THE STATE OF WYOMING
GEOLOGIST'S OFFICE

Bulletin No. 1 **Scientific Series**

PART I.
Petroleum in Granite

PART II.
The Effect of Structure
Upon Migration and Separation of Hydrocarbons

L. W. TRUMBULL, STATE GEOLOGIST

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BY

L. W. TRUMBULL, STATE GEOLOGIST

1916
THE S. A. BRISTOL COMPANY,
CHEYENNE, WYO.

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BULLETIN 11. Little Buffalo Basin and Grass Creek Oil and Gas Fields, 1915.
BULLETIN 12. Light Oil Fields of Wyoming, 8 pp., Map, 1916

REPRINTS OF THE FOLLOWING

BULLETIN 2. The Lander Oil Fields, Fremont County, 1912.
BULLETIN 3B. Muddy Creek Oil Field, Carbon County, 1912.
MAP, Douglas and Big Muddy Oil and Gas Fields, 1915.
MAP OF STATE, colored, 1000-foot contours, scale 1:500,000, price $1.00.

The State Geologist's office has in manuscript form a Geological Map of all but a small portion of the State. This is constructed on the U. S. G. S. 1:500,000 Base Map, a scale of about twelve miles to the inch. While it has been impossible to secure the necessary funds to publish this map, it may be seen and studied by anyone wishing to visit the office for that purpose.

Bulletins are free to residents of Wyoming; non-residents are requested to enclose four cents in stamps for each bulletin.

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PART I.

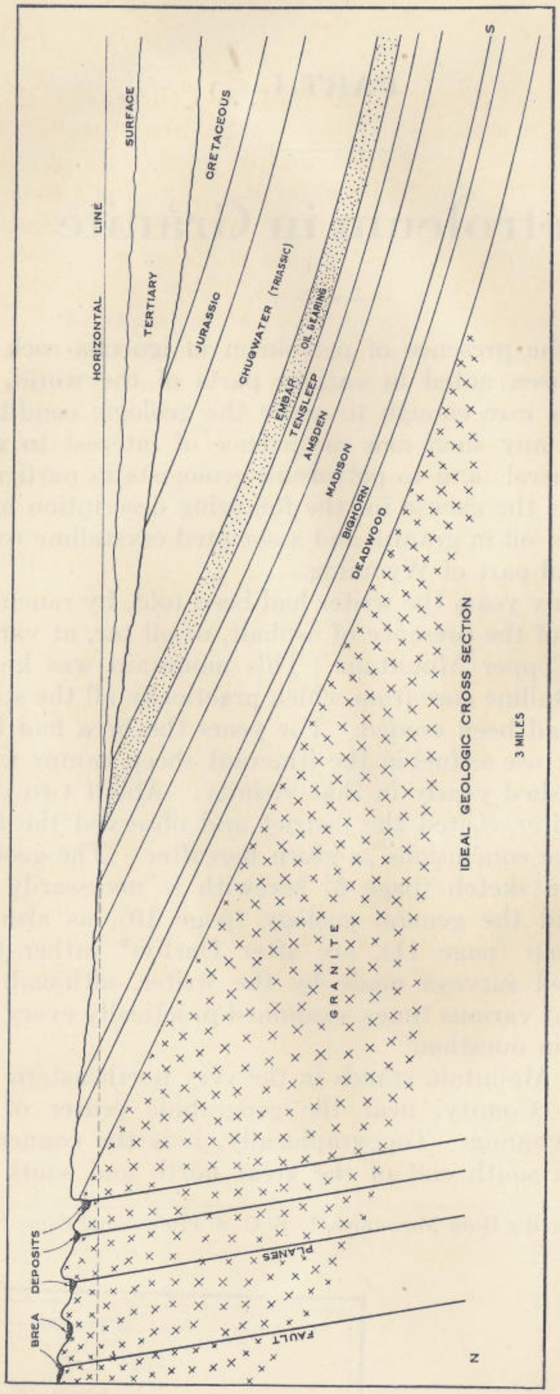
Petroleum in Granite

While the presence of petroleum in igneous rock has frequently been noted in various parts of the world, the occurrence is rare enough to make the geologic conditions surrounding any such new occurrence of interest to geologists in general, and to petroleum geologists in particular. The above is the excuse for the following description of an occurrence of oil in granite and associated crystalline rocks, in the central part of Wyoming.

For many years the writer had been told, by ranchmen and others, of the presence of asphalt, or oil tar, at various points on Copper Mountain. This mountain was known to be a crystalline core from which practically all the stratified rocks had been eroded. For years the brea had been gathered for use as fuel in the itinerant sheep camps which were established yearly in that vicinity. About two years ago, the writer visited the district and observed the facts and drew the conclusions as given hereafter. The geologic cross section sketch (page 6) herewith is necessarily not to scale, and the general geology (page 10), as also the structure map (page 11), are after Darton* rather than from detailed surveys made by the writer, although the writer has, at various times, examined practically every foot of the area in question.

Copper Mountain stands in the very northeastern part of Fremont County, near the geographic center of the State of Wyoming. Topographically, it is the connection between the south end of the great north and south Big

* Geology of the Big Horn Mountains, U. S. G. S. Professional Paper No. 51



Ideal north-south Geologic Cross-Section across the granite-sedimentary contact at the north-east corner of Twp. 39 N., R. 92 W. Nearly horizontal Tertiary beds lying across the bevelled edges of the Cretaceous and Paleozoic strata. Local folding in Tertiary appears farther to the south.

Horn Mountain Range to the east, and the east and west Owl Creek Mountains to the west. Structurally, it is separate from either of these uplifts, but is of the same geologic age. It stands between the Big Horn Basin on the north, and the east side of the Wind River Basin on the south. Along its western side is the great canon into which the Wind River enters and from which the Big Horn River emerges. Along this canon, rocks of all ages, from Tertiary to Algonkian and Archean, are exposed. On a map, Copper Mountain shows as a roughly triangular area about eighteen miles in greatest dimension (E-W), and about twelve miles across at its greatest width (N-S). Its altitude is 8200 feet and the 6000 foot contour encircles its base.

STRUCTURAL GEOLOGY

Geologically, Copper Mountain is a dome, over the granite core of which the stratified rocks were at one time present, but from which erosion has removed all the sediments from the crest down to nearly the 6000 foot contour on the south side of the mountain, and all but the Carboniferous and older sediments on the north side.

The granite area shows some faulting, especially parallel faults of small throw, high dip, and strike nearly parallel with the major axis of the dome. These are quite apparent near the outcrop edges of the oldest sediments. The sketch shows an ideal cross-section across the southern contact.

AGE	FORMATION	CHARACTER	THICKNESS IN FEET
Tertiary		Clays and sands	1000-3000
Cretaceous	Coal-bearing sandstones		1000+
	Pierre	Shales	1500
	Colorado	Shale, few sands	1200
	Cloverly	Conglomerate sandstone and shale	100
Jurassic	Morrison Sundance	Sands and clays Clays	300 250
Triassic Permian	Chugwater redbeds	Limestones and red shale Sandstone and shale with gypsum beds and limestone	750
Carboniferous	Embar Tensleep Amsden Madison	Limestones and shales Massive cross-bedded sandstone Sandstone and limestone shale and sandstones Limestones	200 100 200 500
Devonian	Missing		
Silurian	Missing		
Ordovician	Big Horn dolomite		300
Cambrian	Deadwood	Sandstone, limestone and shale	900
Pre-Cambrian and Archean	Algonkian schists Granite		

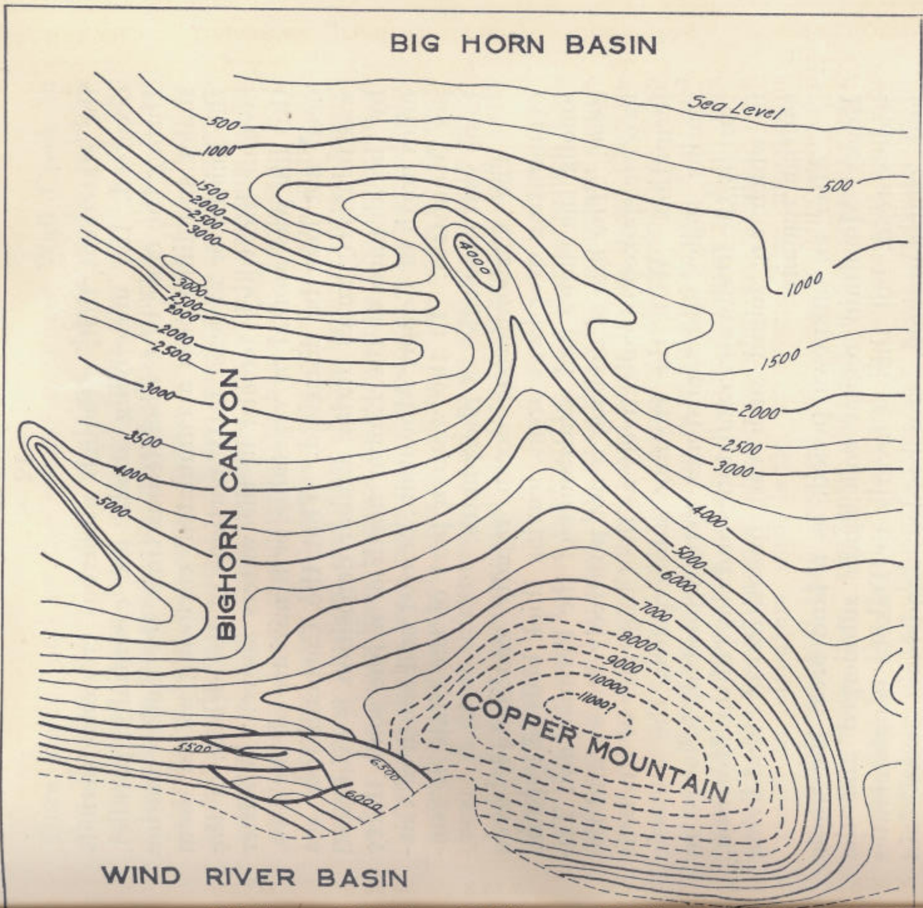
The above geologic table shows the various sediments present in the district, and the structure map (page 11) shows the structure contours drawn upon the base of the Madison limestone. From this, it is apparent that the dome at one time had a trap of 6000 feet, the difference between the altitude of the Madison at its highest point and its lowest encircling structure contour. As all strata are practically parallel throughout the geologic column, we may safely assume that the trap of every stratum was the same in vertical dimension.

The asphaltum oil seeps and brea deposits in the granite area are indicated on the cross section sketch. Asphaltic oil has also been encountered in shafts and tunnels higher up on the mountain in both granite and hornblende rocks. On the north side of the mountain, various exposures of the Embar and Permian formations show saturated outcrops. These have led to drilling down the dip from such exposures in the hope of developing oil in commercial quantities. The Embar-Redbeds horizon is oil-bearing nearly everywhere exposed around the sides of the Wind River Valley, and, along the Shoshone Anticline, which parallels the foot of the Wind River Range, is commercially productive of a heavy black asphaltic petroleum.

The foregoing is given as a statement of facts of the present conditions. In an effort to explain those conditions, we will try to work out the geologic history of the region. In doing this, we will, of necessity, have to make certain assumptions, and accept as true certain theories which may prove untrue. The following portion of this article does, however, reflect the writer's belief in certain of the theories of the origin and migration of petroleum.

HISTORICAL GEOLOGY

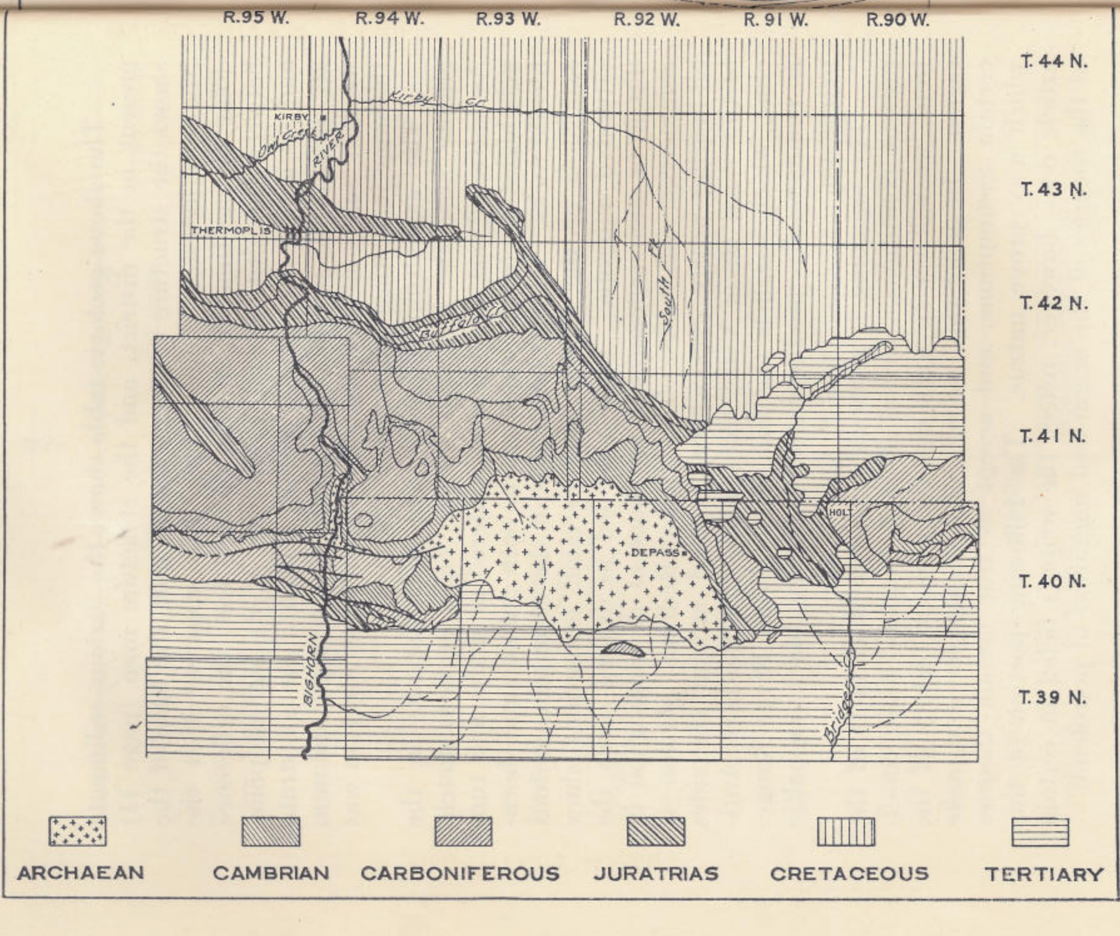
As the oil originated in strata of late Carboniferous Age, we may pass over the earlier geologic history with



Structure of
COPPER MOUNTAIN
and
Surrounding Territory

Contours on base of the Madison Limestone.
500-foot intervals above sea-level.

(*After N. H. Darton*)



Areal Geology
of
COPPER MOUNTAIN
and
Surrounding Territory

(*After N. H. Darton*)

the statement that, although numerous erosional periods occurred, the underlying strata are essentially parallel. During the close of Carboniferous time, the Embar marine shales and limestones accumulated, enclosing within them the debris, or at least fatty portions of the debris, of the oceanic life which teemed in the waters above. Whether this life was animal or vegetable, or a mixture of the two, need not here be discussed. That the Carboniferous sea was relatively small during Embar deposition is evidenced by the absence of the Embar north of a line some thirty miles north of Copper Mountain, or east and south of Casper Mountain. In the western part of the State it contains vast quantities of phosphates.

The Carboniferous ocean rapidly contracted, even evaporating over large areas, leaving thick beds of gypsum among the shales and sandstones of the Permian and Triassic. The line of division is not positively known and the two are spoken of collectively as the Chugwater or Redbeds formation. With the ensuing submergence, the Jurassic marine shales and sandstones were deposited, followed in turn by the freshwater sandstones and clays of the Morrison, in which are found such vast quantities of land-living saurian remains.

After an unknown period, as a land area, the whole Rocky Mountain region was again submerged and the wide-spread, but thin, Cloverly or Dakota conglomerates and coarse-grained, crossbedded sandstones were laid down. These conglomerates may possibly be the debris from the islands which may have at that time marked the position of the future Big Horn, Owl Creek, Absaroka, Wind River, Medicine Bow and other mountain ranges. The submergence beginning with the Cloverly was great, and lasted long enough for some six thousand feet of shales to be deposited in some parts of the Cretaceous Sea. A few sandstones appear among these shales, probably marking the greater of the oscillations which took place. One of these sandstones, known as the Torchlight in the Big

Horn Basin, and as the second or lower Wall Creek in the Powder River Valley, contains characteristic pebbles which may have been derived from the erosion of the Cloverly on the gradually growing Big Horn or Wind River Islands, or from the same source from which the Cloverly had itself been derived. These sandstones are the reservoirs of the high grade paraffine oils which are now being produced in large quantity in the State of Wyoming.

During later Cretaceous time, the sea gradually became more shallow and the shales became more sandy, while the shore lines became wide swamps producing interstratified shales, coal beds and sandstones which eventually spread over the whole area which had been open Cretaceous Sea. A great thickness of sandstones and clays with interbedded coal accumulated in late Cretaceous and early Tertiary time.

In the very latest part of the time during which Cretaceous life still existed, the growth of the mountain ranges was evidently much more rapid than it had been theretofore; for we find that the change in life forms was very sharp, denoting sharp change in conditions, and the vast and rapid deposition of the Tertiary could obtain only under the rapid erosion made possible by uplifts, both great in elevation and large in area. The mountains probably reached their greatest elevations at this (Eocene) time. Since then, the only changes in topography have been due to the tearing down of the mountains and the scattering of the debris in the low areas, perhaps to be again and again worked over as the lines of drainage slowly ate into the earth's crust. It is evident that there have been eroded from parts of the mountain ranges at least 10,000 feet of rocks and possibly as much as 12,000 feet, dependent upon when elevation began and the thickness of the stratified rocks deposited up to that time.

HISTORY OF THE PETROLEUM

We can but guess at what time period the fats buried in the Embar muds became petroleum, or the processes by which they changed from microscopic portions of animal or vegetable fats, into drops of crude oil. But we may safely assume that these processes had been completed long before the first warpings of the present earth folds began to make themselves evident. What migration, from the point of origin of each oil drop, had taken place, was probably one of nearly vertical rise across and through water-filled, pervious materials until such travel was stopped by meeting with an impervious clay roof. Numberless oscillations and slight movements of various kinds had assisted this migration until eventually the oil had all been floated into thin layers and films in porous strata, supported by water, and prevented from rising higher by impervious strata above.

Later began the folding and doming which gradually produced the present mountain ranges. The oil must have risen along the dip as the strata were tilted. The crest of the dome may possibly have been above the hydrostatic level, but as mountains not far distant reached an elevation 5,000 feet greater than did Copper Mountain, we may assume that even the very crest of the oil trap of this dome was under a considerable water pressure.

Even if the travel of oil through sandstone be slow, the Embar-Permian sandstones in the dome probably had become the reservoirs of large quantities of oil long before the mountain had reached its maximum elevation. With the final stresses tending to force the dome still higher, came the fracturing which we find evidenced in the faults in the granite. The oil already entrapped must have entered these fractures and permeated all openings, down to, of course, the general level of the water which supported the oil. The faulting may have been sufficient to badly impair the efficiency of the trap; and oil may have been forced out through to the earth's surface, and lost.

The drainage area, if we may speak of oil "draining" to a dome, or, using the more common expression, the "gathering ground", which fed the Copper Mountain dome covered approximately one thousand square miles. It is not, then, necessary to credit each square foot of the Embar stratum with very much oil in order to account for enough to fill the spaces of the pervious Embar and even the fractures and cavities in the underlying stratified rock and the granite core, from the high point of the Embar down to the six thousand foot plane. Or perhaps not that much oil did accumulate, but as erosion has lowered the surface, oil has followed the water level down simply through force of gravity, and we find oil to-day in crevices in the granite below what was the level of the plane between the water and oil at the time of maximum oil accumulation. In either case, the presence of oil in the granite core is to be expected.

The question arises, "If it is granted that oil has migrated downward from the Embar through some two thousand feet of stratified rocks, and far into the underlying granite, why may we not assume that the oil originated even higher, in the Cretaceous shales at the horizon which is making a commercial production in many fields in the State?" It is true that the quality of the oil cannot be used as an argument against such migration. The light paraffine base oil (saturated hydrocarbons) may possibly be broken down by the action of gypsum or gypsum waters into the asphaltic oils (unsaturated hydrocarbons). The principal argument against the possibility of such migration is the fact that the great thickness of Jurassic and Triassic-Permian sandstones show no evidence of oil, except near the bottom, close to the Embar contact. It does not seem possible that oil could have passed through many hundreds of feet of both coarse and fine grained sandstones, without leaving any trace in those sandstones.

Where oil is found in the outcrop of the lower Redbeds sandstones, to the east of Thermopolis, it shows as saturation of narrow portions of a stratum, the saturated being sharply divided from the oil-free portions by cross-bedding planes. This seems to the writer an evidence of down-dip migration, under the gentle force of gravity only, after erosion had cut deep enough to remove the hydrostatic pressure in this part of the dip slope. That is, the migration from the Embar upward into the higher sandstones was not general, and previous to the deformation of the strata, but was purely local after doming and fracturing, and the points we can now observe received their petroleum through a still later down-dip migration, following tremendous erosion.

SUMMARY

1. That the oil did not migrate vertically from its point of origin to any great number of feet.

2. That it did migrate laterally as the strata were tilted.

3. That migration and tilting occurred simultaneously, so that a pool accumulated in the crest of the dome, and when

4. Fracturing and faulting of the dome occurred the oil travelled in quantity, both upward and downward.

5. As erosion has lowered the surface and the water table, oil has migrated to a small extent, by gravity, down the dip in the most porous sandstones.

6. That drilling down-dip from the saturated outcrops of such sandstones cannot find oil in economic quantity.

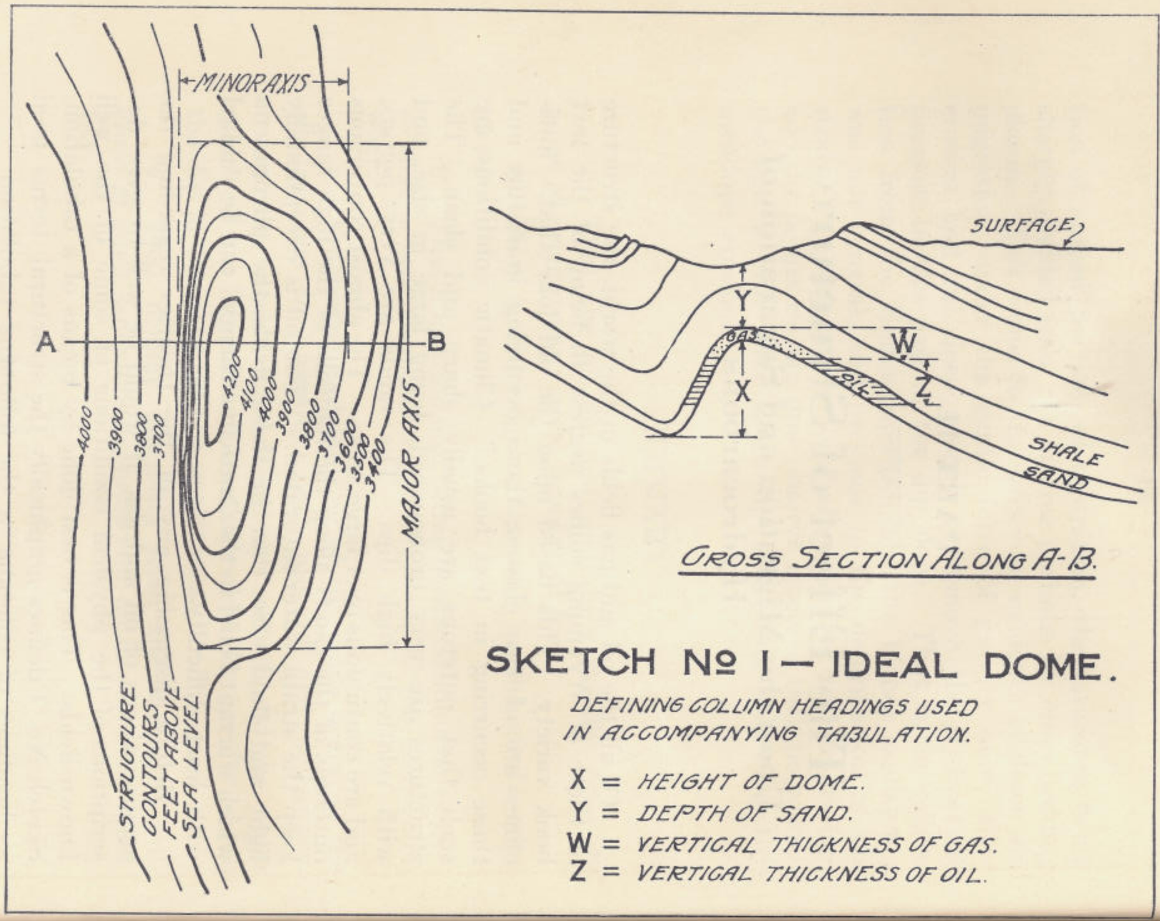
PART II.

The Effect of Structure

Upon the Migration and Separation of Hydrocarbons

Of all the oil and gas fields in the world, the structure of those of Wyoming comes nearest to being of the text book variety. This based upon the old joke that, "anticlines are of two classes; those occurring in nature and those occurring in text books." Climatic conditions are such that outcrops are usually sharp and clean. The structures are very pronounced, being large in size, and with relatively high dips. The sands are very porous, and are continuous over large areas. The almost continuous outcrops of the sands along the foothills of the high ranges keep the strata water-saturated. The oil is exceptionally light and fluid. So that in these fields the phenomena which warrant belief in the "anticline theory" can be studied with least difficulty.

Before discussing any of the theories regarding the accumulations of oil and gas, it would be well to give descriptions of the physical conditions of some of the well known fields. This is best done by means of a tabulation. Sketch No. 1 defines graphically the structural terms used as headings of columns in the following tabulation.



SKETCH Nº 1 — IDEAL DOME.

DEFINING COLUMN HEADINGS USED IN ACCOMPANYING TABULATION.

X = *HEIGHT OF DOME.*
Y = *DEPTH OF SAND.*
W = *VERTICAL THICKNESS OF GAS.*
Z = *VERTICAL THICKNESS OF OIL.*

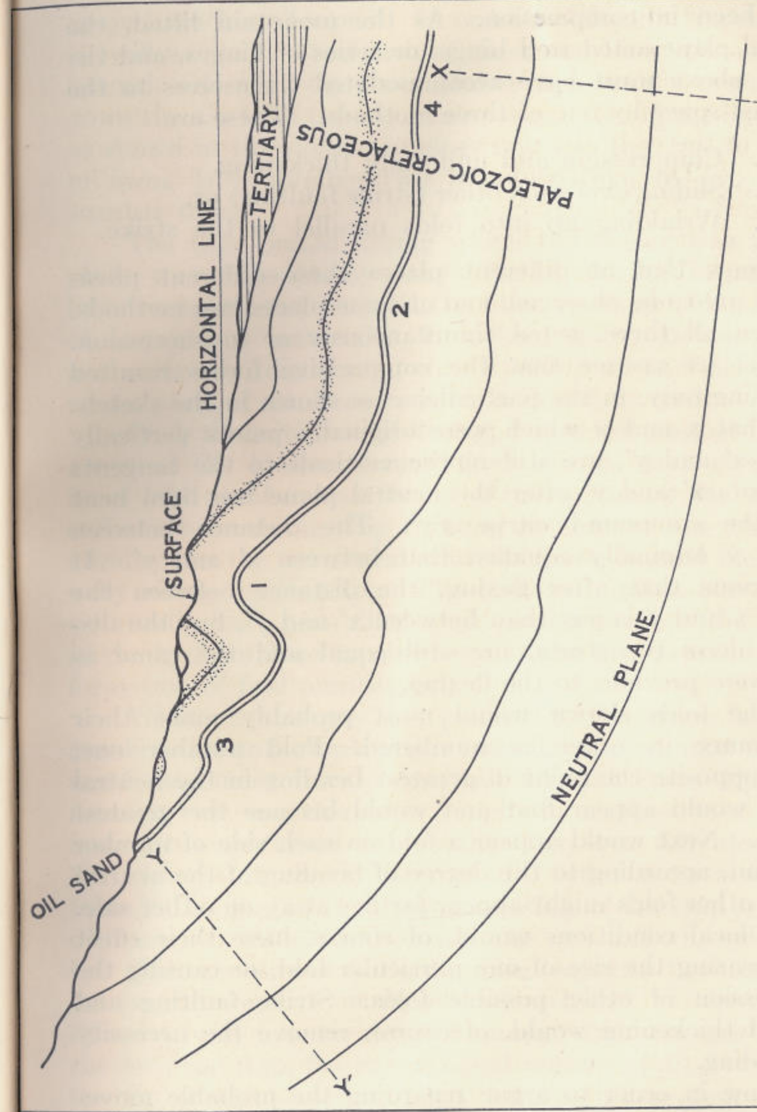
NAME OF DOME	Major Axis (Miles)	Minor Axis (Miles)	Dip of Limbs	Altitude of sands at crest	Altitude of lowest closing contour	Height of Dome	Depth of Sands	Thickness of Gas Body	Thickness of Oil Body	REMARKS
Salt Creek	13	5	20 & 8	4100	2800	1300	900	None	500	
Teapot	4	1½	10 & 4	3300	3000	300	2000	Not drilled		Part of Salt Creek anticline
Grass Creek	8	3	50 & 12	5300	2500	2800	900	None	600	
Buffalo Basin	7	4	40 & 15	4900	3000	1900	1700	Exceeds 500	Not drilled	
Torchlight	5	3	15 & 7	2900	2300	600	400	Slight	200	
Lamb	3	1	6	2700	2600	100	600	100	Slight	Part of Torchlight anticline
Oregon Basin	8 (?)	3 (?)		4700			1000	Not known	None	In Dakota sands
Garland	10 (?)	3 (?)		2300			1700	Not known	None	In Dakota sands
Byron	3 (?)	1 (?)		2100			1900	Not known	None	Secondary dome on Garland uplift
Elk Basin	4 (?)	2 (?)		3400			900	None	Not known	Not surveyed
Big Muddy	6 (?)	1 (?)	Very low	2400 (?)	2200 (?)	200 (?)	2800 (?)	Not drilled		Shale oil at 940 feet
Greybull	4	2	10 & 4	3100	2800	300	800	Blown off	300	Complicated by faults

In a study of the various fields of the State one is immediately confronted by the questions: "Why does this dome contain a reservoir of oil and that dome only gas?" "Are there rules, which if known, will determine ahead of the drill, the presence of gas instead of oil, or vice versa?" "Do depth and altitude have any bearing on the question?" "Will domes be drilled and found barren of either oil or gas?" These are all, economically as well as scientifically, important questions. In order to discuss these problems, it is necessary to follow, if possible, the processes involved in the formation of the domes, and the behavior of the hydrocarbons during the time these processes were operative.

The folds which are possible oil or gas reservoirs are always parts of anticlines, paralleling adjacent mountain ranges. Hence the rule that, "An oil or gas dome always lies with its major axis parallel to the nearest mountain range." The second part of the rule is; "and its limb with greater dip facing that range." These folds were formed at the same time that the uplift of the mountain range occurred. The ranges have usually been eroded into the granite cores, but the oil-bearing sedimentaries at one time enveloped them.

Sketch No. 2 illustrates the folding of the higher strata into anticlines and domes. This is not an actual cross-section. It is greatly shortened, i. e., the horizontal scale is much greater than the vertical. Nor is it meant that all the folds shown in the sketch will be found in one straight line, in the field.

Consider the bending of the earth's surface as a problem in mechanics. At some depth below the surface lies the neutral plane. That is, the plane or stratum in which there were neither stresses of compression nor of tension, at the time the mountain range was forced up. It is not necessary to theorize as to what forces caused the elevation of the mountain. When such elevation took place, whatever the cause, all the strata above the neutral plane must



SKETCH No 2— IDEAL CROSS SECTION.
SHOWING WRINKLING OF UPPER STRATA INTO ANTICLINES AND DOMES DUE TO UPLIFT AT ONE SIDE.

have been in compression. As the mountain lifted, the neutral plane acted as a hinge, or series of hinges, and the strata above must have accommodated themselves to the lessened space by one of three methods. These are:

1. Compressing and uniformly thickening,
2. Sliding over each other (strike faulting) or,
3. Wrinkling up into folds parallel to the strike.

We know that at different places these different phenomena are to be observed, and at some places two methods, or even all three, acted simultaneously or in succession.

Let us assume that the compressive forces resulted in folding only, in the particular case shown in the sketch: i. e. that x and y which were originally points vertically above x′ and y′, are still in the verticals to the tangents at points x′ and y′ after the neutral plane has been bent into the compound curve x′y′. The distance between x and y originally equalled that between x′ and y′. It is obvious that after flexing, the distance between the points x and y is less than between x′ and y′, but the distance along the strata, are still equal and the same as they were previous to the flexing.

The folds shown would most probably make their appearance in order as numbered. Fold number one, being opposite the point of greatest bending in the neutral plane, would appear first and would become the greatest in size. Next would appear a fold on each side of number one, and, according to the degree of bending of the neutral plane, other folds might appear farther away on either side. Many local conditions would, of course, have their effect in increasing the size of one particular fold, or causing the suppression of other possible folds. Strike faulting and general thickening would, of course, remove the necessity for folding.

Now in order to argue regarding the probable movements of the hydrocarbons, let us assume that in a particular area three anticlines parallel to the dominating

range have been formed. In order to simplify the matter, we will assume that in each of these anticlines, a dome was formed, and that the three domes were in a straight line down the dip from the mountain range. Using the numbers as shown in the sketch, number one was the first to begin to form, later number two began to fold up and lastly number three.

The time period during which the flexing was taking place was undoubtedly long. Before flexing began, the hydrocarbons must have lain as films on water under layers of impervious materials. In other words, as widely, if not uniformly, distributed thin layers of oil and gas in the upper parts of sandstone strata, under shale roofs.

With the initiation of flexing, began the gradual up-dip creep of the hydrocarbons. Over all the area down-dip from fold number one, began a movement of the hydrocarbons toward the trap forming in number one. Above number one the movement was, of course, toward the gradually rising main range. The trap in number one would eventually have been filled with oil and gas, but the travel of the hydrocarbons to number one was interrupted by the formation of fold number two.

What oil and gas was present in the space between number one and number two must have continued its upward movement toward one, but all that down dip from number two was thereafter caught in number two. This movement continued till number two was full, down to the high point on the axis of the syncline between the folds. The gas filled the upper portion of the trap and the oil occupied all space between the gas and the synclinal lip. But the strata down-dip from number two had not yet been drained of all their hyrdocarbons. As these continued to rise into the trap of number two, the gas would rise into the trap, forcing an equal volume of oil down past the lip of the syncline. The longer this process lasted the more gas and the less oil there remained in the trap. The oil forced out of, and around, number two trap would, continue to float upward along porous strata until trapped in number one. If there remained enough of the mixed hydrocarbons in the strata below number two at the time of folding, the trap in each sandstone eventually became gas filled, and thereafter both oil and gas would travel past number two, upward to number one. If the supply of hydrocarbons was not sufficient, number two was left with some oil below the gas.

If a great enough quantity got past number two, the same process of filling, and later of separation, took place in number one. But as number one was vastly larger than number two, the supply may not have been sufficient to have ever completely filled its trap.

After number two was formed, the continued flexing resulted in the formation of number three. It is evident that there was no sufficient supply of either oil or gas to fill, or even partially fill, number three until after number one had been entirely filled and began to overflow (or underflow).

After all hydrocarbons had floated from the dipping strata and had been entrapped, or travelled up the dip to waste at outcrops on the mountain range, the conditions in the traps were as follows:

Number two was gas filled. Number one contained some gas in its crest with a body of oil below. Number three was without appreciable amounts of either gas or oil. But with the folding occurred some fracturing and crushing, as well as possibly slight faulting, along the crests of the folds. This allowed some upward (and possibly downward) travel of the gas and oil.

As geologic time passed, erosion gradually brought the surface nearer the porous strata which acted as reservoirs in the domes. As the cover over number one became thinner, the leakage of gas through faults and fractures became possible and, after long enough time, all gas not held in solution must have escaped. With still greater thinning of the cover, the oil also began to escape. But

number two has not suffered erosion as has number one and its store of gas has not escaped.

Let us now apply the foregoing theory to some of the domes of the State and see how the facts, as proven by the drill, agree with the theory. Consider Salt Creek dome first. Here is a large dome with a smaller one (Teapot) lying en echelon with it, and the two having a large tributary gathering ground. The Teapot dome has been withdrawn from all forms of entry, as a future fuel supply for the U. S. Navy. It has never been drilled, so we can only prophesy as to what will be found when it is drilled. The crest of Salt Creek dome has an altitude of 4100 feet; of Teapot 3300. The height of the dome of Salt Creek is 1300 feet; of Teapot 300. Erosion had cut to within 900 feet of the sands on Salt Creek, but the surface is still some 2000 feet above the sand in Teapot dome. Oil was escaping at the surface along the crest of Salt Creek, and when drilled, the oil was found with no gas cap above it. And although the trap is 1300 feet deep, and the gathering ground very large, the oil remaining in the pool extends only 500 feet (vertically) down the limbs of the dome. But a short time more, and the oil would have all escaped, and the driller who came along after the cover had become a few hundred feet thinner would have brought in a water well.

The second field of the State, from production point of view, is Grass Creek. Here, although the cover was only 900 feet thick, no evidence of oil escape has been found, but the drill found practically no gas over the oil. Certain of the sands, are, however, gassy and produce no oil. Here again but a portion of the height of the dome is productive.

While Buffalo Basin lies close to Grass Creek, it is not probable that the course of travel of the hydrocarbons was through Buffalo Basin dome to Grass Creek dome, for a sharp deep syncline between them would seem to prevent such travel. Buffalo Basin has a large deep gas cap. The four wells drilled to date are, unfortunately, so located that they all strike the sands on nearly the same structural contour. They all found gas in the upper sands, and the flow was so heavy that it could not be drilled through with cable tools. These wells showed a rock pressure of about 650 pounds and a flow of 25,000,000 cubic feet per day. Depth about 1700 feet. Wells will be drilled this season (1916) to tap the upper sands at a contour about 400 feet lower. As the gas lines make many gallons of drip gasoline per day it is hoped that the oil horizon is but little below the gas.

The Torchlight and Lamb domes are really one large dome with a double crest. The tabulation gives the dimensions of each, the lowest closing contour of the combined dome being shown in the Torchlight line. Here we have a structure quite comparable with the Salt Creek-Teapot structure. Torchlight is producing oil in commercial quantity, and the Lamb dome, gas.

At Oregon Basin, Garland and Byron no detailed surveys have been made. Each field has been drilled and gas, without oil, has been found. At Oregon Basin the upper Colorado sands are exposed, and at the Garland-Byron structure they are close to the surface. In each case the big gas flows are from the Dakota sands, which are below the shales, and which are water sands everywhere to the south. Elk Basin dome has not been surveyed and the figures are but approximate. It is a heavy producer of high gravity oil.

Big Muddy is of doubtful structure at the Wall Creek horizon, although a slight doming is observable on the surface. Oil has been found at about 940 feet depth in the shales, but no drill has yet reached the Wall Creek sands (the productive sands of Salt Creek dome), which lie some 2800 feet below the surface. If there be a trap in the structure at that depth, the writer expects it to be gas, and not oil, filled, for the gathering ground down-dip is large and the trap, at best, can be but very shallow.

In conclusion the writer wishes to again draw attention

to the fact that this discussion is of a very definite set of conditions. Faulting and thickening due to compression have not been considered. Certainly the gravity, or rather the fluidity, of an oil is one of the controlling factors in its migration. We have here discussed only the very light, fluid, Wyoming oil of the Cretaceous series. What has been said must be vastly modified to suit the greatly different conditions, when the Carboniferous oils are being discussed. And lastly, where the sandstones are not continuous through long distances, migration and separation of hydrocarbons along and in such sandstones is, of course, impossible. In short, each and every structure under consideration for its possible hydrocarbon content, must be a problem unto itself, because the factors entering into the problems are so varied that no two can be exactly alike.