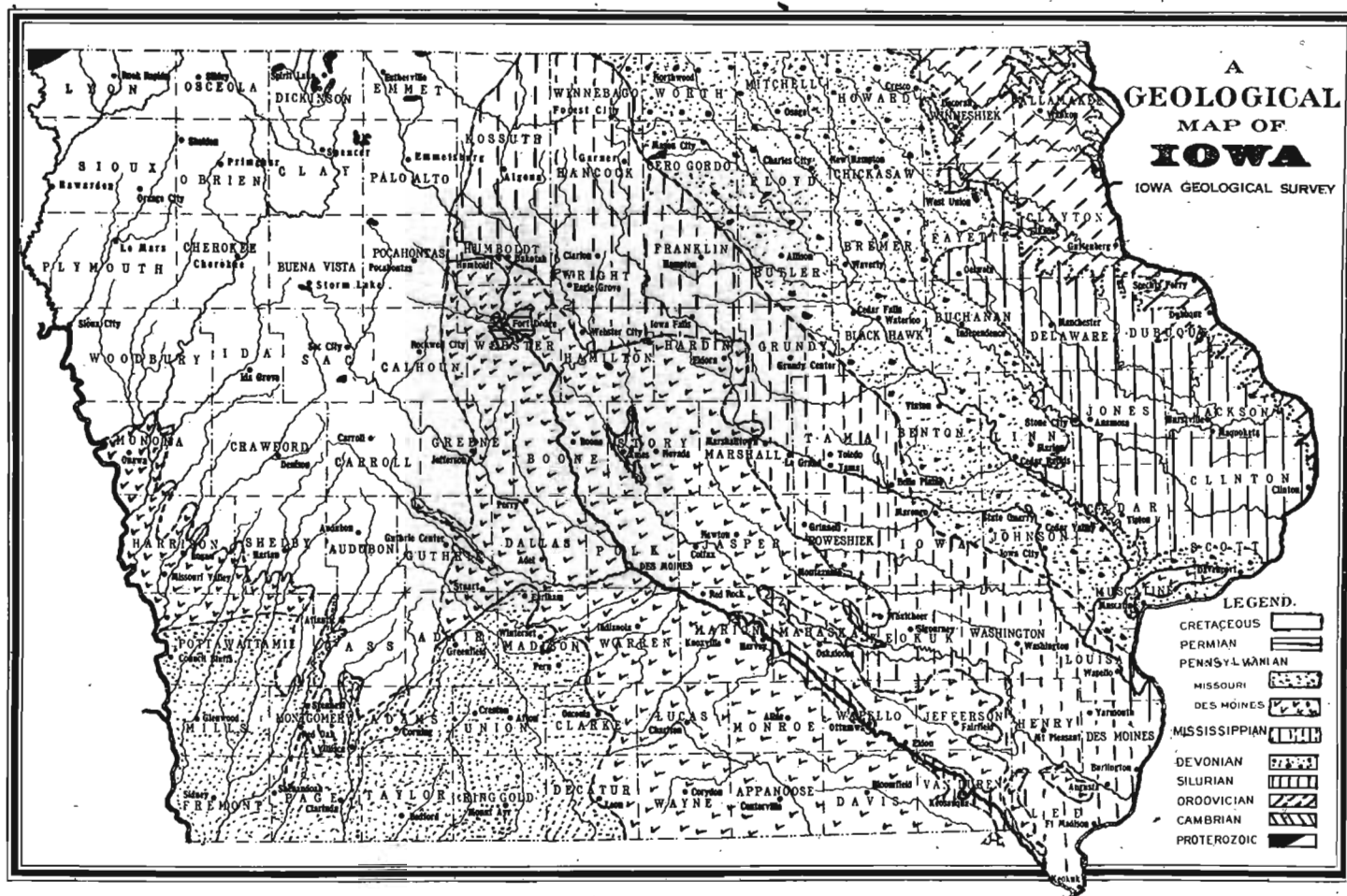
Among the minor erroneous ideas which are current are those which hold that oil occurs along creeks or rivers; that it is more apt to occur under hills, and that oil may be expected in certain regions because the topography resembles that of some producing field. The character of vegetation, the elevation above sea level, the occurrence of such features as sinkholes, have no value as indications of the presence of, or

IOWA GEOLOGICAL SURVEY

PLATE II

SYSTEM	SERIES	FORMATION	COLUMNAR SECTION	Thickness Feet	Character of Rocks
Pleistocene	Wisconsin				
	Iowan				
	Illinoian				
	Hansan				
Upper Cretaceous	Nebraskan				
		Colorado		150	Shales, with soft chalky limestones
		Dakota		100	Sandstone
		Fort Dodge		50	Sandy shale and sandstone
Pennsylvanian				30	Gypsum
		Wabansaw		108	Shale and limestone
		Shawnee		233	Limestone and shale
	Missouri	Douglas		26	Limestone and shale
		Lansing		34	Limestone and shale
		Kansas City		131	Limestone and shale
		Pleasanton			Shale and sandstone
	Des Moines	Henrietta		720	Shale and sandstone
		Cherokee			Shale, sandstone, coal.
Mississippian	St. Genevieve	Pella		0-40	Limestone
	Meramec	St. Louis		35-105	Limestone
		Spargen			
	Osage	Waraw		150-215	Limestone
Devonian		Kookuk			
		Aucilaetan		150	Shale and sandstone
		State - Lime Quarry - Creek		40-120	Limestone Shale
	Upper Devonian	Cedar Valley		100	Limestone, shaly limestone. Some dolomite in the northern counties.
Silurian	Middle Devonian	Wapsipinicon		60-75	Limestones, shales and shaly limestones.
		Gower		120	Dolomite
	Niagaran	Hopkinton		220	Dolomite Very fossiliferous in places.
	Alexandrian			0-40	Limestone and dolomite.
Ordovician	Cincinnatian	Maquoketa		200	Dark shales, shaly limestones, and locally, beds of dolomite.
		Galena		340	Dolomite chiefly, in places unaltered limestone.
	Mohawkian	Decorah		0-40	Shales with thin beds of limestone.
		Platteville		90	Marly limestones and shales.
		St. Peter		80-160	Sandstone.
		Prairie du Chien		20-80	Dolomite
		Shakopee		20	Quartzitic sandstone.
		Hewittichmens		150	Dolomite
Cambrian		Oneota			
		Jordan		100	Coarse sandstone
	Croixan	St. Lawrence		50	Dolomite, sandy
Algonkian		Dresbach			Sandstone, with bands of glauconite
	Huronian	Sioux Quartzite			Quartzite

Columnar section of Iowa rocks.



absence of oil. Neither does the occurrence on the surface of certain kinds of pebbles or gravel, or the occurrence of fossils indicate the presence of oil. The only way by which surface observations can give a clue to the conditions in depth is that which is used by the geologist and which will be described subsequently.

GEOLOGICAL CONDITIONS IN IOWA.

The Geologic Section.—The rocks exposed at the surface in Iowa include representatives of every series from the Algonkian through the Paleozoic. The Mesozoic is represented only by the Cretaceous which covers a comparatively small area in the western part of the state. All of these rocks are covered with a thick mantle of glacial drift, and hence they are to be seen only along streams where the rivers have cut through the mantling materials. The oldest rocks, representing the Algonkian, outcrop in a very small area in the extreme northwest corner of the state and the strata of the Cambrian system, the oldest of the Paleozoic rocks, outcrop in the northeast corner. The succeeding beds of the Paleozoic outcrop in nearly parallel belts successively to the southwest, their strike being generally northwest-southeast. A better idea of the conditions can be obtained by examining the Columnar Section (Plate II) and the Geological Map (Plate III).

Possible Petroliferous Horizons.—The best clue to a horizon which might be found productive in the state is found by studying conditions in nearby states which already produce oil. The lowermost horizon represented in Iowa which has ever proved productive elsewhere, is the Ordovician. In this system is found the Trenton formation from which important production is obtained in Indiana, Ohio, Kentucky and Ontario. In these fields the producing sand is porous dolomite. It corresponds stratigraphically with the Galena and Platteville of Iowa. Production is obtained only at points where the content of $MgCO_3$ is greater than 25 per cent, the reason for this being that only when the percentage rises above this amount, is the porosity of the rock great enough to permit it to act as a reservoir.

In certain parts of the Appalachian fields and in Ontario,

sandstones of Silurian age are productive of gas and oil. The Silurian is represented in Iowa by a thick series of limestone and dolomite. In the Colmar field of Illinois a small amount of oil has been obtained also from irregular sands at the contact between the Ordovician and the Silurian systems.

In the Appalachian region and as far west as Indiana, oil and gas have been produced in Devonian rocks. This system is represented in Iowa, but the character of the rocks makes it extremely unlikely that oil will be found there.

In Illinois, Oklahoma, Texas and the Appalachian district rocks of the Mississippian age have produced large quantities of oil. The Mississippian rocks of Iowa are of similar character.

The great oil producing series in the Mid-Continent fields is the Pennsylvanian, and one of its most productive horizons is the Cherokee shale. The Pennsylvanian is extremely well developed in Iowa, and the Cherokee member is present there also. The Permian and Cretaceous have produced oil in various parts of North America. Rocks of these ages are present in Iowa, but their distribution and character are such that one is not justified in expecting to find oil or gas in them here. The glacial drift of the Pleistocene period, which covers almost every part of the state, can not be looked upon as a possibility, for not only have the glacial deposits never been known to produce, but their very nature seems to preclude the probability of their doing so. It is true that small quantities of gas have been found in the drift of this and other states, but as will be shown later, these occurrences can not be expected to be of any importance.

GEOLOGICAL STRUCTURE IN IOWA.

The regional structure of Iowa is extremely simple. The rocks dip from the northeast to the southwest at a rate which varies between twenty feet per mile in the eastern part of the state and six feet per mile in the southwestern part. Iowa may be considered as lying on the north flank of the great prairie geosyncline, whose trough is in western Kansas and Nebraska. There is but one structural feature which has produced an important variation from the general monoclinial

structure. This is the Thurman-Wilson fault, a dislocation of small magnitude which extends from the southwest corner of the state northeastward into Dallas county. The effect of this fault is most noticeable when one considers the areal distribution of the Pennsylvanian rocks⁴. Modifying the general monocline are numerous minor folds, and these are of particular interest to the geologist who is in search of oil, for it is beneath such minor folds that oil accumulates if it be present in the region. Owing to the thick mantle of drift which covers the state, it is very difficult to find these subordinate folds, and undoubtedly there are many of which nothing is known. Furthermore little effort has been made in Iowa to locate such deformations. However, on the accompanying map (Plate IV) are shown the locations of all such folds as are known to the Survey. Many of these are of ample size to have caused an accumulation of oil and gas provided the other necessary conditions exist.

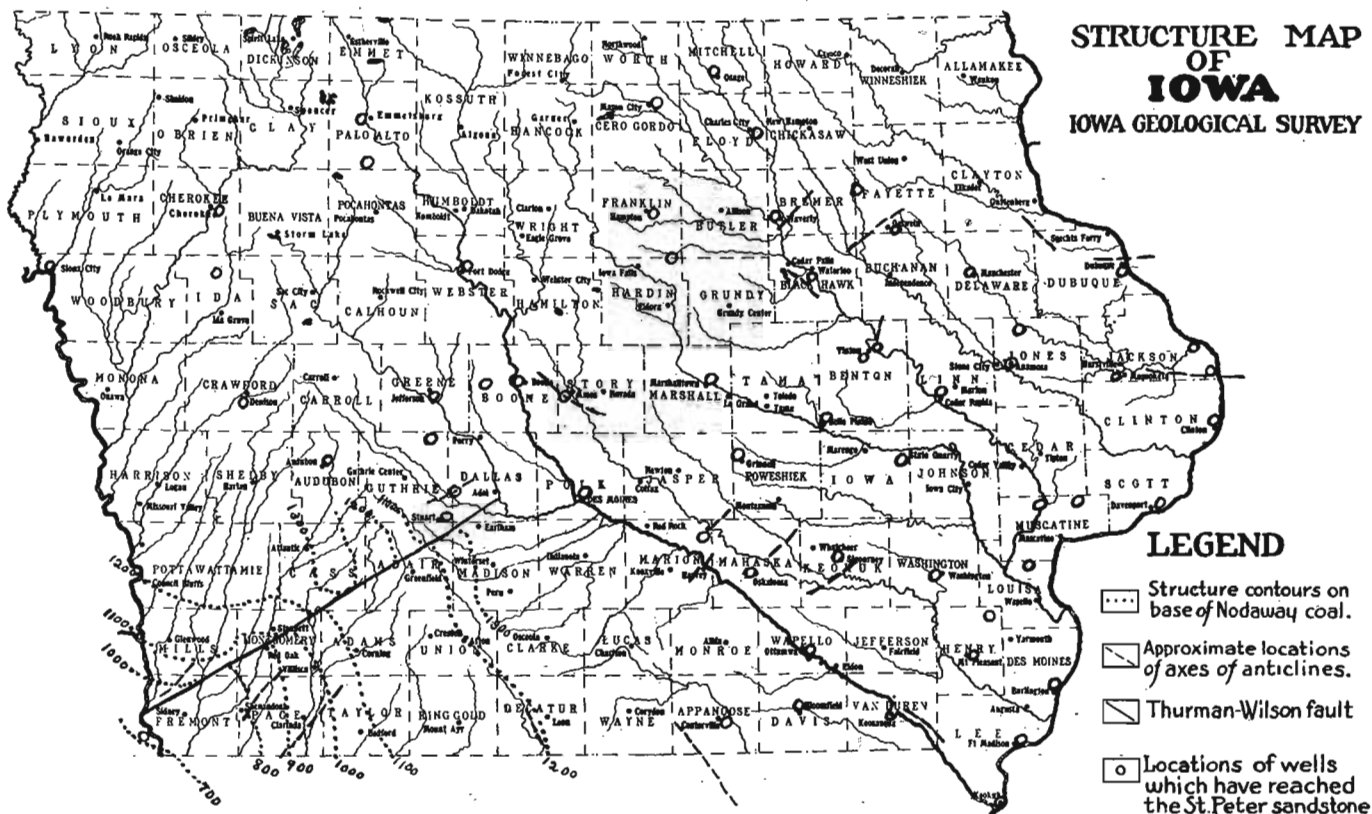
In many parts of the state, notably in Cerro Gordo, Decatur, Floyd and certain of the southwestern counties there are numerous local faults and steep dips. Many of these can be definitely shown to be due to the thickening and thinning of the strata and to inequalities of deposition, and have no significance in determining the true structure.

In a later paragraph (page 38) certain of these small folds will be discussed in greater detail, as favorable locations to be tested.

Metamorphism of Iowa Rocks.—As has been shown previously, the rocks in Iowa have not been subjected to any noteworthy folding. Little metamorphism of the extreme type has taken place, and the only changes in the rocks since their deposition have been of the nature of cementation. The rocks seem not to have been subjected to any considerable lateral pressure and certainly to no great heat. Metamorphism, therefore, which has taken place, must have resulted from the pressure of overlying rocks and the action of ground water. Yet the carbon ratios of Iowa coals cover a range between 45 and 58, which would seem to indicate that considerable de-

⁴Tilton, Jno. L., Jour. Geol., Vol. XXVII, 1919; see also paper by Tilton on the Missouri series, in this volume, also one on the Geology of Cass county in volume XXVII, Iowa Geol. Survey.

STRUCTURE MAP OF IOWA IOWA GEOLOGICAL SURVEY



volatilization has occurred. According to White⁵ a carbon ratio of 45 to 60 is necessary in order that oil and gas be present in rocks of Iowa. This condition has been fulfilled. However, as has been pointed out previously, the evidence of the carbon ratio in Iowa is not conclusive either for or against the presence of oil.

OCCURRENCES OF OIL AND GAS IN IOWA.

No authentic instance is known of the occurrence of oil in Iowa. For many years small amounts of an inflammable gas have been known to occur in glacial drift in the southeastern part of the state. In Louisa county, near Letts, a number of comparatively shallow wells, which penetrated into an old forest bed at the base of the Kansan drift, have produced enough gas to light nearby houses. This gas probably is not a true natural gas of the type which occurs associated with deposits of petroleum. No analyses are available which show the exact nature of the gas, but it is known that the inflammable component is methane. The rock pressure of the gas has been reported⁶ as about 9 pounds per square inch, and the flow is small. In Story county a small flow of gas was found ninety feet from the surface, and between two layers of hard rock. Two other tests drilled nearby obtained small amounts of gas under similar conditions. Beyer⁷ believes that the reservoir is located at the top of the Pennsylvanian but advances no evidence to disprove the possibility that it originated in the adjoining drift.

At various times oil showings have been reported in different parts of the state, but in nearly all cases investigation has shown that the occurrence can be explained on other than natural grounds. The leakage of refined oil from storage tanks has given rise to most such reports.

A few years ago a small amount of dark colored petroleum was found in a spring in a valley about two miles south of Shannon City. This was examined by Dr. James H. Lees, of the Iowa Geological Survey, but he reported that owing to the

⁵White, David, Jnl. Wash. Acad. Sci., Vol. 6, pp. 189-212. 1915; Bull. Geol. Soc. Amer., Vol. 28, pp. 727-734, 1917.

⁶Ia. Geol. Survey, Vol. XI, p. 124. Proc. Ia. Acad. Sci., Vol. I, Pt. II, pp. 68-70.

⁷Ia. Geol. Survey, Vol. IX, pp. 236-237.

absence of outcrops in the vicinity he was unable to determine the source of the oil. The drift at Shannon City is underlain by rocks of the Missouri series of the Pennsylvanian.

Oil has been reported also from a spring a few miles southeast of Decorah, in Winneshiek county, but the circumstances surrounding this occurrence have tended to cast doubt on its authenticity. A well was drilled nearby on strength of this showing, but found no traces of oil.

Small amounts of bitumen have been found in geodes which are common in the Keokuk beds of the Mississippian, but it is not believed that such occurrences are of more than scientific interest.

At the base of the Galena dolomite in northeast Iowa there is found a thin bed of bituminous shale, known locally as "oil rock". This oil rock is distributed throughout the lead and zinc districts of Illinois, Wisconsin and Iowa, and appears to have had an important influence in the formation of lead and zinc ores. When dry the shale burns rather readily, and with a smoky flame. Examination by the Bureau of Mines shows that the shale owes its inflammable nature to the presence of the remains of *Algae*. The following analyses illustrate the character of this shale. This rock has been interpreted by

ANALYSIS OF OIL ROCK (Basal Galena), PLATTEVILLE, WISCONSIN.*

	CAPTOLA MINE	BIG JACK MINE
Moisture	5.75	8.10
Volatile	22.08	18.65
Fixed Carbon	4.23	3.41
Ash	67.93	69.84

some people as an indication of the presence of oil, and at least one or two tests have been drilled in the vicinity of its outcrop, with negative results. In some other cases it has been penetrated in wells and has been reported as coal. This oil shale will be treated further under the discussion of Ordovician Rocks.

A few miles south of Centerville, and just across the state line in Missouri, some showings of oil have been obtained in rocks of Pennsylvanian age, but no commercial production has resulted.

*Illinois Geol. Survey, Bull. 21, p. 29, 1914.

GROUND WATER IN IOWA.

Ground water is found in considerable amounts in every series of the Iowa section, but the most important water horizons are the sandstones of the Cambrian and Ordovician. Owing to the very gentle southwest dip of the strata, the artesian head is generally low and it is only in the northeastern third of the state that flowing wells are obtained. An exhaustive report on the underground waters of the state will be found in Volume XXI of the Iowa Geological Survey.

In general the mineral content of the Iowa waters is low. The highest content is found in the Mississippian and Pennsylvanian beds, and the lowest in the Cambrian.

The gathering ground of all water-bearing strata is in the northeast corner of Iowa, and in states adjoining. It is therefore to be expected that the mineral content of the waters will be found to be lowest here, and to increase towards the southwest. Norton⁸ has shown this to be true.

The movement of ground water in Iowa is from northeast to southwest, or in the direction of dip. The rate probably is slow. The possible effect of this ground water movement is not entirely clear, but it seems probable it may have exercised a "flushing" action, as described by Rick⁹ and thus have removed any oil which may have formed in the Iowa rocks. Such a flushing action would depend on a number of factors, chief of which would be the rate of movement, and the continuity of the sands.

However, under nearly similar conditions in eastern Kansas and Oklahoma, flushing has been inoperative and there seems to be no reason for believing that it would be more effective in Iowa, except perhaps in the northeast part of the state, where the uniformly fresh waters of the early Paleozoic strata probably have had such an action. This view is supported by the fact of the increasing mineralization to the southwest.

STRATIGRAPHIC CONSIDERATIONS.

In the following pages each series of rocks in the Iowa section is discussed in detail, its characteristics described, and the possibilities of the occurrence of oil and gas indicated.

⁸Norton, W. H., U. S. Geol. Survey. Water Supply Paper 293.

⁹Rick, John L., Econ. Geol.

Pre-Cambrian.—The pre-Cambrian rocks of Iowa are quartzite, and intruded greenstone dikes. They offer no hope whatever, of obtaining either gas or oil.

Cambrian.—Small amounts of gas have been found in Cambrian rocks of New York, but at no place has oil been found in rocks of this age. The Iowa Cambrian includes thick sandstones, some sandy shale, and about fifty feet of sandy dolomite. It is almost wholly lacking in organic material which might serve as a source, and could not be expected to act as a reservoir unless through faulting or otherwise, it be brought into contact with younger beds. Cambrian rocks are distinctly unfavorable for prospecting.

Ordovician System.—

Ordovician	{	Maquoketa shale
		Galena { Galena dolomite
		oil rock (0 to 15 feet)
		Decorah shale
		Platteville limestone
		St. Peter sandstone
		unconformity.
	{	Prairie du Chien { Shakopee dolomite
		New Richmond sandstone.
		Oneota dolomite

The rocks of the Ordovician system in Iowa are chiefly limestones and sandstones with a thick shale member, the Maquoketa, at the top. The various formations are here discussed in order.

Prairie du Chien Formation.—Composed of three members, the Oneota dolomite below, the New Richmond sandstone, and the Shakopee dolomite above. The upper and lower members are porous buff, crystalline dolomites, which generally have a sandy appearance and commonly are reported as sandstones by drillers. The New Richmond member is composed of about twenty feet of hard, light colored quartzitic sandstone.

The Prairie du Chien is relatively unfossiliferous, and no traces of organic matter have been noted in it. The high

porosity of the dolomites makes them favorable reservoirs, provided oil be present, but they themselves can not be looked upon as sources of oil or gas. At many points in eastern Iowa the dolomites of the Prairie du Chien carry considerable amounts of artesian water.

St. Peter Formation.—The St. Peter is a massive, uniform, generally rather loosely cemented sandstone. The color is irregular, ranging from white through yellow, brown, and red, according to the amount and stage of oxidation of the iron salts present. Occasional zones are found in which the sand is very firmly cemented, and is almost quartzitic. Fossils are rare, and in Iowa no organic matter is found. Owing to its high porosity and the presence of the impervious Platteville above, the St. Peter would be an ideal reservoir, but any hydrocarbons which it might contain would have to originate elsewhere. And it has been shown that the underlying formations are equally unpromising sources. Oil and gas would therefore have to enter the St. Peter from above.

Throughout the northern and eastern parts of Iowa the St. Peter is an aquifer, and its water is notably pure and of low mineral content.

Platteville Formation.—The lower part of the formation is a calcareous shale, and the upper portion also is shaly. In the middle part is a series of bluish to brown limestone, the entire formation being highly fossiliferous. The Platteville, owing to an abundance of organic remains, might be considered as a possible source of oil and gas. It however, contains no reservoirs, and no hydrocarbons have been found in it.

Decorah Formation.—The Decorah formation is composed of highly fossiliferous soft, greenish shale, with occasional thin layers of argillaceous, nodular limestone. Its thickness in Iowa varies from one foot to thirty-five feet. The organic content is relatively high, but owing to its thinness, it can not be considered a promising source of oil.

Galena Formation.—In most places the Galena is a thick bedded, massive dolomite, buff in color and highly porous. In certain outcrops, however, the dolomitization is incomplete. Fossils occur as casts only, and at the outcrop the only organic matter present is in the "oil rock" at its base. This

oil rock is a highly bituminous shale which, on distillation has been found to give off hydrocarbons¹⁰ and which, in its dry state, burns readily. It is rather local in its occurrence, and is best developed in the lead and zinc district of Iowa, Illinois and Wisconsin, where its presence seems to be related to that of the ores. The thickness in Iowa is usually less than fifteen feet.

It seems probable that under the proper conditions the oil rock might give rise to petroleum or gas. The history of the Ordovician rocks of Iowa, however, seems not to have included such events, for wherever the horizon has been studied, either in wells or at the outcrop, the shale remains high in bituminous material. Evidently the forces necessary to effect distillation have not been active. Furthermore, the slight thickness of oil rock present makes it improbable that large amounts of petroleum would result, even were distillation complete. It will be noted that the carbon ratios of the shale are extremely low, indicating that the force lacking is that of regional metamorphism.

Maquoketa Formation.—The uppermost member of the Ordovician series is a thick bed of dark colored shale, with thin layers of shaly limestone. At many horizons the Maquoketa is highly fossiliferous and its dark brown to chocolate color seems to be due in large part to contained organic matter. Wells at Monticello, Anamosa, Grinnell and Mason City have passed through highly bituminous beds in this formation, but have found no signs of oil.

The following analyses of typical Maquoketa shale give a good idea of its character:

	A.	B.	C.	D.
Moisture	.75	1.20	.54	3.58
Volatile	14.12	8.16	8.26	17.59
Fixed Carbon	6.84	2.85	2.85	3.09
Ash	78.29	87.79	83.17	75.74

A. 1 mile east Savannah, Ill. 10 feet below surface.

B. Howleys Mill, Little Maquoketa R. near Channingsville, Ill.

C. Dubuque, Iowa. Shaft near Levine's diggings.

J. D. Whitney. Geol. of Iowa. Vol. I, pt. 1, pp. 358-360, 1858.

D. Sec. 36-24N-4E. Near Mt. Carrol, Ill.

Ill. Geol. Survey, Vol. 21, p. 83, 1914.

¹⁰Ill. Geol. Survey, Vol. 21, p. 29, 1914.

It is believed that the Maquoketa is the source of the oil in the Colmar field in Illinois. The formation in northwest Iowa is 200 feet thick, but thins to the westward, so that wells at Des Moines and Ames encounter much less than this, and at Centerville the Maquoketa is missing.

In the Colmar field of Illinois the Hoing sand, from which the small production is obtained, is a series of non-continuous sand lenses on the eroded surface of the Maquoketa shale. These lenses are irregular in distribution and of limited extent, and it is only where there is a happy combination of favorable structure, underlain by a thick sand, that accumulation has occurred. Many well defined domes in western Illinois have proven unproductive, owing to absence of the sand.

The Maquoketa shale, as shown by the foregoing analyses, affords a large amount of organic material, sufficient to produce a considerable amount of oil and gas. The highest carbon ratio shown here, however, (Sample A) is only 32, while the average of all four is 24.5. According to White's law, oil should not be expected where carbon ratio is less than 45, hence the chances of oil having been formed from the Maquoketa shale in Iowa are not good. No data are available concerning the carbon ratios of the Maquoketa in the Colmar field.

Summary of the Ordovician.—There are four possible sources of oil and gas in the Ordovician rocks—the Platteville formation, the Decorah shale, the "oil rock" of the Galena, and the Maquoketa shale. These in the aggregate, might produce a very large quantity of hydrocarbons. The only possible reservoir is the porous dolomite of the Galena, whose content of MgCO_3 seems always to be 40 to 42 per cent, well above the minimum 25 per cent which is necessary in order to provide porosity sufficient to make a reservoir of the dolomites in the eastern fields.

Analyses of the Maquoketa shale and the "oil rock" show them to be high in organic material. The carbon ratio of the Maquoketa ranges from 15 to 32 with an average of 24.5. That of the oil rock averages 15. A ratio of not less than 45 seems to be necessary, hence the rocks of Iowa seem not to have been sufficiently metamorphosed to produce oil or gas.

The Silurian System.—The Silurian system in Iowa includes three dolomite formations, all of which are fossiliferous, but none contain organic material in sufficient amount to be considered as a possible source of oil. Absence of impervious shale beds, either within the formation or above render it improbable that the porous dolomite will act as a reservoir.

The Devonian System.—Of the four recognized Devonian formations two, the Lime Creek and State Quarry beds, are discontinuous, occur only in isolated patches, and lie unconformably on the Cedar Valley formation. They are of no importance in this discussion.

The Wapsipinicon and Cedar Valley formations are prevalingly limestone with some thin beds of shale and a little dolomite.

Devonian rocks are productive of oil and gas in the Appalachian region, but no petroleum has been found in them west of Indiana. The character of the Iowa rocks makes it nearly certain none will be found in the Devonian of this state.

The Mississippian System.—This system has been divided, in Iowa, into four divisions, the Kinderhook, Osage, Meramec and Ste. Genevieve formations. Of these the first is composed of dark shale, sandstone and a subordinate amount of limestone, while the others are predominantly limestones.

The dark colored organic shales of the Kinderhook formation may be considered a possible source of hydrocarbons, and the interbedded sandstone layers offer favorable reservoirs for accumulation. Rocks of Mississippian age produce large quantities of gas and oil in Oklahoma, Northern Texas, Illinois and the Appalachian region. At no place in Iowa, however, have beds of this age been found to be notably bituminous. Some small amounts of pitch have been found in geodes which occur in large numbers in the Keokuk beds near Keokuk, but the occurrence seems to be local.

In the Lawrence field, in Illinois, oil has been found in porous zones of the upper part of the Ste. Genevieve series, but there is at least a possibility that it may have originated in the overlying Pennsylvanian beds.

The sandstone beds of the Kinderhook, where they are covered by younger marine strata, seem to offer some possi-

bilities of producing oil and gas. Some years ago a well was drilled¹¹ at Redfield in search of oil or gas, and this seems to have thoroughly tested the possibilities of the Kinderhook at that place. The test was located on an anticline, and thus was favorable structurally, but no oil or gas was found. Sands were found in the following depths.

	DEPTH	CONTENTS
Sand	253 - 293	Artesian water
Sand	388 - 398	Artesian water
Sand	438 - 450	Artesian water
Sand	488 - 498	Heavy flow of mineral water
Sand	616 - 630	Strong flow of water
Sand	823 - 850	Traces of "oil rock"
Sand	868 - 883	Tight sand, water
Sand	960 - 1008	Water sand
Sand	1082 - 1093	Pronounced asphaltum
Sand	1093 - 1100	
Sand	1277 - 1290	Water sand
Sand	1302 - 1341	

The Pennsylvanian System:

The Des Moines Formation.—The lower Pennsylvanian in Iowa has been subdivided into the Cherokee, Henrietta and Pleasanton formations, in all of which the predominant rock is shale, with a large amount of sandstone and a few beds of limestone in the Henrietta and Pleasanton. The Cherokee is the chief coal-bearing horizon of Iowa and contains many workable coal beds, which have been extensively mined in the southcentral part of the state. Like the Des Moines beds of Kansas, Oklahoma and Missouri, the Iowa representatives of the formation contain much organic material.

In the discussion of the origin of oil, it was shown that the conditions under which coal and oil were formed are wholly different. Coal results from carbonization of the plant remains which accumulate in fresh or slightly brackish lagoons adjacent to the coast during periods of critical level, when slight oscillations of the sea level were occurring. Both land and water plants, whose habitat was swamps, are included in the organic material from which coal has been made. So coal may be said to be a near shore or semi-terrestrial product. Oil on the other hand, seems to have been formed somewhat farther out on the continental shelf, from more distinctly marine

¹¹U. S. Geol. Survey Water Supply Paper, No. 293, p. 685; Iowa Geol. Survey, Vol. XXI, p. 825.

organic debris, such as would have been deposited with the finer shales.

Hence it is not surprising that formations which bear coal are not often found to contain oil also in the same locality. That is, the presence of coal in rocks of a certain formation is evidence that oil is not present also, in that region, although it may be found elsewhere in the noncoal-bearing beds of the same age.

Thus it has been found that while the Cherokee shale of Iowa, eastern Kansas, Missouri and northeastern Oklahoma, which are near shore or lagoonal deposits, contain no oil and much coal, beds of the same age, but deposited at a greater distance from the oscillating shore line, contain oil but no coal. The great Bartlesville sand of northern Oklahoma, is of Cherokee age, and corresponds stratigraphically to certain coal-bearing horizons of Iowa.

The conclusion, therefore, is that the Des Moines rocks of Iowa, at least in the area of their outcrop, hold out no hope for the prospector for petroleum. Westward from the outcrop the possibilities increase, but at no place within the state can the possibilities of Des Moines rocks be said to be attractive. The necessary condition of organic shales with interbedded sandstones is fulfilled, but the presence of coal indicates that oil should not be expected.

The Missouri Formation.—The Missouri formation in southwestern Iowa consists of about 650 feet of alternating shales and limestones, the shales being in places sandy or even grading laterally into sandstones. These beds, following the Kansas usage, have been divided into the Kansas City, Lansing, Douglas, Shawnee, and Wabaunsee stages. The Shawnee and Wabaunsee in Iowa are coal bearing, containing respectively the Nodaway and Quitman coal seams. They may, therefore, be eliminated as possible petroliferous horizons.

The Kansas City, Lansing and Douglas stages include beds which are wholly marine in origin and so far as can now be determined are possible sources of petroleum. Beds of this age are productive in Kansas and northern Oklahoma.

Summary of the Pennsylvanian.—The rocks of the Des Moines formation are regarded as impossible sources of oil

and gas, because of the unfavorable conditions under which they were formed. They contain numerous suitable reservoirs.

Beds belonging to the Shawnee and Wabaunsee stages of the Missouri formation may be eliminated for the same reason. Beds of Kansas City, Lansing and Douglas age may possibly be the source of hydrocarbons, but contain few suitable reservoirs. None of these beds, where they can be studied at their outcrops, give any evidence of being petroliferous.

Counties in which these possibly petroliferous beds may prove productive, provided suitable structural conditions exist, include Pottawattamie, Cass, Mills, Fremont, Montgomery, Page, Adams, Taylor, southern Adair, Union, Ringgold and western Decatur.

Permian System.—The Permian is represented in Iowa by about eighty feet of red shales, sandstones and gypsum. These beds appear to have been deposited under arid conditions and offer no inducement whatever to the prospector for oil.

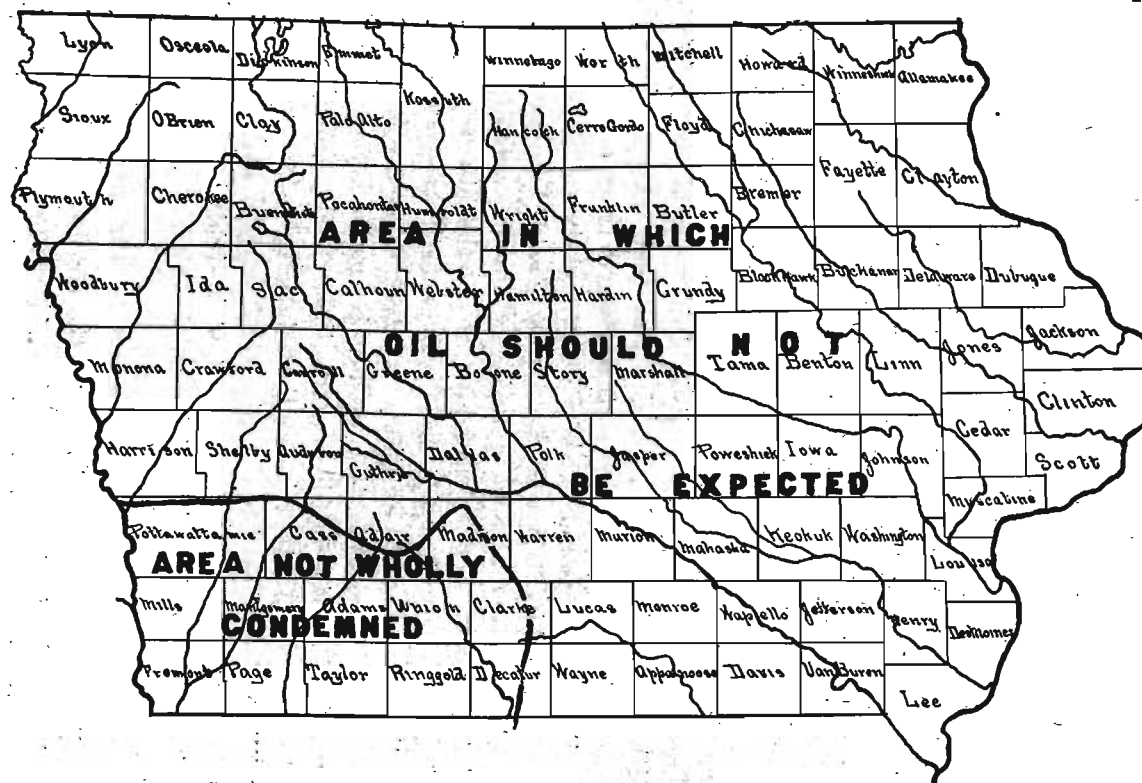
Cretaceous System.—The Cretaceous is represented by sandstones, shales and chalky limestones, which cover a rather large area in western Iowa (see map, Plate III). The series lies unconformably on the older formations below, and is mantled by drift. The Cretaceous terrain is well dissected and study of its outcrops leads to the conclusion that the rocks of this series will prove barren.

The Pleistocene Series.—The Iowa Pleistocene is composed of glacial drift, a terrestrial deposit, formed under conditions that make it certain oil will not be found therein. Small pockets of inflammable gas have been struck in the drift at various places, but these are of small consequence, are of local origin, and their occurrence should not be construed as a favorable indication of oil. These gas pockets will be discovered from time to time during the drilling of water wells, but they can not be located from the surface and are of small value when found. No prospecting should be carried on in glacial drift, for it can lead only to failure.

SUMMARY.

Are Oil and Gas Present in Iowa?

Consideration of the evidence which has been presented in the preceding pages leads to the conclusion that the possibi-



Sketch map of area of Iowa which offers some chance of success.

ties of obtaining commercial production of oil and gas in Iowa are small. In by far the greater part of the state the chances are negligible, and expenditure of money in prospecting these areas should be advised against. In one rather limited area there may be some slight chance for success and while tests in this area are not recommended, it is felt that they may be in some manner justified. These areas are indicated on the map (Plate V).

In the area indicated as being not wholly condemned, tests should reach the St. Peter sandstone, the deepest possible reservoir, at depths less than 3500 feet. Especial care should be taken in testing any sands in the lower two-thirds of the Missouri stage, those of the Kinderhook and the Maquoketa shale. No test should be drilled deeper than the upper part of the St. Peter sandstone.

There are two locations within this general area, drilling on either of which would afford a fair test. An anticline has been reported as extending northwestward from a point about one mile east of Shenandoah in Page county to the northeast part of Township 70 North, Range 38 West. Another elongate fold, which may really be a series of domes, extends from a point four miles west of Braddyville northeastward for some eighteen miles to a point five miles north of New Market. Only the approximate locations of these folds are known, and a more careful examination should be made before a test is begun. If there is no oil beneath these folds, then it is useless to prospect further in southwestern Iowa.

Drilling should be begun only after careful examination by a competent geologist. Unless a test is drilled on a favorable structure the results will not be conclusive.

THE UNFAVORABLE AREAS IN THE STATE

In all parts of Iowa, aside from the southwestern area, drilling should be discouraged for the following reasons:

1. Of the horizons which might be suspected of being productive, the Ordovician has been so well tested that it may well be eliminated from consideration. The St. Peter sandstone has been penetrated by many wells in all parts of the

state (see map, Plate IV), many of them on anticlines, and the results have been negative.

2. Areas of Silurian, Devonian and Cambrian rocks are considered practically hopeless.

3. Areas in which Mississippian and Pennsylvanian beds outcrop are not favorable, as any hydrocarbons present in these rocks can escape.

4. Areas in which the Pennsylvanian series contains coal are not worth testing, except in the deeper horizons.

CONCLUSION.

Iowa contains but one area which, in the writer's judgment, in any degree merits a test for oil. At least two anticlines are known in this area, and a properly drilled well on either of them should show conclusively whether there is oil in Iowa. No other part of the state deserves a test at this time. In the localities indicated a well should be located only after a careful survey by a competent geologist.

It should be emphasized that the chances of failure are very high. The strongest argument in favor of drilling is the fact that few deep wells have been drilled in this part of the state, and hence little is known of the older rocks. There is no direct evidence to indicate that oil will be found. But if citizens of the state insist on drilling within its confines, these seem to be the least unfavorable places in which to operate.

PART II.

OIL AND GAS STOCK PROMOTION

LOSSES BY IOWA PEOPLE IN FRAUDULENT OIL COMPANIES.

It has been estimated that in 1920 the people of Iowa lost nearly \$100,000,000 through speculation in wild cat oil stock. This means an average of over \$1,000,000 in each county. The losses in the following year probably were smaller, but their total, if it were known, undoubtedly would reach a very respectable figure.

If these losses had been merely a part of the legitimate hazards of the business, little need be said about it, but the fact is that nearly all of this money was worse than wasted, and that from the start the so-called investors had no chance whatever of even securing the return of the principal. Lured by promises of rapid and enormous returns people entrusted their funds to promoters of whom they knew little, and whose schemes they made little effort to investigate. It seems remarkable that men who have had the ability to accumulate a considerable amount of money, and who would never think of buying a farm or a store or a car load of cattle without the most careful investigation, and usually not without expert advice, could so readily be persuaded to invest large sums of money with comparative strangers, and in a business of which they knew nothing. Yet this is what has happened in every county in the state.

It is one of the purposes of this report to point out some of the pitfalls that lie in the path of an investor in oil stocks, and to suggest some means of avoiding them.

WHAT AN OIL COMPANY IS.

An oil company is an organization, usually incorporated, for the purpose of producing, transporting, refining and marketing petroleum. The smaller concerns usually confine their activities to a single one of these departments of the business. The larger companies engage in all of them. Many of the largest

companies have comparatively small capitalization, while many very small companies are heavily over-capitalized.

Let us take for example the operation of a large company such as those of the Standard group. Such companies own oil and gas leases on lands which they believe will be productive. On these leases they drill wells, some of which will produce oil, some gas, and others nothing. The oil must be raised to the surface, unless it flows naturally, placed in tanks from which it can be pumped into the pipe lines, and through them conveyed to the refinery, which may be located a few miles or several hundred miles from the wells. At the refinery the oil is passed through stills where, by applications of heat it is broken up into various fractions which are known as gasoline, kerosene, lubricating oil, fuel oil, paraffine, tar, etc. These products must be sold either to the jobber or direct to the consumer. It will be seen therefore, that an oil business embraces the elements of prospecting, mining, transporting, manufacturing and selling and that in order to obtain the maximum of profit a company should carry on all of these. To do so however, requires very large capital, and the majority of small companies find it possible to engage in only one of these elements. Most of the small companies are engaged either in the production of crude oil or in refining. By far the larger number of fraudulent promotions have been by companies of the former class.

The profits obtained in the oil business have been enormously exaggerated. While it is true that many companies have been fortunate in making returns of several hundred per cent on their investments, it is known that the oil business as a whole has made no such profits. The losses resulting from the drilling of dry holes, and purchasing, at high prices, leases which never prove productive, are very effective in keeping down the margin of profit. A dry hole undoubtedly is the most useless thing in the world, and unsuccessful tests costing as much as \$200,000 are extremely numerous.

THE OIL BUSINESS.

The business of producing oil, and that of mining, represent the greatest hazards of any legitimate enterprises. The ex-

penses of operation usually leave their returns negligible. Efficiently managed oil companies attempt to remove, as far as possible, the hazards of the business, but there are many of them which are inherent, and which can not be gotten rid of. The best safeguard is that of a scattering of risks, and this, of course, is difficult for a small company. Statistics covering long periods of years show that only 80 per cent of all wells drilled are productive, and this includes the wells in proven fields. Not over 5 per cent of wild cat wells ever prove productive. From this it can be seen that if one drills but a single well he stands an excellent chance of losing that which he has put into it, while if he should drill ten wells, his chances would be greatly improved. In the operation of large companies it is expected that a certain percentage of all wells drilled will be dry, but that the profits on the productive wells will more than balance the losses on the dry ones.

There are numerous instances in which individuals or companies have drilled as many as fifteen or twenty dry holes before getting a productive well. An average well in the Mid-Continent field costs \$20,000. It is necessary then before embarking in the oil business to be prepared if necessary, to take considerable loss before any profit may accrue.

Another important safeguard is the use of the best brains and of the best technical advice in the conduct of the business. For instance, if one merely goes out and drills a wild cat well at random his chances of getting oil will be about one in a hundred, whereas if he drills on the basis of good geological advice, his chances are increased to about one in four. It is not putting it too strongly to say that a concern which insists upon carrying on its operations by rule of the thumb is due to fail sooner or later unless it has extremely large resources to draw upon, so that it can afford to play the law of averages. But it is an expensive operation, if one must drill one hundred dry holes in order to get one producing well.

It is the function of the geologist to indicate those places where the chances of obtaining oil and gas are best, to advise against drilling in places where the chances are poor and to remove, so far as possible, the hazards of the dry hole.

The Purchase of Stocks in Promotion Companies.—There

is but one safe rule in the purchasing of stock in oil companies; that is to buy only stock in going companies, those which have been and are making money, although not necessarily paying dividends. In the case of new companies which have no dividend record, and have as yet no production, but which are organized solely for the purpose of prospecting there is no such rule that can be applied. Investment in such a company is speculation, pure and simple, and in just the same degree as the wagering of a sum of money on the turn of a card. If however, one wishes to speculate in this way his first consideration should be the character of the men who compose the organization, whether they are first, honest, and second, experienced and competent. A man whose honesty is unquestioned and whose ability to successfully operate a bank is known, may well prove a tragic failure in a business he does not understand. If the officers of a company are dishonest, their competence is not important, for the enterprise probably is due to fail regardless.

The tremendous increase in the use of petroleum and its products in the past decade, with the resultant expansion in the oil industry, has given rise to a veritable flood of stock promotions, many of which, of course, have been legitimate, but the vast majority of which have been only fraudulent. The market for such promotion stock seems to have been unlimited. It is a comparatively simple matter to distinguish an honest promotion from a dishonest one. The advertising methods of the fraudulent promoter are in most cases stereotyped. They are highly sensational and extreme. His circulars and advertisements are printed in huge type, and he does not scorn the use of red ink to attract attention. All of his leases are "located in close proximity to great gusher wells," or at least they are located between important fields. He seldom admits a probability of failure. The prospects of success are the only ones he mentions.

Below are listed a number of the advertising devices which are favored by these promoters. The presence in any circulars or advertisements of one or more of these devices should lead the investor to be extremely suspicious.

1. Gaudy circulars printed in large type, and often in

colored ink. A legitimate proposition does not require such advertising.

2. Pictures of large wells (on someone else's lease) and photographs showing the intensive development in well known fields. Such illustrations usually have no relation to the property discussed, and are inserted wholly for psychological effect.

3. Photographs and lists of men such as Rockefeller, Sinclair and other less well known persons who have made fortunes in oil.

4. Lists of small companies which, with an investment of a few hundreds or thousands of dollars, have paid millions in dividends. Such instances undoubtedly are true, but they have no importance unless there be listed with them the enormously greater number of companies of equal size which have never returned even the principal.

5. Computation of the profits to be made "if the well comes in". When one considers the hazards which have been mentioned previously, the folly of such statements is apparent.

6. The offering of "ground floor" opportunity. If there is such a thing as a "ground floor" opportunity, one may rest assured that the promoter himself will take care of it.

7. Map showing the location of the company's property, and directing attention to its proximity to highly productive wells. Mere proximity to a producing well means little. A common occurrence in a producing district is that of a dry hole only a few hundred feet from a large well. Every oil field has its limits, and there is always a last well on each side. The lease shown may be only a quarter of a mile from a producing well, yet if this well be on the edge of the field, the lease is worthless.

8. Statement that after a certain date the price of the stock will be advanced. This is an almost infallible indication of fraudulent promotion.

9. The offer of immediate dividends.

10. The offer of stock at or below par value, and agreement to pay dividends. Any dividend paying stock is sold above par value.

11. Urging the reader to wire for stock before the well comes in. This also is an almost infallible warning.

12. Geological reports. Most present day promoters realize the weight that attaches to a geological report, and their advertising usually includes several such reports. If these reports are couched in terms that are not readily understood by the ordinary reader, they should be viewed with suspicion. There are many pseudo geologists at large who, for a consideration, will write any sort of report desired. They cover their lack of knowledge of the science by an almost ludicrous profusion of technical terms which are designed to confuse or impress the reader. Such a report usually contains glowing promises of gusher wells, and predicts that the property discussed will prove to be one of the greatest producers in the field. A report of this kind is a positive guarantee that its writer is not only incompetent, but probably is dishonest as well. A report by a well trained and honest geologist should readily be understood by any intelligent person.

What Constitutes an Honest Geological Report.—1. It is conservative. There are no glittering promises. The geologist contents himself with the statement of the facts, from which he draws conservative conclusions.

2. It is written in simple language. It can be readily understood. There is usually a minimum of unfamiliar and technical words.

3. It generally includes a structural map (see figs. 2. 3.). On this map there is presented information which makes it possible for another geologist to readily check the work of the first.

4. The standing and reputation of the geologist is as important as that of a lawyer or physician, and it is not more difficult to ascertain. The simplest way to learn whether or not a geologist is reliable is to write to the state geologist at the capitol of the state in which the company operates. Most reputable geologists are members of the national geological societies and a letter to the secretary of any of these societies will bring the desired information. The American Association of Petroleum Geologists maintains an extensive file of information pertaining to all geologists who are engaged in oil

work, whether they be members or not. No geologist whose standing is doubtful can obtain membership in this organization. Dr. Chas. E. Decker, Secretary, may be addressed at Norman, Oklahoma, and will be glad to furnish such information as may be desired regarding any member of the profession. He will not, however, recommend a geologist, but will simply report regarding his training and his standing.

Stock Selling Methods.—While a large part of the promotion stock is sold through newspapers and mail advertising, more of it is sold through agents. By this means the promoter avoids possible trouble with the Post Office authorities. Agents as a rule receive commissions of from 20 per cent to 35 per cent, so that from one-fifth to one-third of the investment is lost immediately the stock is taken. If the remaining operations of the company are conducted on the same lavish basis, it can readily be seen that not much will remain for development. It is estimated that not to exceed 15 per cent of the money paid in for wild cat oil stock ever is used for actual development purposes.

A favorite device of the stock salesman in preparing for a campaign in a county, is to sell or even give to certain prominent citizens, a few shares of his stock. Well known merchants and bankers are the best persons with whom to "plant stock." On this stock immediate dividends are paid for several months. When the salesman again returns and opens his real campaign his prospects are referred to the well known men who already hold stock, and from them they learn that dividends have been paid promptly according to promise. In many cases the merchant or banker may feel so well satisfied with his investment that he becomes an active aid to the salesman. All the usual advertising methods are used, and an intensive selling campaign begins. Particular attention is paid to persons who are known to have some ready money. For instance, the salesman may learn that a certain man has sold a farm or has sold a lot of cattle; or he turns his attention to some widow who has received a considerable amount of insurance. To these persons, particularly if they be individuals who are unaccustomed to making investments, he presents his glittering argument; he points out the advantages of an

investment in oil stocks with a certainty of perhaps 12 per cent annually, and the possibilities of truly enormous returns, as compared with the meager 4 per cent or 5 per cent to be obtained from the savings bank or mortgage. It is often the business men with whom he has placed his earlier stock, who are unintentional aids in his campaign.

As soon as the community has absorbed all of the stock that the salesman feels it will take, he disappears. The dividends may continue for a few months, after which they too disappear. There being no assets to speak of, and no production, it is obvious that the dividends paid have not been from earnings, but from income from the sale of stock. This of course can not go on indefinitely.

As a rule the investor has no recourse, for the assets of the company usually include little except office furniture. The money he has paid in to them has been dissipated in the form of commissions, advertising expenses, large salaries and dividends. His only return has been a few beautifully engraved stock certificates, and a liberal amount of experience which, unfortunately, he is all too prone to forget when the next stock salesman comes around.

HOW TO DETERMINE THE VALUE OF AN OIL STOCK.

1. The assets of the company. Before purchasing a store almost anyone would first inquire as to the value of the stock and fixtures. The same rule should apply in purchasing oil stock. An oil company's assets may include: (a) Producing leases, (b) Undeveloped leases, (c) Equipment, machinery, etc., (d) Oil in storage, (e) Cash on hand and receivable, (f) Other tangible assets, such as stock in other companies, buildings, office equipment, etc., (g) An oil company does not have "good will", which may be a valuable asset to a mercantile establishment. Its assets are of the tangible variety.

2. Liabilities. (a) Capital stock, (b) Bonds, (c) Accounts payable.

Simple subtraction will show the condition of the company, provided the items listed have been verified. The setting of values on undeveloped leases is a difficult problem. A lease which is not yet producing has only the value which it would

bring if sold. Conservative operators usually place a value of \$1.00 on all undeveloped leases, for a very large proportion of such property will eventually prove valueless. In order to place a proper valuation on a producing property, it is necessary to have a careful survey made by a competent engineer or geologist. A rough approximation may be made, however, by considering that a lease which is producing one barrel of oil per day is worth from \$500.00 to \$1,000, and therefore a lease which is producing ten barrels of oil per day is worth from \$5,000 to \$10,000. The differing values pertain to different fields.

It is suggested, however, in case an individual or group propose to invest a sum of money in an oil company, that they club together and employ a competent geologist, familiar with the field, to investigate and report on the value of the property involved. If the proposition is a legitimate one, there will be no objection. If objection is made, it is evident that something is wrong. It should be emphasized that it is worse than useless for anyone other than an expert to attempt to determine the value of an oil property. No matter how much experience one may have had in the estimation of the value of farms and livestock, he should not attempt to evaluate either developed or undeveloped oil lands.

INVESTMENTS AND SPECULATION.

Let us distinguish clearly between the two terms investment and speculation. An investment is an enterprise in which the principal is as safe from loss as possible, and the returns from which are subordinate to the safety of the principal. In this class are included: savings deposits, bonds and well secured mortgages. The returns from an investment are, as a rule, small. Speculation on the other hand is an enterprise in which large profits may be expected but in which the safety of the principal and the certainty of any profits at all are not assured. Most oil stocks, the stocks of all new untried concerns, fall into the latter class. The profits made may be extremely large, and the enterprise eventually develop into an investment when its standing becomes assured, but the chances for loss, especially at the beginning, are correspondingly large.