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# THE MINERAL RESOURCES OF OREGON

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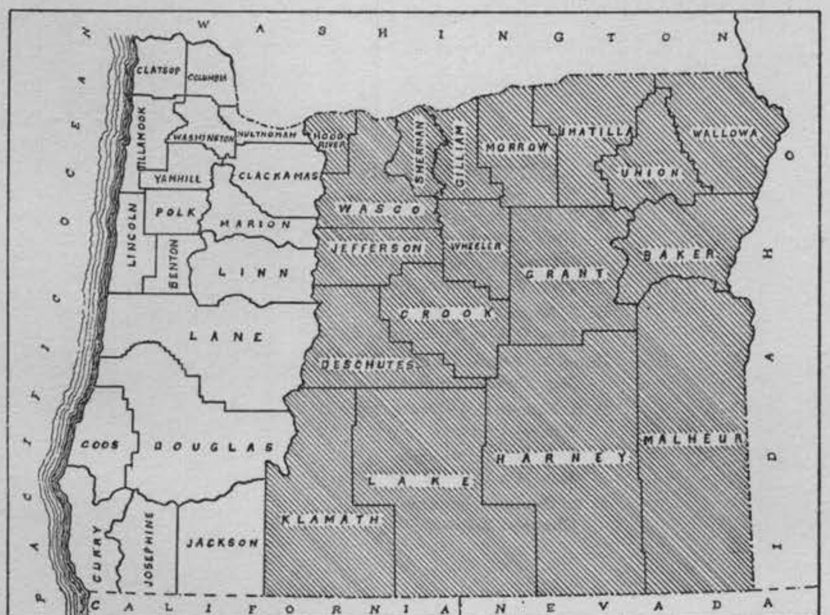


Sketch map of Oregon. Shaded portion covered in the oil and gas investigation.

REPORT ON

## Oil and Gas Possibilities of Eastern Oregon

BY

JOHN P. BUWALDA.

IN CO-OPERATION WITH U. S. GEOLOGICAL SURVEY

Forty-eight Pages Four Illustrations

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## INTRODUCTION

During the past ten or twelve years the annual consumption of petroleum and its numerous derivatives has increased enormously in the United States, due mainly to the expanded use of crude oil as fuel under boilers and the development of internal combustion engines and automotive vehicles. The use of natural gas as a fuel for producing heat and power has also greatly increased, so that it has long since come to be regarded as a very valuable commodity. As prices of crude oil have risen the natural response has been greatly increased production; but the increase of consumption of the liquid fuels has been even greater, amounting in 1920 to about 531 million barrels of oil. As a consequence, while we as a nation were a large exporter of oil a few years ago, in 1920 we imported nearly 100 million barrels, chiefly from Mexico, in excess of our exports of crude. The high prices and the hugh dividends paid by successful oil companies have created a strong interest among the public in oil-fields exploitation.

The people of eastern Oregon have been keenly alive to the benefits to be gained from the discovery of oil or gas in paying quantities in that region. The presence at certain localities of magnificent sections of stratified rocks resembling somewhat in appearance those from which oil is obtained in the California fields, and the occurrence of notable quantities of combustible gas in numerous springs, wells, and prospect drill holes, have encouraged the belief that oil and gas could be obtained if wells were drilled at the proper places and to sufficient depth. A considerable number of companies have been organized during the last ten years who have drilled holes to various depths at widely separated localities, and other companies are preparing to drill at the present time.

In view of these facts it seemed highly desirable that an examination of the geologic conditions and the evidence for the presence or absence of oil or gas in the various districts of the eastern part of the state should be made by a trained oil geologist. The Oregon Bureau of Mines and Geology accordingly entered into a co-operative agreement with the United States Geological Survey under which the expense of the work was shared by the two organizations. Dr. John P. Buwalda of Yale University, a geologist of experience, was employed to make the field investigations, on which he was engaged in the field seasons of 1919 and 1920. Additional information bearing on the oil and gas problem in the Ontario-Vale region was gained incidentally in the course of later studies in neighboring parts of Idaho during the summer of 1920.

The results of Dr. Buwalda's examination are published herewith by the Oregon Bureau as Number 2 of Volume 3, Mineral Resources of Oregon. This paper constitutes a general statement concerning the oil and gas possibilities of that portion of Oregon which lies to the east of the Cascade Range, while No. 1 of Volume 3, issued in March, 1920, covers from a similar standpoint all of Oregon between the Cascades and the Pacific Ocean. I regard the present report on eastern Oregon as a worthy complement of the western Oregon paper in that, so far as available knowledge can be brought to bear, it is a careful presentation of facts from which logical conclusions are drawn.

HENRY M. PARKS, Director.

VOLUME 3 NUMBER 2
JULY, 1921

# THE MINERAL RESOURCES OF OREGON

*A Periodical Devoted to the Development of All Her Minerals*

PUBLISHED AT PORTLAND BY

THE OREGON BUREAU OF MINES AND GEOLOGY

HENRY M. PARKS, Director

## REPORT ON OIL AND GAS POSSIBILITIES OF EASTERN OREGON

By JOHN P. BUWALDA

The only published reports on the oil and gas possibilities of eastern Oregon with which the writer is acquainted are two papers based upon investigations made by Chester W. Washburne,[1] then of the U. S. Geological Survey, about 1909, covering parts of the Vale and Harney valley districts, and a third, a short discussion by A. J. Collier[2] of asphaltum reported to have been found near Clarno in the John Day valley.

Certain districts where drilling has been or is being carried on, or is contemplated, as near Dufur, Ontario, Vale, Burns, Madras, Klamath Falls, and Lakeview, were inspected somewhat more carefully, but the examination of the larger part of the area covered was necessarily of a reconnaissance nature. Such reconnaissance sufficed for an appraisal of the oil and gas possibilities of many extensive areas since the writer had already acquired a first hand knowledge of the geology of the eastern part of Oregon during journeys across it in previous years and because the broader features of the geology of many of these areas had already been described by other workers.

The author is pleased to acknowledge the valuable aid received from the publications of other geologists, especially those of Bretz, Diller,

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[1]Gas and oil prospects near Vale, Oregon, and Payette, Idaho. Bull. U. S. Geol. Survey, pp. 26-55, 1911.

Gas prospects in Harney Valley, Oregon. Bull. U. S. Geol. Survey, pp. 56-57, 1911.

[2]The geology and mineral resources of the John Day Region, Oreg. Bur. Mines and Geol., Mineral Resources of Oregon, vol. 1, no. 3, pp. 37-39, 1914.

Lindgren, Merriam, Russell, Waring, Washburne, and Williams. It has not been found practicable to cite references to all the publications from which information was gleaned in the course of the investigation.

The writer also expresses gratitude for the aid rendered him in the field by numerous public-spirited citizens, especially Mr. H. B. Cockrum of Ontario, Mr. D. W. Barnett of Madras, and Mr. H. M. Nolte of Lakeview.

This report does not pretend to be a contribution to the geology of Eastern Oregon but is a general discussion of the oil and gas possibilities of the various districts in simple terms for the non-technical reader. The geology of each district was reviewed in the field to obtain a basis for a judgment, and all reported evidences of the presence of either petroleum or natural gas were investigated. Large numbers of well logs which might have been included are omitted to economize space and because in the files of the Oregon Bureau of Mines and Geology in Portland many are available to those interested.

In the following pages the discussion of the oil and gas possibilities of the different districts is prefaced by brief statements relating to the nature and origin of oil and natural gas, the character and value of geologic principles in determining favorable areas, and the nature of the facts and principles used in the Eastern Oregon work. The units of discussion will be the various areas or divisions within which the geologic formations are more or less similar, at least so far as oil and gas possibilities are concerned.

## NATURE OF PETROLEUM AND NATURAL GAS

Petroleum and natural gas are substances closely related chemically, even though the one is a liquid at ordinary temperatures, sometimes quite thick and viscous, while the other is an invisible gas. The principal constituent chemical elements of both are carbon and hydrogen; minor constitutents are often nitrogen and sulphur, and, more rarely, oxygen. Carbon and hydrogen are both very combustible elements, that is, they both unite readily with oxygen, and a great deal of heat is liberated when they combine chemically with that element. This is of course the reason why substances like oil, gas, coal, wood, and other materials made up chiefly of carbon, or of carbon and hydrogen, yield so much heat and power when burned, and it is the chief secret of their value to mankind.

Petroleums and natural gases differ from each other chiefly because of differences in the proportion of carbon and hydrogen present in them. Gas is composed to a larger degree of hydrogen, with relatively less carbon than has oil. The so-called lighter oils, which are generally more liquid in character and contain larger proportions of gasoline and lubricating oils and less asphalt and are hence more valuable, in turn contain more hydrogen and less carbon than the heavier oils.

Hydrogen is a gas and carbon a solid; mere mixtures of these two substances could not form petroleum or natural gas, which seldom contain any considerable quantities of free hydrogen. Carbon and hydrogen unite chemically, however, in definite proportions and form substances entirely different from either of the parent elements. For instance, if two atoms of carbon unite chemically with six atoms of hydrogen, a molecule of the gas ethane is formed. If nine atoms of carbon unite with twenty atoms of hydrogen a molecule of the liquid substance nonane is formed. Similarly if twelve atoms of carbon unite with twenty-six atoms of hydrogen a molecule of a solid paraffine is formed. Since the total number of possible proportions of the two elements carbon and hydrogen is very large, they form a long list of different substances. Some are gases; others are liquids or solids. Petroleum and natural gas are mixtures of these chemical compounds of carbon and hydrogen in indefinite proportion; the proportion of the different hydrocarbon compounds present determines whether the product will be a heavy oil, a light oil, or a gas. There is thus every gradation, as the proportions of the hydrocarbons vary, from the heavy oils to the very light combustible gases.

Since the different hydrocarbon compounds forming oil vaporize or volatilize at different temperatures, it is possible to separate crude petroleum into fractions, each made up of hydrocarbon compounds having about the same boiling temperature, by heating the crude petroleum gradually and condensing into different tanks the vapors given off at successively higher temperatures. In refinery practice crude oil is separated into such commercial fractions as naptha, benzine, gasoline, kerosene, distillate, light and heavy lubricating oils, vaseline, and paraffine or asphalt, many of which are mixtures. It is probable that some of the definite chemical compounds which can be isolated in the laboratory are produced by the decomposition or breaking down of other compounds existing in the crude petroleum.

## ORIGIN OF THE NATURAL HYDROCARBONS

The existence of vast volumes of petroleum and natural gas within the crust of the earth has excited much interest, and anything like a general agreement among geologists as to their origin has been reached only within very recent years. It might at first be thought that these substances have always existed where they are now found, since the formation of the earth itself. But geologists are convinced that none of the rocks near the earth's surface, from which oil, coal, and the metals are mined, were part of the original surface rocks of the earth when it was first formed. On the other hand, these rocks have been formed in the later stages of the earth's history. The surface rocks have resulted either from the rising of molten material up to or near the surface and cooling and solidifying there, or from the deposition of fragments of waste rock worn off the land by the rivers, ice, and winds and deposited in the sea, or in lakes or river valleys as sedimentary strata. The oil and gas, which is practically always found in sedimentary beds, must also have originated during the formation of the beds or at an even later date, so that we are thus confronted by the problem of the *mode* of origin. It is important to know how the hydrocarbons originated because that knowledge will aid in determining the oil and gas possibilities of any area.

### INORGANIC ORIGIN

Certain geologists and chemists have maintained that oil and gas were probably formed from rocks in the crust of the earth or at considerable depth containing large quantities of carbon compounds such as carbides. They argue that if water or other substances containing hydrogen came in contact with these rocks new chemical combinations might result, some of which would be hydrocarbons. These might concentrate in certain parts of the crust and form oil and gas pools. While such possibilities may be undeniable, little evidence has been brought forward to support this hypothesis, and relatively few geologists hold this view at the present time.

### ORGANIC ORIGIN

While several modes of origin of petroleum and natural gas have been suggested, interest has centered chiefly around two. When oil first began to be produced in large quantities it was found, in most cases in the United States at least, in the same general regions which had been producing coal in large quantities. It was thus natural that the origin of the oil should be considered as related to that of the coal. But when oil was found in abundance in many areas where no coal was known and where it appeared improbable that coal existed, it was clear that the earlier explanation was not in general correct. It is no longer thought that the coal produced the oil.

Studies made largely during the last twenty years have shown that oil and gas are practically always found in sedimentary rocks, that is, rocks made from sand, clay, mud, or gravel which were carried into and deposited in the sea or in lakes or swamps, to be later compressed and hardened into sandstone, shale, or conglomerate. In most fields the oil is found in rocks which were deposited in the sea, or in nonmarine strata lying in contact with the marine rocks so that the oil could migrate from the latter; though freshwater beds are also to be considered as possible oil producers.

It has been found that in a large number of cases the sedimentary rocks in oil-bearing localities are made up in part of the skeletons or residues of organisms, many of them minute, which grew in the water, and of the partly carbonized fragments of plants. All these sank to the bottom and were buried in the accumulating sediments. At certain localities, notably in California, the oil and gas appear to be present in areas only where the rocks contain an abundance of the remains of an order of microscopic plants called diatoms; oil in considerable quantity has not been found in other regions even where all other geologic conditions are similar. It is thus the conclusion of most geologists who have studied the California fields that these particular organisms are, in this region at least, the chief original source of the petroleum and gas. Also, since most if not all of the great oil deposits are found in beds laid down in salt water, it is the belief of most geologists that oil originates only in beds formed in sea water. It is, however, to be noted that this view, which directly concerns the question of finding oil in Oregon, has not been proved and may not be correct.

When the small organisms have been buried in the sediments they do not decay like plant and animal remains commonly do at the surface of the earth. Decay consists for the most part of oxidation, the uniting of the oxygen of the air with the carbon in the decaying substances to form carbon dioxide gas, and the union of the hydrogen in the organic compound with oxygen, forming water. Carbon dioxide and water are the two most common products of decay but are usually accompanied by relatively small quantities of other gases having foul odors. Decay on the earth's surface is usually not direct oxidation by the oxygen of the air but is brought about through the agency of the bacteria of decay; these require moisture and hence moist climates hasten decay and dry climates retard or prohibit it. In the bottom of a body of stagnant water oxygen may not be abundant, and if the organic matter is deposited sufficiently rapidly or if it is quickly enough buried and sealed under muds, it does not decay and wholly disappear through oxidation but gradually decomposes or becomes transformed into a variety of substances, from which sooner or later petroleum and natural gas may result. How soon the oil is generated after burial of the remains is somewhat uncertain and, in part, is a subject of disagreement among scientists. Generation of petroleum probably goes on slowly for a long time, and may have been renewed at different periods. As a consequence shale, which is the type of rock usually richest in organic remains, is likely to contain a certain amount of oil wherever the original mud or clay enclosed an abundance of organic remains. But shale is not openly porous and no large quantity of oil can ordinarily be extracted from it through drill holes; concentration of the oil is required and this is brought about through certain geologic conditions to be discussed presently.

## GEOLOGIC PRINCIPLES AS AN AID IN DETERMINING OIL AND GAS POSSIBILITIES

It seems desirable in a report of this kind, intended mainly for readers of whom many, perhaps the great majority, have had no technical training in geologic science, to indicate how geologic principles are used in judging the oil and gas possibilities of a given region.

During the past twenty-five years geologists have studied the geology of scores of oil producing districts in different parts of the world, and they have found that certain geologic conditions almost invariably accompany the production of oil or gas. The reasons why certain conditions should influence the presence or absence of the hydrocarbons are interesting, but it is the fact itself which is more important for practical purposes, and it is that which governs the well-trained oil geologist in reaching his conclusions regarding an area. The type of reasoning is not essentially different from that of the farmer who after long experience on the part of his forbears and himself has found that gravel and sand are not good soils on which to expect a heavy wheat crop and who therefore chooses loam or clay areas in which to carry on his agricultural operations.

The oil geologist similarly, from having noted the geologic conditions accompanying failures in exploratory drilling on the one hand and the conditions in the regions of successful drilling on the other, and having as well been educated by the experience of other geologists as stated in their published writings, is in a position to prophesy with a fair degree of accuracy what the chances of finding oil and gas will be. He can, moreover, indicate in a region of presumed small, mediocre, or large possibilities the most favorable areas, that is, the districts in which the chances are best for bringing in wells. To be sure, his judgments are not infallible, but oil companies the country over have learned through years of experience and the expenditures of enormous sums of money that the services of well-trained oil geologists are desirable if maximum production is to be secured.

The geologic factors and conditions concerned in a judgment of this sort are discussed in the following section, and it will be seen readily that the geologist uses no occult knowledge nor does he guess, but he utilizes his knowledge of the rocks of the earth, and applies common sense.

## GEOLOGIC FACTORS CONCERNED

### PRESENCE OF ORGANIC SHALE

Experience has shown that oil and gas are found almost invariably in a certain class of rocks. The rocks of the earth's surface are of three general kinds: igneous, sedimentary and metamorphic. Igneous rocks are those which have once been molten and have come up in that condition from deep down in the earth, either flowing out on the surface as lava and on cooling forming such fine-grained rocks as basalt or rhyolite, or not quite reaching the surface, and cooling under a cover of other rocks to form coarse-grained rocks like granite. Sedimentary rocks are formed for the most part from clay or mud, sand, and gravel which have been carried by rivers or by other means from upland areas into basins of deposition such as oceans, lakes or river valleys, where these fragmental materials accumulate in layers or strata. They are often known therefore as stratified rocks, and include shales, sandstones, and conglomerates. Metamorphic rocks are formed from either igneous or sedimentary rocks through alteration to such a degree that the original character is to some extent or sometimes almost entirely obscured. They are hence profoundly changed rocks, the changes being due to crushing during uplift or mountain-making, to heat, pressure, solution and re-precipitation, etc. Examples of metamorphic rocks are schists, marbles and slates.

Oil is not found, barring a few exceptional cases, in igneous rocks. This is not surprising, considering that igneous rocks have been molten, and therefore highly heated. The exceptional cases are apparently due to migration of the oil from nearby rocks of other types into the crevices of the igneous rocks and there is no reason to believe that it originated in the latter. Likewise, metamorphic rocks have commonly been so crushed, broken, or affected by solution and re-precipitation, that if they formerly contained oil or gas these would have escaped during the process of metamorphism. We do not find hydrocarbons in metamorphic rocks in important quantities.

The vast bulk of the oil and gas in different parts of the world is found in sedimentary rocks. All the evidence at hand suggests that in most cases it is formed from organic matter in shales, limestones and sandstones, but mostly, however, in such shales as are made up in considerable or large part of the remains of the small organisms already referred to. When such shales or earthy limestone containing organic matter are not found in an area, oil is not usually present in worth while quantities, and gas is rare in such amounts as exist in the important oil and gas fields. In drilling in a field the oil and gas are not usually obtained directly from the shales, but if such organic shales are absent the likelihood that large quantities of oil and gas will be secured is lessened.

Organic shales have originated in fresh water bodies as well as in the sea, but the fresh water shales do not usually contain liquid oil in notable quantities although they do often contain large quantities of solid hydrocarbons. Such are the oil shales of Colorado and Utah. Marine organic shale is therefore regarded by many geologists, including the writer, as, in general, favorable to the occurrence of oil in commercial amounts in a field, though its presence has not been shown to be necessary. The organic shale deposits should be preferably of considerable aggregate thickness. They are recognized as more or less clayey in substance, often dark brown or black in color due to the included organic matter, sometimes greasy when rubbed and commonly smelling like petroleum when broken open to fresh surfaces. Under the microscope the remains of the small organisms are usually visible. Such shales constitute one of the lines of favorable evidence for which oil geologists search in examining a territory.

In the course of geologic ages the organic debris in the rocks becomes gradually altered by the operation of dynamic forces within the earth so that progressive changes occur in the proportions of the carbon, hydrogen, and oxygen. These changes, marked by losses of volatile matter, are included under the terms "carbonization" and "metamorphism." They are the results of what is in effect, distillation of the organic matter in the buried strata by natural geologic processes attended by pressure and some heat. Gases and, supposedly, oils are products of these changes. When the carbonization and metamorphism have advanced too far, oil pools are no longer to be expected in the beds. This also is taken into account by the geologist.

### POROUS SANDSTONES TO ACT AS RESERVOIRS

In general, shale is not a good reservoir for oil, because it is apt to be so compact and deficient in permeability by reason of the clayey matter of which it is composed that oil cannot readily move through it to escape into a well. Where it is less argillaceous it is more porous and may then serve as an oil sand though it seldom makes a good one. Usually the flow is relatively slow. More often there is no flow. This is well shown in most oil-fields.

The ideal underground oil reservoir is a porous rock which can hold large quantities of oil and gas in its open spaces and through which the oil and gas can flow freely to the drill hole and hence to the surface. It is for this reason that oil and gas are found in what are known as oil or gas sands, which are not particular kinds of sands but merely sands or sandstones or even porous shales, as noted above, which contain oil or gas. In some cases broken up or porous limestone strata or even honeycombed sheets of interbedded igneous rocks serve the same purpose. The oil or gas having been formed in the shale and limestone layers, move out of these into the porous sandstone or limestone zones lying over or under them, which then become the great underground reservoirs of commercial supply. Oil does not exist under the ground in great caverns or lakes, as is often thought, but merely fills the pores of open-textured rocks, or the solution circulation passages in such as limestone, from which it can be drawn freely through a well. The oil geologist, therefore, hopes to find in a prospective field not merely considerable thicknesses of organic carbonaceous shale, but between the shales sandstone beds also that are of sufficient thickness to serve as the oil reservoirs.

### ANTICLINES AND DOMES

Experience has shown that oil and gas are not found evenly distributed throughout areas containing strata of favorable composition and physical condition, but that they usually occur under regions where the rocks have been arched upward, forming anticlines or domes. Shales and sandstones are deposited in nearly-horizontal sheets, each bed ranging in thickness from almost nothing up to several hundred feet. Later, however, as the result of lateral pressure, or for other reasons, these sheets are often warped or folded as sheets of paper will be when the ends are pushed toward each other. The arches are called anticlines; the troughs synclines. In other cases limited portions of what were once horizontal strata, have been pushed up apparently by pressure from below, above the general level of their continuation in the surrounding country; these are domes. Stated in simplest terms, gas is usually found in the highest part of the sandstone in the anticline or dome; below the gas lies the oil, also in the sandstone, and beneath the oil is usually water, commonly salt to some degree. This arrangement is undoubtedly due to the fact that gas is the lighter of the three, and the oil is lighter than water.

Oil has been found in strata not forming anticlines or domes. Sometimes it occurs beneath terraces as in Oklahoma, these being formed simply by the flattening of beds which otherwise have a uniform dip in one direction over large areas. It is sometimes found in synclines or troughs but not commonly. Lastly, oil has also been found under a considerable variety of structural conditions.

The reason why oil and gas are found largely in anticlines and domes is because these structures tend to concentrate the oil and gas into relatively small areas. When the hydrocarbons in the shales, where as indicated above they are largely inaccessible so far as extracting the oil and gas is concerned, migrate in part into the adjoining sandstone strata which lie horizontally, they are still distributed over large areas and the amount in the sandstone would in most cases probably be insufficient to produce commercial wells. But if the strata are folded into anticlines or domes and saturated with water as they usually are, the oil and gas on emerging from the shale into the sandstone find themselves surrounded with a medium heavier than themselves, and by gravity tend to rise in it as a piece of wood might do if liberated from one's hand at the bottom of a filled tub of water. Rising means movement within the sandstone stratum toward the top of the dome or anticline, for the shale which overlies the sandstone is more or less completely impermeable to the oil and gas and tends to oppose the further vertical passage of these hydrocarbons. Movement of the water aids the latter in their motion up the sides of the folds. Hence the hydrocarbons progress toward the tops of the anticlines and domes from the whole area of the sloping sides and thus bring about accumulation of the oil and gas, a very fortunate circumstance for mankind.

The pressure in the anticlines and domes, which is usually known as rock pressure and often drives out the oil and gas and causes thereby oil and gas springs and flowing wells, is not believed to be due in reality to the weight of the overlying rock at all; in my opinion, it is due to the fact that as the organic matter decomposes to form the oil and gas, solid material is being changed in part to a gas which naturally needs a larger space, and a certain degree of pressure is thus produced. The case is similar to the decomposition of preserved fruit in a can; the gas pressure often bursts the receptacle.

Having indicated here the important role which anticlines and domes commonly play in the accumulation of oil underground, it ought to be pointed out that anticlines and domes are not necessarily hills or ridges on the landscape. Hills are formed of course when the strata are folded rapidly but they are often worn entirely away by streams and other erosional activities, so that often a region is a plain or even a valley and yet has anticlinal or dome structure in the strata beneath it. The oil geologist in search of anticlines or domes in an area of sandstones or shales does not therefore simply seek ridges or round hills; he searches for areas where the outcropping rocks dip away in both directions from a line or in all directions from a point, the former indicating the anticline and the latter the dome. Surface topography often has little or no relation to the underground structure which governs the accumulation of the oil and gas.

## OTHER FACTORS

Besides the presence of organic shales, preferably marine, porous sandstone beds interstratified with the shales, and anticlinal or dome structure, there are certain other field evidences favorable to the possible occurrence of oil or gas in a region. Such are oil seeps, oil springs, gas springs, presence of tarry material in the edges of outcropping strata, or of solid bituminous substance in veins or seams in the strata.

Seepages of oil are commonly characterized by accumulations of black or brown tarry material representing the heavier parts of the oil that are left after the light constituents which make up gasoline and kerosene have evaporated. This accumulation may weather to a light gray color so as to effectually conceal the character of the material which composes it, and even oil-impregnated sandstones may give no hint by their surface appearance that they were once saturated with live petroleum. Weathering rarely penetrates far from the surface, however, and a fresh fracture commonly not only reveals a brown or black color but liberates sufficient gas to give the characteristic smell of oil. Very light or thin oil with a paraffine base may not leave any tarry accumulation, and seepages of the liquid may be light brown to lemon yellow in color, in contrast to the blackness of most asphaltic oils. The presence of residues from such oils in sandstones which they have impregnated may sometimes be determined only through chemical tests, and through the petroleum odor of freshly broken surfaces of the oil-bearing rock. Oils that are clear or transparent have never been detected in seepages, and reports of natural occurrences of such oils in seepages can justifiably be doubted.

Oil springs are among the commonest supposed evidences of oil reported by the people living in a region under investigation. Oil in water wells may be grouped with these, since wells are in a sense only artificial spring holes. There is little difficulty in recognizing an oil spring; oil comes to the surface of the water as drops of amber, brown, or nearly black material, usually floats to the side of the pool and adhering there loses its lighter constituents and becomes a tar. The oil spring is therefore very commonly surrounded by viscous to solid asphaltic material. The water commonly has an iridescent or multicolored film on it characteristic of oil. By far the great majority of springs reported by interested people as showing signs of oil have films on the water which are often iridescent, but the films are not oil. They usually represent an iron compound which has been in solution in the water and which on coming in contact with the air at the surface has become insoluble and thus formed the film. Iron in the form of rust-colored material often coats the bottom of such springs or pools. The iron film can be distinguished immediately from a true oil film by pushing a stick through it; if it cracks and breaks into angular patches on the surface of the water it is iron or some other substance not oil. This is a simple test.

Gas springs and both artesian and common water wells are often cited as evidence of oil and gas in a region. In all three cases bubbles of gas sometimes rise through the water which it may even be possible to ignite as they burst on the surface, with a resulting explosive sound of greater or less distinctness. If the gas issues in sufficient quantity it is sometimes possible to pipe it for domestic use in nearby buildings. The quantity and the composition of such gas determines whether it is to be considered as suggestive evidence of the presence underground of quantities of oil and gas. If it issues in large amounts and at considerable pressure, and the pressure or amount do not decrease rapidly with time, it may be inferred that considerable quantities of gas possibly fill the porous rocks underlying the region and that it might pay to drill for such a gas supply at nearby points. If the gas consists almost entirely of the constituent methane or marsh gas, as is the case with gas showings in large areas of the country, it is not a favorable suggestion as to the presence of oil accompanying it. Marsh gas is commonly known as dry gas. It is usually derived from wood, leaves, and other vegetable material buried in the sediments at the time of their deposition. Larger or smaller quantities of it issue from a large fraction of all deep wells drilled in freshwater sediments.

In the neighborhood of oil-fields the outcropping strata are often impregnated with oily or asphaltic material which is commonly brown or black in color. This material represents residues left after the evaporation of the lighter constituents of the oil which filled these beds. It is therefore first hand evidence at least of the former presence of oil in the region, and suggests strongly that oil may exist in commercial quantities in neighboring areas at the present time. It indicates that the proper formations are present in the region for the formation of oil. While the material in the outcrops may evidence the dissipation of that particular body of oil, the general region is likely to contain reservoirs from which the petroleum has not yet escaped.

The presence of veins or seams of bituminous substances are likewise suggestive evidence for the presence of oil in the general region where they occur, unless regional carbonization has advanced too far.

From the foregoing remarks it is apparent that the more favorable indications of the presence of petroleum and natural gas in a territory are the existence in it of notable quantities of organic shale, especially marine shale, the presence of porous sandstones to act as reservoirs, gentle folding in the strata by which anticlines and domes are produced, and oil seeps and oil-impregnated strata.

It is scarcely necessary to mention that the so-called divining rod and other similar devices, held in the hands of self-styled "oil experts" and claimed by them to indicate, by pointing, the position of oil or gas pools, are absolutely unreliable and valueless.

## TOPOGRAPHIC FEATURES OF EASTERN OREGON

Nearly two-thirds of the area of the state of Oregon lies east of the Cascade Range. This portion is commonly known as Eastern Oregon. Topographically most of it is a plateau. It rises from a few hundred feet above sea level at the Columbia river which bounds this portion of the state on the north, to general elevations of about 5,000 feet in the central and southern parts. Along its eastern border in the Snake river region the elevations descend to about 2,500 feet. To the northeast of the center of this plateau area lies a mountainous tract known usually as the Blue Mountains, the principal parts of which consist of a main ridge west of Baker trending roughly north and south and three east-west ridges extending westward from it and descending gradually in elevation toward the Deschutes river. The main ridge near Baker attains elevations of over 9,000 feet and is continued northeastward beyond Pendleton into southeastern Washington. The southern portion of the plateau also contains mountainous ranges extending northward from California and Nevada. Except for the mountains noted the plateau surface is quite even. It is mainly a sagebrush country due to its semi-arid climate.

## OUTLINE OF THE GEOLOGY OF EASTERN OREGON

A sketch of the geology of each district will precede the discussion of its oil and gas possibilities in the following pages, but it is perhaps desirable to present a brief outline of the broader geologic features.

The whole plateau region, north, west, and south of the Blue Mountains is underlain by volcanic rocks of Tertiary age in the form of lava flows and interstratified tuff and volcanic ash beds. Associated with these at some localities, as in the John Day region and in the vicinity of Vale and Ontario, there are thick series of Tertiary sedimentary rocks which usually contain also large admixtures of volcanic ash. The lavas are believed to have issued from fissure vents rather than from craters; the ashes were probably blown out of these same fissures and spread over the surrounding country. The sedimentary beds both underlie and overlie the lavas and are hence believed to have been deposited by lakes and streams both before the lavas flowed out on the country and afterward on the surface of the lavas. Since the lavas and sediments were deposited they have been warped, folded, and faulted somewhat, and to varying degrees in the different parts of the plateau area.

The principal exception to the geologic conditions just enumerated occurs in the Blue Mountains, where there are high-lying areas of granite,

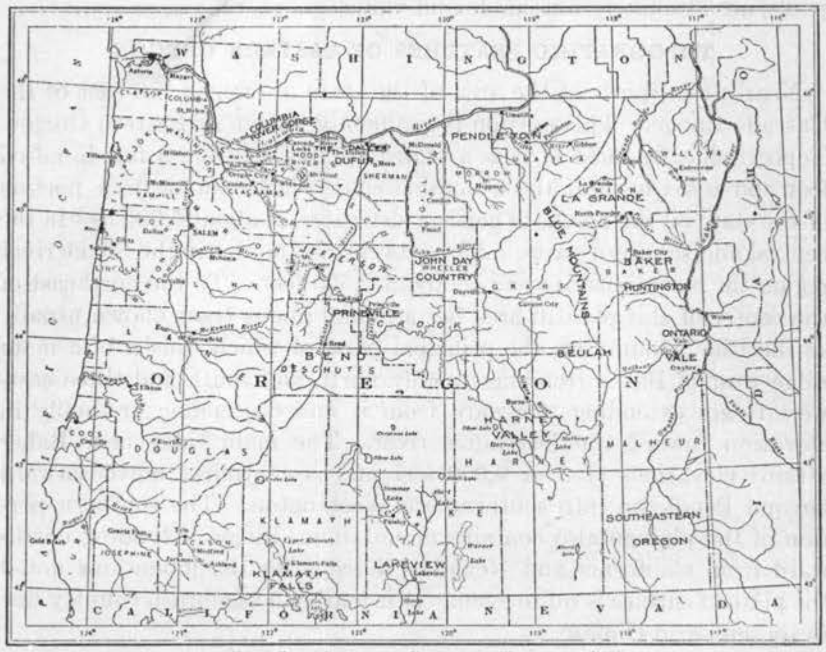


**Fig. 1. Districts of Eastern Oregon discussed in this report.**

Paleozoic and Mesozoic sedimentary rocks—all older strata than the Tertiary lavas, ashes, and sedimentaries of the plateau portion of the country. These areas of older rocks are, however, relatively insignificant in size as compared with the areas underlain by the volcanic rocks of the plateau. The older sedimentaries are acutely folded and considerably faulted.

The physiographic features of the country, such as the mountain ranges, valleys, plains and river canyons, are all relatively young, geologically speaking. They have been formed through crustal folding and erosion since about the end of the Miocene, that is, since the outflow of the most extensive of the lava series. It has been held in the past that the Blue Mountains stood as islands in this lava flood, but if so they were certainly much smaller and lower than at present, for the lavas still lie over much of the high areas and slope down the sides, indicating that the uplift has occurred mainly since, rather than before, the lava floods.

## OIL AND GAS POSSIBILITIES OF THE DIFFERENT DISTRICTS

For purposes of discussion the eastern part of Oregon has been divided into fifteen districts based in part upon topographic and geologic considerations and in part upon the interest manifested in them by drilling and intentions to drill. These districts differ greatly in size and are not sharply marked off from each other.

A brief summary of the geologic conditions in each district will be given, followed by a statement of the exploratory drilling which has been done. A judgment as to the oil and gas possibilities will follow and the evidence on which it is based will be indicated.

### COLUMBIA RIVER GORGE

The fact that oil and gas are commonly found in arches or anticlines in folded rocks has become rather generally known during recent years, even to those not technically trained in oil geology, and it is also a matter of common knowledge that mountain ranges are usually composed of a series of such arches alternating with downfolds or synclines. Presumably because of these facts a number of persons suggested to the writer during his investigation that the main fold of the Cascade Range, exhibited so beautifully in cross section in the Columbia river gorge, might contain oil and gas if properly drilled. The writer examined the gorge along both sides of the Columbia with this possibility in mind, and it seems desirable to give an answer to the above proposal here.

The Cascade Range trends north and south, and where the Columbia cuts through it, consists of three upfolds or anticlines separated by troughs or synclines, all trending roughly parallel to the Range itself. These folds are beautifully shown in cross section in the steep walls of the gorge, and have been clearly exhibited in drawings by Williams.[1] The major fold, the middle or axis of which lies somewhere near the

[1]The Columbia River Gorge: Its Geologic History, by Ira A. Williams. See "Mineral Resources of Oregon," published by the Oregon Bureau of Mines and Geology, vol. 2, no. 3, 1916.

town of Cascade Locks, is broad and forms the main ridge of the Cascades, but it is paralleled on the east by two sharper anticlines between Hood River and The Dalles which have steeper sides but are considerably narrower. The rocks which make up these folds consist mainly of lavas. The topmost or youngest rocks in the main fold, outcropping along the rim of the gorge, are basic lavas somewhat different from those found lower down in the face; they are termed andesites and basalts by Williams and Bretz. Beneath these sheets of lava lies a formation of river gravels, sands and ash prevailingly from one to two hundred feet thick. Under this gravel formation lie the great Columbia River basalt sheets, the main formation exposed in the gorge. The Columbia river flowed across this area before the Cascades were uplifted, and while they were being slowly upraised across its path it cut its great channel down through the 2,500 to 3,000 feet of basalts. It exposed beneath them a set of beds known as the Eagle Creek formation, made up mainly of volcanic ash, pumice, and other volcanic materials, along with sands, gravels, and shales. Its thickness is unknown because the river has not yet cut through it. The Eagle Creek formation is not of marine origin; its volcanic materials were for the most part distributed with the aid of fresh water. It contains fossil wood and fossil leaves.

No deep drilling has been done in the vicinity of Cascade Locks or Bonneville so far as the writer is aware. The exposed formations being dominantly volcanic in nature, obviously do not suggest the presence of oil or of gas in commercial quantities. The Coast Ranges west of Portland are composed mainly of marine strata, however, and these are interstratified with and extend under the lavas of the Cascade Range to a greater or less distance. It is possible that they underlie the Eagle Creek strata in the Cascade Locks and Bonneville region.

The prospects for striking oil in the gorge are nevertheless not encouraging. Even if the marine strata should extend beneath the Eagle Creek formation at Cascade Locks, there is little reason to think they will contain oil, for these marine beds where exposed over vast areas in western Oregon, have not to date produced oil in paying quantities. Furthermore, since the thickness of the overlying Eagle Creek formation is not known, they might even if present lie at such great depth that it would be impracticable to try to prospect them with the drill. Since the Eagle Creek beds are volcanic in character, it is not unlikely that lava flows would be encountered in them; this would make slow and expensive drilling.

It is quite possible that small flows of gas might be encountered in drilling in the Eagle Creek, since it contains a certain amount of fossil wood, leaves, and other vegetable matter, but the quantities derived from such sources are commonly not large or valuable.

If, in spite of the facts above adduced, there are still those who would wish to test out the gorge area with the drill, it might be suggested that the least undesirable locality in which to put down a hole would be near the axis of the fold, that is, at some point in the gorge between Bonneville and Cascade Locks, preferably a mile or two east of the mouth of Eagle creek. It should be recognized, however, that the chances for success are very slender.

## THE DALLES

Several wells have been drilled in the past sixteen or seventeen years west of The Dalles at Chenoweth ranch and farther up Chenoweth creek, to depths ranging from about 100 feet to about 400 feet, to prospect for coal. The stimulus for this drilling was the report that a 15-foot seam of coal had been struck in a well on or near the Murray place many years ago at a depth near 400 feet. No oil or notable quantities of gas are reported to have been struck in these wells, but on account of the sedimentary rocks prominently exposed in the vicinity of The Dalles the writer examined the surrounding region in response to interest shown in the oil and gas possibilities.

The principal formations exposed in The Dalles region are, first, a sedimentary formation heretofore commonly known as The Dalles beds, consisting of white to gray and bluish white beds of sandstone and volcanic ash with some conglomerate strata; second, some basic volcanic rocks overlying The Dalles formation in the upper part of the drainage of Chenoweth and Mill creeks; and third, the Columbia River basalt underlying The Dalles beds and well exposed both north of The Dalles and to the west in the Columbia gorge. The lavas and overlying Dalles formation along the east side of the mountain west of Chenoweth creek dip eastward, but in the bluffs east of Chenoweth creek the sandstones lie approximately horizontal.

Since sedimentary rocks are the only types which need to be considered from the standpoint of oil possibilities, The Dalles formation above and such sedimentary beds as may underlie the Columbia River lava are the only formations in this region to deserve discussion. The Dalles beds are clearly of freshwater origin; they were apparently deposited in lakes and by streams. They may contain considerable amounts of vegetable organic matter but there do not appear to be among them strata which would originate petroleum. The structure, furthermore, so far as examined by the writer, is not favorable for oil accumulation, since the beds form a fold which is more nearly synclinal than anticlinal in form. The oil possibilities are therefore probably poor. Gas in small quantities might be produced by wells sunk into The Dalles formation, the gas coming from wood and other vegetable material buried in the formation at the time of deposition; but the experience of gas wells in freshwater deposits of similar character in other parts of the country does not encourage hopes of obtaining a large supply.

The chances of getting oil or gas from sedimentary rocks which may lie below the Columbia River basalt are conditioned by a number of uncertain factors: first, drilling through some 2,500 or 3,000 feet of basalt as exposed in the gorge to the west, a tedious and very expensive task; second, the uncertainty as to whether sedimentary beds underlie the basalt at The Dalles; third, the uncertainty whether oil or gas in important quantities would occur in the beds beneath the lavas, even if sedimentary beds are present there. There does not appear to be a basis for a more optimistic view regarding oil or gas beneath the lavas than regarding these substances in The Dalles beds resting upon them.

### DUFUR

For more than fifteen years interest has been shown in the oil and gas possibilities of the Dufur region in northern Wasco county. At some time previous to 1907 the Dufur Oil Company drilled five holes, according to Mr. L. M. Smith of Dufur, about five miles west of Dufur on Fifteen-Mile creek. The writer found part of the casing in the ground and wreckage of derricks and machinery still remaining at three of these holes. The holes are reported to have been sunk only a few hundred feet. Farther west, on Ramsey creek, ten miles west of Dufur, the Beavis-May Oil Company drilled a hole in 1907 to a depth of 1,710 feet. The derrick is still standing. Another hole was drilled in April and May, 1919, about 200 feet from the first. It had reached a depth of 1,125 feet at the time of the writer's visit in July, 1919, and while work had been discontinued, the operators expected to resume drilling.

Geologic conditions in the Dufur region are essentially similar to those at The Dalles. The surface formation is a series of volcanic gravels, agglomerates, ash beds and sandstones, lying on basic lavas which are exposed to the west, the whole series dipping gently eastward in the region between Dufur and the wells on Ramsey creek. Like The Dalles beds the formation is not marine in origin but was formed as volcanic mud flows, by river deposition and in lakes. Small pockets of gas may be encountered in drilling through it, derived from vegetable material buried with the sediments, but the volcanic components of the strata, the lack of organic shales, and the absence of favorable structures for the accumulation of petroleum or natural gas in large quantities, indicate that there is little or no basis for the hope that commercial quantities of oil or gas will be secured in this territory. The task of drilling through the thick lavas which underlie the sedimentary beds is similar to what it would be at The Dalles, and since there is no evidence at hand that oil or gas is present in notable quantities in the sedimentary beds which may underlie the lavas at depths of presumably 3,000 feet plus the unknown thickness of the sedimentary beds, deep drilling through the basalts can only be characterized as most hazardous.

### PENDLETON

The general region between The Dalles and Pendleton in Umatilla county and extending as far south as Shaniko in Wasco, Fossil in Wheeler county and the crest of the northern ridge of the Blue Mountains, is a relatively smooth surface sloping northward to the Columbia river. While deep drilling for water has been reported at two or three localities, no exploring for oil or gas has been done so far as the writer is aware.

The geologic conditions are somewhat similar to those at The Dalles and Dufur in that the bedrock of the country is mainly volcanic lava, though the sedimentary rocks which overlie the lavas are apparently not so extensive as at The Dalles and Dufur. Instead, there are surficial deposits of wind-blown silt and soil, and of clays and gravels in some districts. The lavas nevertheless constitute the surface rocks over large areas. Such sedimentary rocks as occur can scarcely be considered a likely source of oil or gas.

Holes put down in this region are almost certain to encounter the Columbia River basalt at no great depth; to drill through its thickness of 2,000 to 3,000 feet is obviously a highly expensive task and doubtfully justifiable in view of the uncertainty regarding the nature of the formations which underlie these lavas. This general region cannot be characterized, therefore, as one in which the indications for securing commercial quantities of oil or gas are hopeful. A well to hazard the test should be located on good structure and backed only by money the loss of which will not be seriously felt.

### THE JOHN DAY COUNTRY

The term John Day country is here used to designate not merely the John Day valley along the south fork of the stream of the same name, but the whole region comprised by the drainage basins of the three forks of that stream, in Wheeler and Grant counties.

The John Day country has extensive exposures within its boundaries of a larger number of formations and probably as great a variety of rocks than has any other district in eastern Oregon to be discussed in this report. Sedimentary strata stand exposed in magnificent sections and those who depend merely upon similarity in appearance of the formations in a region to those of a productive oil territory, would be impressed with the possibilities of the John Day country.

The geology of parts of the John Day country was described by Professor John C. Merriam[1] some twenty years ago, and a geologic map of a part of the area with further description was published by Collier[2] as a bulletin of the Oregon Bureau of Mines and Geology about five years ago.

The oldest rocks are found in the east-west range paralleling the east fork of John Day river on the south. These are first, old sedimentary strata now much changed by folding, crumpling, faulting and other altering activities, and second, granitoid rocks. Overlying these formations are Cretaceous strata, in the southwestern part of the territory, distributed in several relatively small areas. The Cretaceous beds are of marine origin, having been deposited over this region at a time when the sea invaded northeastern Oregon. Whether they are present beneath the younger formations over most of the John Day country is not known.

The next younger formation is one of dominantly volcanic origin known as the Clarno, of Eocene age. Its most extensive exposures are in the region between Mitchell and Clarno. Lavas, volcanic ash, and some sandstones and shales of freshwater origin compose the series. While the older Cretaceous formations contain sea shells as fossils, and the overlying Tertiary rocks have numerous bones distributed through them representing the land life of the time, the Clarno has not thus far furnished fossil material except the imprints of leaves.

Overlying the Clarno is a set of strata exposed mainly between Twickenham, Spray and Monument known as the John Day formation. The large quantity of fossil bones found in these beds has made the John Day region famous as a collecting ground. The John Day formation is made up of volcanic tuffs, sandstones and shales, all laid down in lakes, by rivers, or on land. A great series of black basaltic lavas of middle or upper Miocene age, two to three thousand feet thick, rest upon the John Day beds and are exposed over extensive areas in various parts of the John Day region. This is the Columbia River basalt.

Along the south fork of John Day river middle or upper Miocene beds rest upon the Columbia River lava These strata consist mainly of volcanic ash and ashy sandstones and also contain the bones of land

[1]A contribution to the geology of the John Day Basin: Univ. Calif. Bull. Dept. Geol., vol. 2, pp. 269-314, 1901.

[2]Vol. 1, no. 3.

animals. They were deposited by fresh water and on land, and are known as the Mascall formation.

The youngest sediments in the region, excepting the alluvium of the valleys, compose the Pliocene Rattlesnake formation. Like the Mascall, these beds are distributed mainly along the south fork of John Day river. They are mainly gravels and coarse sands and like the Mascall and John Day contain bones of land animals sparingly. These sediments are of fresh water origin. The Rattlesnake formation includes also a prominent bed of rhyolitic tuff.

The thickness of these formations varies widely from place to place. The thickness of the Cretaceous strata is not definitely known, but the post-Cretaceous beds have an aggregate thickness of 7,000 or 8,000 feet. The whole area has been folded along east-west axes in general, and deep erosion has occurred since, resulting in a region of mountainous relief.

A number of wells and springs in the John Day country which were reported to carry films of oil were examined by the writer but in each case the material on the water was an iron scum. The most suggestive information reported is the supposed occurrence of asphaltum in the Clarno formation first cited in 1914 by Collier in the bulletin already referred to and located by him as approximately in S. 26, T. 7 S., R. 19 E.; this is two or three miles east of Clarno.

It was reported to Mr. Collier that quartz geodes were found containing grains of asphaltum; one geode is said to have contained a quart of the hydrocarbon. On the Huntley ranch a little farther east several bushels of asphaltum were reported to Mr. Collier to have been taken out of the bluffs, the whole deposit having been exhausted, only small particles of the asphalt being still found scattered through the ashy beds. The writer's rather hurried visit to this territory added few facts to those reported to Mr. Collier. This occurrence is certainly an interesting one. The writer examined considerable areas of the Clarno formation north of Mitchell but failed to discover any further occurrences of asphaltum.

The supposed asphalt occurrences east of Clarno are deserving of more careful investigation than either Mr. Collier or the writer have been able to make. The Clarno formation is the oldest of the Tertiary deposits in the John Day country; presumably the Cretaceous marine formations immediately underlie the Clarno formation if they are present in this part of the Blue Mountains. These facts are of interest because the Cretaceous strata are the youngest marine strata in the region; being marine they hold out somewhat more hope of being petroleum producers than the non-marine series overlying them. Cretaceous strata are known to have produced paraffine oil in the

Coalinga oil field in the Coast Ranges of California and it would not be a matter of great surprise if Cretaceous beds in the Blue Mountains were found to have originated a certain amount of petroleum. The immediately overlying Clarno formation would probably be the most likely set of strata, other than the Cretaceous beds themselves, to show indications of the presence of oil originating in the Cretaceous beds. These facts make the reported occurrence of asphalt in the Clarno formation all the more interesting.

The writer therefore agrees with Mr. Collier as expressed in Volume I, No. 3 of this publication, that the sinking of one or two deep wells near the Huntley ranch would be justified. The chances for success are of course small in any unproved oil territory, but speaking entirely in relative terms the chances at this locality appear to be better than in other parts of the John Day country or for that matter in most other parts of eastern Oregon. Before drilling is done, however, a more detailed examination of the whole surrounding region should be made by a competent geologist; the exact nature of the materials reported as asphalt should, if possible, be ascertained; other seeps should be looked for; and the structure of the country should be more thoroughly determined. The locality is an interesting one, but it should be emphasized that exploratory drilling will have only one chance in many of success.

The Clarno formation is exposed over considerable areas in the John Day region and it is possible that there are other localities in it or in the underlying marine Cretaceous formations that are fully as promising as the Huntley Ranch area. In the writer's rapid reconnaissance, however, no other such areas were outlined. Detailed work with this end in view would be worth while from the standpoint of furnishing helpful advice to those who desire to explore the John Day country with the drill.

The Columbia River lava and the John Day, Mascall and Rattlesnake formations, consisting entirely of volcanic materials such as lavas and ash, and of freshwater sediments, are not in general looked upon favorably by most geologists as originators of oil or gas in quantity, on account of their fresh water and volcanic origin. They lie much higher in the succession of beds stratigraphically, and it is not likely that they could have received important quantities of any hydrocarbons which might originate in underlying marine beds, though there is of course a bare possibility that oil or gas may have formed in one of these sedimentary formations if the carbonaceous matter is ample. The John Day country is, however, on the whole a district in which the chances for obtaining oil are not promising. Relatively small flows of gas can probably be obtained in some localities from the John Day or the Mascall formation, the gas having been derived from vegetable material buried with the sediments. The amounts are not likely to be large and the history of gas wells in fresh water formations suggests that they are usually short-lived.

## BLUE MOUNTAINS

The Blue Mountains, situated in northeastern Oregon, are in a sense outliers of the high Rocky Mountain country of Idaho and western Montana, from which they are separated mainly by the faulted La Grande and Baker valleys. The trend of the higher parts of the range is roughly north and south along the west side of the above named valleys. From this north-south line of heights three broad ridges with intervening valleys slope westward to form the John Day country. The Blue Mountains can be thought of as a huge block of the earth's crust that has broken away from the country to the east by a zone of faulting situated at its eastern base, the block having been raised some thousands of feet along its eastern margin and tilted westward. The structure is of course complicated by additional faulting and folding which occurred for the most part at a yet earlier date, but the break along its eastern margin seems to have blocked out the range and produced the main features of the present topography. This faulting occurred in relatively recent geologic time, most of it at least since the extensive lava flows of the region were extruded

The higher parts of the Blue Mountains are made of older rocks than those which compose nearly all the remainder of the state. Older Paleozoic sedimentary formations and early Mesozoic strata are found here, sharply folded, faulted, and intruded at numerous localities by granite and other coarse-grained igneous rocks. Later lavas broke through these rocks and covered much of the middle and lower slopes. While these geologic conditions are favorable for the development of ore bodies, they are not likely to lead to the accumulation of oil or gas in quantity. The writer has received no reports of seeps or other indications in this territory. A large part of the rocks are of marine origin and it would not be surprising if asphalt or other carbonaceous residues were found in them locally but the deformation they have suffered has no doubt led to the leakage and dissipation of any oil or gas which may originally have been present.

## LA GRANDE-BAKER-HUNTINGTON

A series of valleys extend along the east side of the Blue Mountains from north of LaGrande in Union county to the Rye valley region northwest of Huntington, in eastern Baker county. The geologic history of this whole valley region has apparently been quite similar in its broader aspects and it is therefore proposed to treat of its oil and gas possibilities in one section.

This valley district was formed through the depression of a north-south area of the earth's crust between the Blue Mountains and the Wallowa Mountains. The depression resulted in part from faulting along the western margin of the valley zone, and in part from warping of the crust. The rocks of the floor of the valleys are in part the old rocks of the adjacent mountains, but over large areas these are covered by later freshwater sedimentary strata and lavas of about the same age.

It has commonly been considered that the freshwater beds were deposited in lakes which in Miocene time filled essentially the present valleys, but the writer is of the opinion that the major part of the movements which created the present valleys and mountain ranges has occurred since the sedimentary strata were deposited. To be sure, the valleys in which the sediments were laid down and in which the associated lavas came to rest occupy areas in part identical with those of the present valleys, but the strata extended in many cases beyond the margins of the present valleys and were cut off by the faulting. The relief was apparently much less in Miocene time, and the present valleys and mountains are due mainly to post-Miocene faulting and warping.

During the Miocene, basaltic lavas flowed out over the older rocks and basins of deposition were formed, in part by warping of the surface and in part by damming of drainage lines by lava flows. Freshwater sands, clays, and gravels were deposited by streams and in part by lakes, together with beds of volcanic ash. Through faulting and erosion these strata and the lavas are now exposed at many points in the valley zone from north of LaGrande nearly to Huntington. They have been faulted somewhat and folded so that the beds seldom lie horizontal.

The older rocks are in a broad way similar to those found in the Blue Mountains to the west, from which they have been separated by faulting. In part of marine origin, they have, however, been folded, faulted, and metamorphosed to a degree which makes it improbable that they still retain stores of oil or gas. They are not unlike the rocks of the Blue Mountains in this respect. The younger rocks overlying them do not offer much greater hope. The basaltic lavas can at once be eliminated. The freshwater strata, if dependence can be placed upon the prevalently supposed absence of petroleum in beds of that origin, also do not offer much promise for an oil supply. Drilling in them can be expected to encounter pockets of gas especially on anticlinal or domal structure, and it is even possible that the freshwater beds may contain oil, though the rarity of oil in commercial amounts in non-marine strata is a somewhat discouraging factor. The freshwater beds do not lie in direct contact with marine beds.

### PRINEVILLE

The great series of basaltic lavas of Miocene age, which is so extensive between The Dalles and Pendleton, and known as the Columbia River basalt, extends southward through the depression followed by the Deschutes river between the western end of the mountainous John Day country and the Cascade Range, and underlies much of south-central and southeastern Oregon. The lavas extend varying distances up the south flanks of the broad east-west ridge which forms the southern part of the Blue Mountains between Prineville and Vale.

The geology of some of the region stretching westward from Prineville toward the Deschutes river, northwestward beyond Madras, southward and southeastward toward Burns and the Harney valley, is intimately related to this great lava series. The region is mostly hilly but not mountainous; it contains some exposures of sedimentary beds but the great bulk of the rocks are lavas. Besides the basalts there are areas of rhyolites and rhyolitic tuff, especially in the Madras, Hay creek and Ochoco regions. Between the lavas are often white beds of ash or volcanic agglomerate. Such sedimentary beds as occur are freshwater or landlaid; marine strata may occur in the mountains to the north or northeast, but none were found in the Prineville region.

A number of supposed oil seeps were visited by the writer, but all were found to be springs or pools bearing iron films.

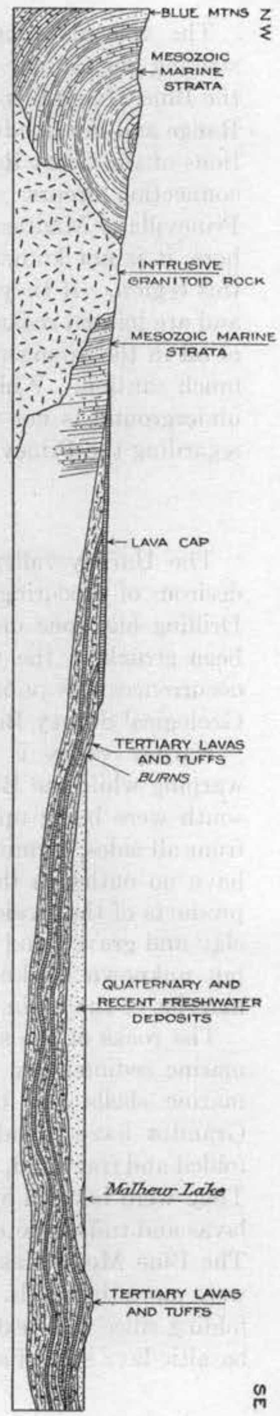


Fig. 2. Generalized northwest-southeast sketch section through Burns, Oregon. Vertical scale greatly exaggerated.

The volcanic nature of the country does not encourage hopes of striking petroleum. It is probable that the marine Cretaceous beds in the Blue Mountains extend westward beneath the lavas of the Cascade Range and intermediate country to connect with the Cretaceous formations of the Coast Ranges but it is not known through what region the connection occurs. It cannot be stated that it is not through the Prineville or Madras sections, but even if it were assumed to be present here, it is not known whether the Cretaceous rocks are oil-bearing in this region. If they are, the lava flows overlying them are very thick and are jointed rocks unadapted to storing petroleum. The occurrence of oil in the younger sediments is a possibility to be viewed only with much caution. While condemnation of any region where the geology underground is not fully known is unsafe, the facts as far as known regarding the Prineville region are not encouraging.

## HARNEY VALLEY

The Harney valley has for many years excited the interest of those desirous of procuring a commercial oil or gas supply in eastern Oregon. Drilling has gone on intermittently and small quantities of gas have been struck in the wells from time to time. A brief note on these occurrences was published by Chester W. Washburne in 1911 in U. S. Geological Survey Bulletin No. 431.

Harney valley is a broad synclinal depression formed by downwarping while the Blue Mountains to the north and the region to the south were being uplifted. The drainage is therefore into the valley from all sides, forming the shallow Malheur and Harney lakes, which have no outlet to the sea. This drainage carries into the valley the products of the erosion of the surrounding country in the form of sand, clay and gravel, and it has built up a series of deposits of considerable but unknown thickness in the middle, and of some extent along the margins of the basin.

The rocks of the slopes of the Blue Mountains to the north are old marine sedimentary formations, probably of Jurassic age, containing marine shells and consisting of sandstones, shales and limestones. Granites have invaded these strata. They have been considerably folded and fractured, and metamorphosed to some extent by the granite. They were beveled by erosion before about middle Tertiary time, when lavas and tuffs were deposited across their beveled edges (see fig. 1). The Blue Mountains were then much lower than now, if indeed they were more than hills. The lavas too have been deformed somewhat by folding since their extrusion. Still later, probably during the Pliocene, basaltic lava spread as a thin sheet over nearly the whole region. It is these thin lava flows which form the rim of the valley at so many points near Harney and Burns. The considerable slope of these thin sheets toward the Harney valley probably indicates that the uplift of the Blue Mountains and depression of Harney valley has in the main occurred since the outflow of these latest lava sheets.

At the time of the writer's visit active drilling was in progress on two wells in the Burns region. About 1912 the Central Oregon Oil and Gas Company commenced drilling near Dog mountain, about 12 miles south of Burns (fig. 1). Mr. Stemen, the driller, reported the depth of this well at the time of the writer's visit as 3763 feet. The well is said to have given a little gas and to have shown a trace of oil. It is located in a gulch opening out into Harney valley. The formation into which it is being drilled consists of basic volcanic agglomerates, tuff and ash with some basic lava, the whole series gently folded. The well is reported to have been drilled through volcanic material its entire depth and fragments of the rock taken from the bottom of the hole at the time of the writer's visit were clearly basic lava. It is stated that between $100,000 and $150,000 has been spent on this well. The rig is a heavy one of the standard type.

The second well in the Burns region is that of the Fidelity Oil and Gas Co., located about 24 miles south and somewhat east of Burns and 8 or 9 miles from the Narrows connecting Malheur and Harney lakes. The company was organized early in 1918. At the time of the writer's visit the well was reported as having reached a depth of 1200 feet still in soft brown and gray clay. (This hole later reached a depth of approximately 1400 feet.) An earlier hole had been started 6 feet from the present one and carried to a depth of 460 feet, when gravel was struck and the hole was lost, it is said, through gravel sifting up into it for about 200 feet. The first hole was still producing a little gas. The rig used is a light one, without derrick. The location of the well is on the flat on which the two lakes lie (fig. 1), several miles from the margin of the valley, and the strata into which the well is being drilled are probably but a continuation downward of the silts and clays being deposited in the lake basin at the present time. If drilled sufficiently deep this well ought to strike the same strata into which the Central Oregon Oil and Gas Co. well penetrates 8 or 9 miles to the northwest.

Several wells were drilled 10 or 12 years ago into the sediments pierced by the Fidelity well out in the valley, to depths of a few hundred feet and some gas flows are reported to have been struck but they were not important in quantity.

The oil possibilities for wells drilled near the middle of the Harney valley depression cannot be said to be promising inasmuch as the beds are freshwater strata and are largely unconsolidated as well as recent; beneath these are thick volcanic formations. Gas, possibly only marsh gas, might, however, be secured in quantities sufficient for local domestic use from the soft lake beds, in which it originates mainly from vegetable material buried in the sediments. Chances for success in securing any considerable gas supply cannot be accurately appraised but the wells drilled thus far do not lead to great optimism. Deep wells which pierce the soft clays will presumably enter the thick volcanic series, in which the chances for securing oil or gas are not greatly different. This is the series in which the Central Oregon well is being drilled. Should it pass through the volcanics it will presumably strike the Mesozoic sedimentaries. These rocks, beautifully exposed 12 or 15 miles north of Burns, are much folded and intruded by granites, and it is improbable that they still contain any notable quantities of oil which they may once have held.

If, in spite of the discouraging outlook, further drilling is contemplated in the Harney valley region, it should be done either out in the flat where the relatively recent deposits are thick and the chances of securing a gas supply are relatively the best, even if not good, or it should be done on a favorable fold in the Mesozoic sedimentary strata on the slopes of the Blue Mountains north of Burns. A favorable locality would be one in which an anticlinal structure is present with dips not too steep on the sides and in which granite is absent. If localities can be found where the strata contain any traces of asphalt these with the proper structure offer the greatest promise. However, the meagre chances of success in untried territory do not justify risking a large fraction of any man's means in a drilling enterprise. A careful study by a competent geologist of a large region in which the marine sedimentaries are exposed should form the basis for the choice of a locality for exploratory drilling. Pains must be taken to ascertain, if possible, whether the marine strata are too far altered to offer hope for oil, even though gas may be present.

## BEULAH

An area lying about 12 miles north of Beulah in northwest Malheur county on the old Burns-Vale stage road has been the center of a certain amount of interest on the part of oil men during the past two or three years. The writer did not have an opportunity to examine this territory in detail but the general features of the geology were ascertained and form the basis of the following discussion.

The area lies in the general zone along which the Tertiary lava tuffs lap up on the southern slopes of the Blue Mountains. The Tertiary lavas slope gently southward in a general way but they have in addition been somewhat warped or folded. Due to the dissection of the region by streams the line between the Tertiary rocks and the older formations is rather irregular, running northward on the ridges and southward down the canyons. The older rocks on which the lavas rest are reported to contain numerous large marine shells, which accords well with the idea that the strata here are but an eastward extension of the general belt of marine beds exposed to the north of Burns. The section is essentially like that north of Burns so far as oil possibilities are concerned, in that the underlying marine formations are also quite steeply tilted and deformed. Figure 1 showing the structure and relations of the rocks in the Burns region applies in a general way to the conditions in the Beulah country.

Since the underlying beds are of marine origin, many geologists will think more favorably of this area, but the writer has learned of no authentic seeps or tar accumulations. The highly disturbed condition of the strata, moreover, makes it rather possible that any oil or gas which might have originated in them has escaped to the surface. Pre-Cretaceous strata have not yielded petroleum in the West Coast states thus far, and while they may do so at some future time, these older beds in the Beulah region cannot be regarded as a likely source for oil or gas.

The Tertiary lavas and ash strata are of course not of a type to originate petroleum or notable amounts of natural gas and it cannot be presumed that they act as reservoirs for the hydrocarbons unless a source for the latter can be reasonably postulated.

## BEND

From a point about 20 miles east of Bend in central Deschutes county, fresh lava flows extend westward to the Cascade Range. They overlie older volcanic formations. The recent flows still retain in many places the rough original surfaces of cooling. They extend northward from Bend; southward volcanic materials of relatively recent origin are met with as far at least as the Klamath lakes. Perhaps 15 miles east of Bend and about 3 miles south of the Burns-Bend road a cave in these lavas contains a considerable quantity of ice throughout the summer and is an interesting feature of the region.

The writer's reconnaissance was too rapid to permit him to become acquainted with more than the general features of the geology. No formations other than volcanic were noted and it is probable that any marine strata which may exist in the region lie at very considerable depth. The structure of any such beds would also be masked by the overlying cover of lavas, so that a determination of the location of any probable areas of accumulation would be difficult or impossible. The Bend region cannot therefore be regarded other than rather pessimistically so far as oil and gas possibilities are concerned.

## KLAMATH FALLS

A number of wells a few hundred feet or more in depth have been drilled in the Klamath Falls region, southern Klamath county, within the last 12 or 15 years and at least one well was being carried downward at the time of the writer's examination of this region. Stratified rocks are exposed at numerous localities in this general area and it is not surprising that these should lend encouragement to those public-spirited citizens who desire to test the possibilities of their home district with a drill.

The rocks of the Klamath Falls region are largely, if not entirely lavas, tuff and volcanic ash beds, with occasional clay, sand and gravel formations of fresh water origin, locally of thicknesses to be measured in hundreds of feet. The area lies within that physiographic province of the United States which is usually known as the Great Basin, and while it has outside drainage to the sea southwestward through the Klamath river, the same fault-block structure so common throughout Nevada and parts of Utah and California is evident here.

The valley in which the Klamath lakes lie is a block of the earth's crust which has been separated from the block on the east, and probably also from the Cascades on the west, by a great break or fault, the valley block having dropped down at least a number of hundreds of feet while the two adjoining blocks rose. The displacement may have been as much as several thousand feet. Uplift of the two adjoining blocks caused them to be vigorously attacked by erosion, so that where soft formations were present good sized valleys, such as Poe valley, were soon sculptured out while those parts of the face which were made of hard rocks still remain quite steep and bold. The displacement along these fault lines occurred, for the most part at least, in very recent geologic time; it has taken place since the white so-called lake beds were deposited. These strata, contrary to popular notion, are not the product of deposition in a lake which filled the present valley, but were laid down while the region was still one of much less relief than at present, and the mountains have been uplifted since.

Wells have been drilled both in the main valley and in at least one of the subsidiary valleys cut into the uplifted mountain block—Poe valley. An oil company in which Capt. J. W. Siemens of Klamath Falls is the moving spirit, was drilling in August, 1919, on a knoll about 10 miles south of Klamath Falls well out toward the middle of the valley. The well already referred to on page 32 had attained a depth of about 500 feet, a good part of which was said to be in sand requiring casing.[1] The knoll on which the well is situated is quite certainly not a dome but an erosional residual; it stands about 25 feet above the surrounding flat. There is therefore no reason to believe that it is a favorable area for the accumulation of any oil or gas which might exist in the surrounding region. The strata through which the drill first passed are quite certainly part of the fresh water series of the district which offer very little encouragement as to oil, though a chance possibly exists.

In Poe valley drilling was begun by a group of gentlemen associated as the Poe Valley and Lost River Prospecting Co., about May, 1915, and carried on intermittently until about July, 1918, when a depth of about 606 feet had been reached, according to Mr. J. T. Roberts of Oline, Oregon. Mr. Roberts states that various kinds of material were passed through, most of it volcanic clay, sand and mud. Reconnaissance of the area surrounding the well indicates that the strata in the section are largely of volcanic ash and sediments of the freshwater type. It is not known at what depth other kinds of rock underlie this series, nor what type of rock it may be.

A question which comes up for answer is of course whether there may not be underlying formations which are or might be oil or gas producing. This is possible, but judging from the thickness of the lavas exposed in the face of the upthrown fault blocks, the underlying formations must lie at a great depth, at least under the main valley. Such underlying formations may or may not be marine, and they may or may not be oil-bearing; if oil-bearing it would be exceedingly difficult to determine from the surface exposures in the overlying lava series where the oil had accumulated, since only a small part at best of any region made up of marine rocks contains oil or gas reservoirs. And this is due to the fact that oil and gas ordinarily occupy certain structures, as pointed out earlier in this paper, the area of which is usually quite limited.

Relatively small quantities of gas, derived from the vegetable material buried in the fresh water sediments, can possibly be secured at certain localities in the Klamath Falls region but the chances of securing a commercial oil supply do not appear to be promising. On the whole there appears to be but a slender basis for expecting production of oil or gas in the district.

[1] Known as the Siemens well. Down to between 1,500 and 1,600 feet in June, 1921. The log shows a few hundred feet of lake-bed sediments below which are only basaltic lavas and related volcanic rocks.

## LAKEVIEW

The Lakeview region in southern Lake county is remarkably similar in physiography, type of country rock, structure, and in the general features of its Tertiary history to the Klamath Falls district. It is a north-south valley occupied in part by Goose lake, from the eastern margin of which rises a very formidable range of mountains. On the west somewhat lower mountains rise less boldly from the valley floor. The valley is a dropped block with a fault of great displacement along its eastern side and possibly a second along its western margin, although the evidence for the latter is not so convincing. The bold face of the range to the east exhibits a section of some 3,000 feet of lavas, tuffs, and to a minor extent, gravel, sandstone and shale beds. The moun-

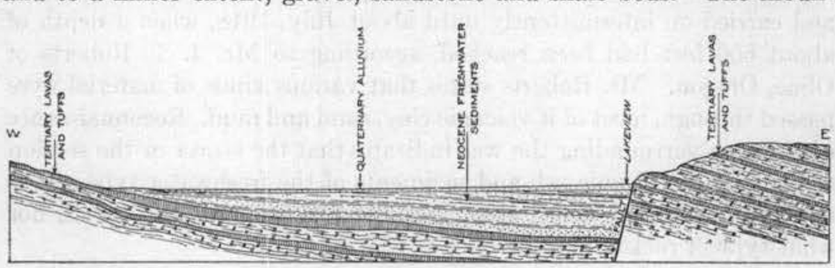


**Fig. 3. Generalized sketch section from west to east through Lakeview, Oregon. Distance about 15 miles. Vertical scale greatly exaggerated.**

tains to the west are composed mainly of the same sort of materials. The volcanic formations have been gently folded as well as faulted.

In the valley of Goose lake, in which the town of Lakeview lies, very recent clays and soils mask the underlying formations to a great extent but to the north and west of Lakeview exposures in some of the low hills in the valley indicate the presence of Tertiary strata made up of gravels, sandstones, clays, and ash beds with a total thickness of at least several hundred feet. These beds presumably overlie the volcanic rocks of the adjoining ranges in a normal section, but they have quite certainly been faulted down into their present position. They therefore do not represent the deposits of a lake which as a precursor of Goose lake occupied the valley. They were deposited in the gentler topography which existed before the mountains were thrown up and the valleys depressed by faulting. These strata have been deformed by warping or gentle folding so that dips of 10 or 12 degrees are not uncommon.

Mr. H. M. Nolte, one of a group of substantial business men of Lakeview, courteously accompanied the writer to a number of localities in the district which he and his associates regarded as interesting from the standpoint of oil and gas possibilities. Several springs which were reported as showing oil films were examined but in each case the substance was hydroxide of iron. An artesian well known as the Carter well, located nine miles southwest of Lakeview, having a depth of 370 feet of which the upper 260 feet was cased, was producing bubbles of an inflammable gas continuously. The well was drilled about 1915 and it was reported to have yielded the same amount of gas from the time it first began to flow. The amount was estimated at a few cubic feet per hour. A sample of this gas was taken and analysis in the laboratories of the U. S. Bureau of Mines showed that it had the following composition:

| | Per cent |
|---|---|
| Carbon dioxide | 0.5 |
| Methane (marsh gas) | 73.5 |
| Nitrogen | 26.0 |

No ethane gas, no free oxygen or free hydrogen were present in the sample. The gas had a specific gravity (air=1.0) of 0.67. Its heating value in British Thermal Units per cu. ft. of gas at $0^0$C. and 760 mm. pressure was 783.

The well is reported to have passed through soft sediments its entire depth. The gas quite certainly originated in the soft alluvial material which overlies the Tertiary sediments in the middle portions of the valley possibly to depths of a few hundred feet, or in the underlying freshwater Tertiary strata. The composition of the gas indicates that it is a typical marsh gas such as is commonly derived from beds deposited in lakes, streams or on waste slopes, where vegetable material is buried in the process.

The fact that the formations which underlie the valley in which Lakeview is situated are of freshwater origin tends somewhat to prejudice the case as to oil, for as has been indicated earlier in this paper, freshwater formations do not in general seem good sources of oil in commercial amounts, though there appear to be exceptions. In this valley the thick section of lavas shown in the mountain face east of Lakeview underlies the Tertiary fresh water beds in the valley. It is not to be supposed that the beds would receive hydrocarbons from the lavas.

With reference to natural gas, it is possible that drilling in the valley might develop gas flows sufficient for local domestic use in nearby homes. At Prosser, Washington, gas in a fresh water formation developed a closed well pressure of about 10 pounds per square inch and the wells flowed many thousands of cubic feet of gas per day.

Drilling in the mountains of volcanic rock to the east and west of the valley cannot of course be hopeful if the oil and gas are to be derived from the volcanics. The only hope of reaching a possible oil-bearing formation would be by drilling through the lava section. The total thickness of the lavas is not less than about 3,000 feet and may be more than double that figure. In the valley this entire thickness would have to be passed through, as would also be the case at the top of the mountains east of Lakeview and in those to the west. But just east of the western base of the range east of Lakeview, near the base of the great scarp, drilling could be commenced in the oldest lavas, that is, the lowest stratigraphically, and it would be here that the formations underlying the lavas would be most easily reached. In view, however, of the fact that they may be granites or other igneous or metamorphic types of rock, or if sedimentary that they may be highly deformed and barren of oil or gas, and in view of their probable depth and the difficulty of determining where the oil would have accumulated in them if present at all, drilling in such locations would be fraught with great hazards.

## SOUTHEASTERN OREGON

The southeastern portion of the state is very sparsely inhabited. It is a region of prominent north-south ranges which extend into Oregon from Nevada and of flat-floored valleys or extensive plateaus between the ranges. Nearly the entire region is lava covered. The altitude of nearly the whole territory is more than 5,000 feet.

From Lakeview eastward one crosses first the high range rising immediately from the town and after traveling for some distance across a plateau finds himself in Warner valley. The Warner range next to the east presents a bold fault scarp facing west like the Lakeview mountains. Beyond them lies another broad lava plateau stretching to the west base of the Steen mountains. This range appears to be faulted to some extent along its west side but it slopes westward and its eastern face is a magnificent escarpment indicating a displacement of thousands of feet. Lower mountains lie to the east, and beyond them are very extensive plateaus drained by the Owyhee river and its tributaries.

The lava series, made up mainly of basalts, is apparently thick throughout this whole region, for in the faces of the high ranges where they may be seen in section, it is seldom that the faults, often of several thousands of feet displacement, expose the base of the volcanic series. An exception to this is in the eastern scarp of the Steen mountains, where fresh water strata of Tertiary age have been brought up by the faulting, as well as a variety of still older rocks.

The writer did not attempt detailed work in any part of this vast area and his observations are therefore scarcely sufficient upon which to base a judgment. The predominance of the lavas as the country rocks, however, and the thickness of the series, as well as the absence of marine sedimentary beds so far as known, would tend to militate against the oil and gas possibilities of most of this region.

## ONTARIO AND VALE

The valleys of Snake river near Ontario and of Malheur river near Vale display very extensive exposures of light colored stratified formations. Resembling in a superficial way the sedimentary rocks in many of the oil fields of the country, it is natural that the citizens of the local towns should desire to test their possibilities for oil and gas production. The scarcity of good local fuels and the long transportation required for coal or oil from neighboring states have enhanced the desire to supply this rich agricultural region with hydrocarbons from nearby sources. Intermittent drilling has hence been carried on in this region for 20 years or more. Gas in quantities probably larger than has been struck in any other well in eastern Oregon was obtained in the deep Boyer well at Ontario in 1902, and a comparable flow of gas was obtained a little later in a well drilled in Payette, Idaho, across Snake river and a few miles distant from Ontario. At least a few drops of oil are also reported to have been secured in this general region.

### Geology

Chester W. Washburne, in Bulletin 431 of the U. S. Geological Survey, published in 1911, has discussed the geology and oil and gas possibilities of the Ontario-Vale region in interesting fashion. This paper contains the logs of several wells which had been drilled before that time, reports the extraction by solution with chloroform of a few drops of a light oil from sands exposed along the west side of Sand Hollow, 10 miles southwest of Vale, and enters into a discussion as to the origin of the gas and oil.

The large area of exposures of Tertiary strata, extending many miles to the north, west and south of Vale and Ontario, deserves a more careful and detailed examination than the writer was able to make in the limited time at his disposal. A conception of the broader features of the geology of the region was gained in the field, however, and it serves as a basis for the following discussion of the oil and gas possibilities.

Geologically the Vale-Ontario district is part of a much larger province which includes the Snake river valley from south of Boise, Idaho, to north of Weiser, Idaho, and many of the tributary valleys entering the valley of the Snake from the south and west. This province is characterized by being underlain mainly by Tertiary sedimentary strata in contrast to the mainly granitic composition of the rugged mountains of Idaho to the north and east, and the largely lava-mantled north-south ranges extending southward from the margin of the valley.

The Tertiary sediments are known to be very thick. They were studied in detail about 20 years ago by Waldemar Lindgren and the results were published in the Boise, Nampa, and Silver City folios of the U. S. Geological Survey. Mr. Lindgren divided the sediments into two formations, the older of which he named the Payette, and the younger the Idaho formation. The Payette was first regarded as of upper Miocene age on the basis of fossil leaves found in it which were studied by Dr. F. H. Knowlton, but in the two later folios it was considered Eocene on the basis of a redetermination of the plant material. The Idaho formation was believed to be Pliocene, fossil mammal bones having been discovered in it which were regarded as pointing to that age.

The investigations of the writer appear to indicate that at least the larger part of the areas regarded as of Eocene age are in reality Miocene or possibly lower Pliocene, and that the Idaho formation, if Pliocene, was deposited very late in that epoch and may be Pleistocene in age. It is probable, moreover, that the Tertiary strata are divisible into more than two formations. Collections of mammalian fossils made by the writer in Idaho very near the Oregon boundary suggest that the Payette formation is itself divisible into at least two formations of somewhat different age.

To indicate the complexity of the sedimentary section, a few exposures may be cited. Mitchell Butte, about 15 miles south of Vale, is composed of rather hard sandstones, conglomerates, and ashy shales resting upon older lavas and dipping at a considerable angle toward the Snake river valley. Strata of somewhat similar character outcrop on the hills immediately east of Vale. The hardness of these beds has been ascribed to cementation by hot waters which rise in springs along the base of the hills, and it may be due in part to that agency. The writer is of the opinion that the beds are harder because they are part of an older formation than the strata of the immediately surrounding country and that they outcrop among these younger strata because they have been brought up by faulting, through which process the position of the hot springs was determined. The strata at Mitchell Butte and Vale are therefore considered as older strata than those exposed over most of the region around Vale and Ontario; but whether the more extensive overlying beds rest upon them conformably or unconformably, and whether the older beds are to be considered a distinct formation, is not yet known. The older strata are probably upper Miocene or early Pliocene in age.

The younger beds so extensively exposed in the hills around Vale and Ontario, and in which the drilling around Vale has been started, have not yielded sufficient fossil material for a positive age determination. Their lithologic characters stamp them, however, as younger than the Mitchell butte and Vale butte exposures.

On the east side of Payette river, on the opposite side of the Snake river valley, are extensive exposures of strata which differ somewhat in appearance from the younger beds extensively exposed around Vale and Ontario, and they may well be still younger. A fourth series of beds which differ considerably in lithologic characters from the foregoing and which are apparently late Pliocene or Pleistocene in age, are exposed widely along Snake River just east of the Oregon boundary, in Idaho. These were termed the Idaho formation by Lindgren. It appears from these facts that the stratigraphy is by no means as simple as formerly believed, and a very considerable amount of detailed work will be required to determine the age of the different groups of strata, and their stratigraphic relations to each other. The writer hopes to take up this study during a succeeding field season.

From the standpoint of oil and gas possibilities our present knowledge of the stratigraphy may be summarized as follows:

The broad Snake river depression, including the Vale district, is underlain by a thick section of Tertiary sediments, possibly divisible into several formations, consisting of shale, sandstones and conglomerates. Shale seems to predominate, to judge from the sections of deep wells drilled through the sediments. The beds are at least 4,000 feet thick, since at Ontario the Boyer well, approximately of that depth, did not reach the base of the series. These beds have been considered as lake beds heretofore, but the writer's studies indicate that they are probably in large part river flood plain and waste slope deposits and were laid down only in part in lakes. They are fresh water deposits.

The Snake river region must have been an area of subsidence relative to the adjoining provinces for a long period of time, during which the sediments accumulated to enormous thickness. Probably during the various stages of this subsidence, the beds in the depositional trough were gently folded or warped, so that now they dip at considerable angles away from the margins of the trough toward its middle parts; in addition, the strata were gently deformed along irregular axes, so that while open folds can now be made out in some localities, the structure in the later beds is mainly of the nature of irregular warping. While inclinations at the border of the valley are 20 to 30 degrees, dips in the younger beds in the middle of the valley are usually less than 5 degrees, and often they lie nearly flat over large areas. Most of the series of strata contain a certain amount of petrified wood, while fossil leaves, fresh water molluscan shells, and mammal bones occur occasionally, indicating the non-marine origin of the sediments.

### Wells Drilled for Oil and Gas

A number of deep wells have been drilled in the Vale and Ontario regions during the past twenty years. Washburne stated in his report published in 1911, "Seven companies were operating in October, 1909. At that time there were fifteen wells in the field, including six wells drilled primarily for artesian water, having the depths of 3,596, 1,700, 1,506, 1,400, 1,140, 1,100, 1,050, 900, 850, 740, 340, 335, 320, and 163 feet. Drilling was progressing on seven wells near Vale and on well No. 2 of the Oregon Oil and Gas Company in Payette."[1] Washburne gives logs of eight wells, in all of which shale and clay are the most common materials passed through.

At the time of the writer's visit in the summer of 1919 drilling was in progress on one well, that of the Northwestern Pacific Oil and Gas Company in Sand Hollow about 13 miles southwest of Vale. The Sunset Oil Company had ceased drilling on a well about 12 miles north and slightly west of Vale in May of that year. In the summer of 1920 a well was also being drilled on the Idaho side of Snake river somewhat farther north at Weiser by citizens of that city.

The Northwestern Pacific Oil and Gas Company's well southwest of Vale has reached a depth of 1,140 feet in the summer of 1919, the materials passed through being entirely soft shales, sands, and ashy beds of light color. A heavy rig was being used but the casing had been reduced to 5⅝ inches, which would probably prohibit drilling to a much greater depth. The strata at this point dip about six degrees northward, an inclination that is mainted for about two miles to the south, which indicates that a very considerable thickness of sediments lies beneath the well. The series lies on lavas to the south. The beds appear to be stream and lake deposits, consisting of shales of gray and blue colors, stratified ash beds, and sandstones which are often very much cross-bedded. Freshwater molluscan remains are very common in the low cliffs along Sand Hollow not far from the well. The structure at the well does not appear to be distinctly anticlinal; the dip in the surrounding area for a considerable distance is in general northward with some fluctuations in degree of steepness. No notable signs of oil or important quantities of gas had been developed in the well.

The Sunset Oil Company well about 12 miles north and a little west of Vale was also drilled with a heavy rig, beginning with a 7-inch hole.

[1] Gas and Oil Prospects near Vale, Oregon, and Payette, Idaho. U. S. Geol. Surv. Bull. No. 431, page 26, 1911.

The depth reached was not ascertained, but it is reported in Vale to have been less than 500 feet. The strata penetrated belong to the same series as those in which the Northwestern Pacific well southwest of Vale was begun. The topography is hilly but the structure is rather difficult to make out further than that the strata dip at very gentle angles. A conspicuous hill about one mile north of the well is capped by a thin sheet of basic igneous rock. So far as the structure can be made out, the well has neither a particularly advantageous nor disadvantageous position.

The well being drilled at Weiser, Idaho, during the summer of 1920, by local capitalists under the leadership of Mr. Bradshaw of that city, had reached a depth of 1,140 feet, having been started with 12-inch casing and reduced to 6-inch. The well passed almost entirely through blue clay and emitted small quantities of gas.

Two wells drilled many years ago and discussed in Washburne's report yielded more data of interest from the standpoint of oil and gas possibilities than any others in the region. The first of these is the Boyer well in Ontario, already referred to, which was drilled to a depth of about 4,000 feet and which yielded notable quantities of gas. Washburne states:

> A small amount of gas was encounered at 640 feet, and at 986 feet a stronger flow of gas blew the water out of the well. At 1,070 feet, when the hole contained 1,000 feet of water giving a resistance of over 440 pounds per square inch, gas was struck which blew water and mud over the top of the derrick. This operation was repeated at 2,204 feet, when the hole contained about 2,000 feet of water giving a resistance of over 880 pounds per square inch. These depths were all measured from the derrick floor, about 4 feet above the ground surface. Instrumental measurement of the gas pressure, made somewhat later, gave 420 pounds per square inch. At the time of the writer's visit, in October, 1909, the well was capped and on opening the cocks the accumulated gas escaped with a roar which indicated high pressure but which decreased notably in half an hour. No means were at hand for measuring the pressure and no attempt has been made to determine the amount of gas which the well will deliver. It is probable, however, that if the well were cleaned and if the casing were cut at the higher gas horizons a very good flow night be obtained. The gas has an odor resembling gasoline and burns with an almost colorless flame.[1]

At the time of the writer's visit the Boyer well was capped, although gas was escaping around the casing. For some time previously Mr. Boyer had used the gas in lighting his house and for cooking but had discontinued doing so. When a small pipe tapping the casing was opened and the gas lighted, a yellowish flame about three feet in length was produced. The pressure was apparently slight but it might have been considerably more if small quantities of gas had not been per-

[1]Oil and Gas near Vale, Oregon, and Payette, Idaho. U. S. Geol. Surv. Bull. No. 431, p. 40, 1911.

mitted to escape constantly around the casing. It is certain that there has been a very notable diminution in the open-well pressure since 1902 and 1903 when the gas shot water and mud over the top of the derrick. It is now reported that the casing in this well has been drawn but that gas still bubbles up through the water. The writer collected over water a sample of the gas issuing from the Boyer well in 1919, the analysis of which in the laboratories of the United States Bureau of Mines gave the following composition:

| | Per cent |
|---|---|
| $CO_2$ (Carbon Dioxide) | 0.0 |
| $O_2$ (Oxygen) | 0.0 |
| $CH_4$ (Methane or "marsh gas") | 99.1 |
| $C_2H_6$ (Ethane) | 0.0 |
| $C_2H_4$ | 0.0 |
| $H_2$ (Hydrogen) | 0.0 |
| $N_2$ (Nitrogen) | 0.9 |

The specific gravity of this gas (air=1) is 0.56. Its heating value in British Thermal Units per cu. ft. at 0°C., and 760 mm. is 1055.

No mention is made in any of the reports concerning this well of notable amounts of oil such as often occur in the unsuccessful oil wells drilled in the outlying parts of a producing oil field, and in view of the nature of the gas it does not appear that the well can be regarded as evidence of the presence of oil in the region. The gas, composed almost entirely of methane or marsh gas, is the characteristic type found in freshwater sediments, and is believed to have been formed through decomposition of vegetable material buried in the sediments. It is quite possible, however, that if the well had been manipulated with the sole purpose of securing from it the largest possible amount of gas instead of drilling it to greater depth for oil, it might have been the source of a certain amount of revenue for a number of years as a supply of gas for domestic use. This well is to be regarded as suggestive evidence for the possible occurrence of notable amounts of natural gas of good heating and lighting value in the region. It is nevertheless clear, in view of the number of other wells which have been drilled in the district without striking quantities of gas equal to that in the Boyer well, that reservoirs of gas under considerable pressure do not underlie the whole territory by any means, nor, probably, at shallow depths.

A second well producing considerable gas was drilled in Payette, Idaho, across the Snake river from Ontario and a few miles to the north, in 1907. Washburne says of this well:

The depth of the gas sand was 740 feet, and the pressure was sufficient to blow a column of water, sand and shale to a height of 150 feet. The well was drilled through an almost continuous body of smooth, blue-gray shale, with occasional thin layers of sandy material containing smaller flows of gas. This small hole became clogged with sand and gravel and was finally plugged. A new well of larger diameter has been started near by for the purpose of trying to get through the gas stratum, in order to obtain oil at lower depths.[1]

In the summer of 1920 two wells were producing small amounts of gas in Payette. One of these, in the basement of a fruit packing plant near the railway station, had been drilled for water supply. The water obtained was not suitable for use but sufficient gas bubbled up through it to supply several lights. The second well, in the rear of a steam laundry nearby, produced sufficient gas for the heating of one of the machines used in the laundry. The exact depth from which this gas rose was not ascertained. Gas also occurs here in small quantities in other wells.

### Oily Sandstone in Sand Hollow

Besides these occurences of gas in the Vale-Ontario region, a locality of interest lies in Sand Hollow not far from the Northwestern Pacific Company's well, and about 13 miles southwest of Vale. Just east of an abandoned artesian well now flowing a very little water, sandstones outcrop in a bluff a few feet high. Somewhat similar strata outcrop on the west side of Sand Hollow a few hundred yards away. On being freshly broken these beds yield a strong odor of petroleum, or perhaps it would be more nearly correct to say that the odor is that of some of the lighter fractions of petroleum, such as kerosene or gasoline. Washburne reports that he dissolved out of these sands with chloroform a few drops of a very light colored oil. The beds are not markedly stained by oil like those outcropping in many productive oil fields. Such oil as is present must be diffused in very minute quantities through the rock exposed at the surface.

### Discussion of Conditions

The Vale-Ontario region is manifestly one of the most interesting, if not the most interesting, of the various districts of eastern Oregon considered in this report. It probably contains the greatest thickness of Tertiary sediments. The rocks are largely shales and clays, in which types of sediments organic remains are most likely to accumulate in quantity. The beds are only in minor part volcanic in origin, in which character they differ from those underlying most of the other districts discussed. The strata are gently flexed. Small quantities of gas escape from most of the deep wells of the region and certain wells have flowed considerable quantities of gas at very notable pressures. Films of oil have been reported in a number of deep wells during drilling operations,

[1]Oil and Gas near Vale, Oregon, and Payette, Idaho. U. S. Geol. Surv. Bull. No. 431, pp. 41-42, 1911

and certain strata in the district emit distinct odors of petroleum on fresh fracture, although the oil is not apparent to the eye.

Considering the foregoing as favorable conditions, the district has also certain negative features that enter into an appraisal of its oil and gas possibilities. It contains so far as known only freshwater sediments, a fact generally regarded somewhat prejudicially. The region lacks oil seeps of the type common in and about oil fields. The odoriferous sandstone in Sand Hollow is an interesting occurrence but scarcely to be considered as a typical oil seep. The gas found in the region does not point to an association with oil. Gases are not entirely diagnostic as to whether or not oil is associated with them in the ground, but gases in oil fields commonly contain a considerable proportion of ethane, a constituent lacking in the Ontario gas. A considerable number of wells have been drilled to depths varying from a few hundred to 4,000 feet or over, distributed over a large part of the territory, without encountering notable quantities of oil; though they found in the most favorable cases pockets of gas under notable pressures which gave considerable flows for a short period but in which the pressures decreased very rapidly. Structurally the wells were probably not well located. While sandstones which would make good reservoirs for oil are present in the sections as shown in the outcrops along the valley margins where the beds are upturned, and in the wells, shales containing organic materials in such large amounts as to make them probable oil producers have not been identified in the sections.

The conclusion arrived at, after considering these various factors, is that the Vale-Ontario region is not impossible oil territory but that the probabilities of obtaining commercial flows of petroleum are not good. The area is not decidedly unfavorable like the granite mountains which bound the Snake river valley on the northeast or absolutely hopeless like the areas in which thick sections of lavas overlie granitic basement rocks. In a classification of territory on the basis of oil possibilities in which the grades of possibility decrease from certainty of production to impossibility, as follows, proven productive, unproven but probable, hopeful, possible but unpromising, impossible, the writer would characterize the Ontario-Vale region as possible but unpromising.

The chances of securing commercial quantities of natural gas are considered to be very much better. It should be recognized, however, that the chances in a particular well are correctly estimated, not by stating that it is quite probable that a commercial flow of gas will be struck, but that it is possible that such a supply may be obtained. In drilling test wells in the region the possible value of any gas obtained should be kept in mind as well as the desirability of securing oil, and the well should be handled from the outset so as to conserve the gas supply for future use and so as to permit of its free flow when the gas is to be utilized.

The origin of the gas is a matter of interest. Washburne was apparently inclined toward the view that it came from great depths into the Tertiary strata, for he says:

> The apparent solution of this question for the Vale field may be summarized by saying (1) that throughout the region hot springs are abundant and carry inflammable gas; (2) that the Payette formation is not a likely source of the gas and oil which it contains; and (3) that the Payette formation probably rests on granite and metamorphic rocks from which these substances could not have been derived. The presentation of these facts is a strong argument for the solfataric or abyssal origin of the gas and oil.[1]

The writer believes that the gas has originated in the strata themselves because, first, nearly all deposits containing carbonaceous organic matter contain certain amounts of gas; second, the deposits of the Snake river region contain considerable quantities of vegetable matter which by decomposition in the absence of oxygen would appear to be capable of producing the gas; third, if the rocks in which it is now found are so nearly impervious as to hold the gas under considerable pressure it is not probable that the gas would have risen up through them from great depths; fourth, if the gas had risen with the water in such hot springs as occur at Vale, there appears no reason why it should have moved out into the adjoining rocks and be held there under pressure instead of coming to the surface through the spring.

#### Future Drilling

It is not at present practicable to outline in the Vale-Ontario region the exact areas in which the chances of success in further exploratory drilling would appear to be best. Certain general considerations can, however, be stated which may prevent waste of money. Future prospect drilling should be done in the middle parts of the valleys in such areas as those within a few miles of Vale and Ontario, and should not be undertaken close to the higher hills which surround these valleys. The higher hills are composed almost entirely of lavas, in many cases of great thickness, and drilling carried on near the hills is very likely to result in striking the lavas before great depths are reached. The best chances for securing gas would appear to be in the areas where the greatest thickness of sediments can be penetrated and this is obviously away from the hills. With reference to the choosing of sites for wells in relation to the structure of the region, it is of course desirable to locate them on anticlinal areas, but this may not be as important as it

[1]Gas and Oil near Vale, Oregon, and Payette, Idaho: Bull. U. S. Geol. Surv. No. 431, p. 47, 1911

might seem at first sight, for it is possible that the surface rocks on which the structures are identified do not reflect very closely the structure in the older strata beneath them. If an unconformity occurs between the younger strata which are so extensive on the surface and such probably older strata as are exposed at Vale and Mitchell butte, it is quite possible that the axis of a fold in the older strata may not coincide with the axis in the surface beds; and even that the folds in the older rocks were beveled off before the younger beds were deposited upon them. While folding is apt to recur along the same axes, it may not, and it is quite possible that folds in the deeper strata trend in different directions and are of different intensity from those seen at the surface.

In the Ontario region and in other level parts of the Snake river valley it is impossible to make out the structure of the Tertiary strata beneath the river gravels of the valley, except by inference through projection of axes from adjoining areas. In the rolling country the structure can be made out but considerable careful work will be required to define it in detail.

## SUMMARY AND CONCLUSIONS

The geology of eastern Oregon can be summarized by stating that nearly the whole of that portion of the state is underlain by Tertiary lavas. Relatively small areas of Cretaceous and older strata occur in the Blue Mountains, and Tertiary freshwater sedimentary strata, commonly more or less ashy in composition, overlie or locally underlie the lavas and form the surface formations in scattered areas. Tertiary strata of freshwater origin but chiefly non-tuffaceous in character and of great thickness occupy the valleys of Snake river and tributary streams in the Vale and Ontario region.

Drilling for oil and gas has been done or is now being carried on in The Dalles region, west of Dufur, south of Burns, south of Klamath Falls and east of that city, and around Vale and Ontario. All the wells have gone down in Tertiary sediments. Many of them have struck small quantities of gas and certain ones, such as the Boyer well in Ontario, have encountered considerable quantities at high pressure which, however, decreased rather rapidly. Traces of oil have also been reported in a number of these wells but no verifiable cases in which a notable quantity of crude petroleum was brought to the surface were discovered.

Many reported seeps of oil were investigated in various parts but no true seeps were found; the reported oil colors in every case turned out to be iron films.

As to prospects for oil in commercial amounts, eastern Oregon can not be regarded as impossible territory, but it is rather improbable territory. This judgment is based on the absence so far as known of typical oil seeps, the freshwater origin of all the sedimentary strata except those in relatively small areas in the Blue Mountains, the scarcity of the mother rocks of petroleum, the dominantly volcanic nature of the rocks underlying the sediments, and the failures to date. The chances of securing oil in the relatively small areas of considerably deformed marine strata in the Blue Mountains can not be appraised accurately on the basis of the brief examination made of them. An oil supply is probably not to be expected in them.

The possibility of a commercial gas supply is somewhat better; considerable drilling has thus far encountered, however, only one or two bodies of gas which in quantity approached a commercial supply. Gas occurs in small amounts at many points in the Tertiary strata, but it would appear that the thick sections in the Ontario-Vale region afford the best chances of encountering a commercial supply. It is to be recognized that even here, however, the likelihood of developing a large output does not seem very good. In drilling test holes in this region locations should be chosen on folds at some distance from the higher hills which surround the district. This is advisable, inasmuch as these hills are composed mainly of igneous rocks and because the thickest sections of strata undoubtedly lie in general in the middle parts of the valleys.

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**Copies of this report may be obtained by application to the Oregon Bureau of Mines and Geology, 417 Oregon Building, Portland, Oregon.**