DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 661—I

PHOSPHATIC OIL SHALES NEAR DELL AND DILLON, BEAVERHEAD COUNTY, MONTANA

BY

C. F. BOWEN

Contributions to economic geology, 1917, Part II
(Pages 315-320)

Published January 12, 1918

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By C. F. Bowen.

INTRODUCTION.

Reported occurrences of oil shale in Montana led to a preliminary investigation by the United States Geological Survey in the early part of October, 1916, of two localities, one in what is known as Muddy Creek basin, 8 or 10 miles west of Dell, and the other in Smallhorn Canyon, about 10 miles south of Dillon. (See fig. 33.) The oil shale that promises to be most valuable occurs at about

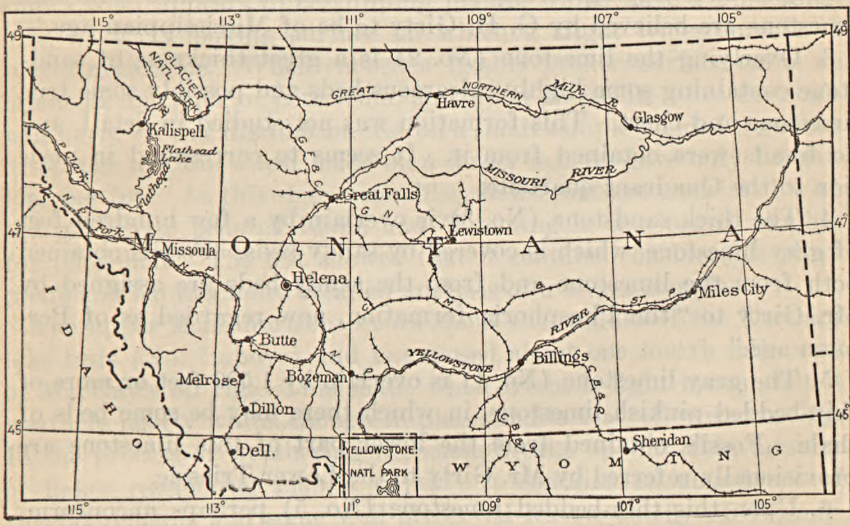

FIGURE 33.—Index map showing location of Dell and Dillon, Beaverhead County, Mont.

the same horizon as the phosphate deposits of Montana, Idaho, and Wyoming and, in addition to the oil it yields, contains considerable phosphate. Laboratory tests have shown that the phosphate is not driven off by distillation, and the fact that the shale yields oil on distillation and yet retains a notable quantity of phosphate in the ash presents to the technologist a problem whose solution may be economically as valuable as it is scientifically interesting.

STRATIGRAPHY AND STRUCTURE.

The strata are greatly disturbed by folding and faulting; at some places they are very much shattered and stand nearly vertical, so that the sequence of formations is difficult to determine by hasty examination, but the sequence in the Muddy Creek basin seems to be as follows:

1. A hard vitreous quartzite, probably a few hundred feet thick, seems to be the oldest sedimentary rock. This quartzite was not seen in normal position at any place, but on Muddy Creek and at the mouth of Smallhorn Canyon it appears to underlie limestone of probable Mississippian age. No fossils were obtained from the quartzite, and its age is therefore not known.

2. Apparently upon the quartzite lies a gray, massive to thick-bedded crystalline limestone, which at Smallhorn Canyon and at Sheep Canyon, about 2 miles southeast of Smallhorn Canyon, seems to be conglomerate at the top. The conglomerate is overlain by a bed of red shale, and both the conglomerate and the shale may belong to an overlying formation. A few fossils obtained from this limestone are believed by G. H. Girty to be of Mississippian age.

3. Overlying the limestone (No. 2) is a great thickness of sandstone containing some highly calcareous beds and possibly some true limestone and chert. This formation was not studied in detail, and no fossils were obtained from it. It seems to correspond in position to the Quadrant quartzite.

4. The thick sandstone (No. 3) is overlain by a few hundred feet of gray limestone, which is covered by sandy beds. Fossils obtained both from the limestone and from the sandy beds are assigned by Mr. Girty to "the Phosphoria formation, now regarded as of Permian age."

5. The gray limestone (No. 4) is overlain by 1,500 feet or more of thin-bedded pinkish limestone, in which there may be some beds of shale. Fossils obtained from the lower part of this limestone are provisionally referred by Mr. Girty to the Lower Triassic.

6. Upon this thin-bedded limestone (No. 5) perhaps unconformably lies a series of red beds, which are highly conglomeratic at the base.

7. The greater part of Muddy Creek basin is occupied by a series of fresh-water conglomerates, sandstones, shales, and limestones, from which were obtained a few fossil shells and leaves that indicate Tertiary age. These fossils are not sufficiently distinctive, however, to fix the age more definitely. The beds appear to overlap the underlying formations and vary considerably from place to place in lithologic character and in color, the prevailing colors being

green, gray, brown, and white. Some of the sandstones appear to be tuffaceous. Conglomerate is distributed more or less through the mass but is most abundant in the lower part.

THE OIL SHALE.

OCCURRENCE AND PROPERTIES.

The interesting thing in connection with the section described above is the occurrence in it of oil shale at two horizons, one at the top of No. 4 (Phosphoria (?) formation) and the other in the Tertiary lake beds. Both these shale zones are exposed in Muddy Creek basin but only the lower one is exposed in Smallhorn Canyon, the Tertiary beds not being represented there.

The lower shale is exposed on the east side of Muddy Creek basin and dips westward at an angle of 25° to 30°. The shale is black, gives a brownish streak, and has an oolitic texture. In general the oolites seem to be distributed promiscuously, but in some specimens there are narrow bands nearly devoid of them. On fracture the shale shows what appears to be slipping planes, which have a glistening, oily, or waxy-looking surface on which a slight iridescence is in places noticeable. When rubbed a freshly broken surface emits an unmistakable odor of petroleum, and when placed in a fire the shale will burn. A dry distillation test on a small sample yielded 9 gallons of oil per ton, but a test made on a larger sample gave only 7.5 gallons per ton. As this shale resembles shales that are associated with the phosphate beds of Idaho and Wyoming it was tested roughly for phosphate. The test showed that it contains considerable phosphate and led to a more detailed analysis of a larger sample.

The upper shale horizon occurs about the middle of the Tertiary lake beds (No. 7 above) and is exposed about one-fourth mile west of MacKay's oil rig. This shale, when fresh, is light brown, but it weathers nearly white, though in places it bears a yellowish coating. In the process of weathering the shale breaks up into thin laminae or flakes resembling manila paper. It contains an abundance of vegetal remains and some well-preserved leaves, chiefly of *Sequoia*. This shale, like that from the lower horizon, will burn when exposed to a strong flame, but does not give an odor of petroleum on freshly broken surfaces. On distillation it yields about eight gallons of oil per ton. The bed is about 100 feet thick. Thinner beds occur in other parts of the section, some of which contain thin streaks of lignite. In fact, except for its somewhat lighter color, the shale has very much the aspect of an ordinary carbonaceous shale, such as is commonly associated with coal beds.

About 10 miles south of Dillon, 2 miles above the mouth of Smallhorn Canyon, a bed of oil shale that is believed to lie at about the same horizon as the lower shale in Muddy Creek basin is exposed. The bed has been opened up by a tunnel about 150 feet long, driven in the hope of finding coal. The shale is dark brown, tough, and dense, without oolitic texture. It contains numerous megaspores and minute bodies of vegetable origin. A sample representing a thickness of about 5 feet taken from the tunnel mentioned above yielded, on distillation, 24 gallons of oil per ton. In its natural state, however, it does not give any odor of petroleum. It also contains only a small quantity of phosphate.

ANALYSES OF THE SHALE.

Analyses of a sample of the shale from Muddy Creek basin and from the lower horizon in Smallhorn Canyon are as follows:

Analyses of oil shale from Muddy Creek basin and Smallhorn Canyon, Mont.

[Chase Palmer and R. M. Kamm, analysts.]

	Petroleum.			Phosphoric acid.		Equivalent in calcium phosphate ($Ca_3(PO_4)_2$).	Potash.
	Dry distillation.	Ether extraction.	Carbon tetrachloride extraction.	Original sample.	After incineration.		
	Gallons per ton.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Muddy Creek basin	7.5	0.2	0.45	15.56	15.57	33.96	0.39
Smallhorn Canyon	24.0	....	....	2.62	2.53	5.70	.46

Perhaps the most interesting and significant fact in connection with the analyses is the association of phosphate and oil in considerable quantities in shales which seem to occur at or near the same horizon as the extensive phosphate beds of Idaho, Wyoming, Utah, and parts of Montana. Evidences of petroleum or bituminous compounds have been observed over wide areas by those who have worked on the phosphate deposits, but few if any tests have heretofore been made to ascertain the quantity of oil in the rocks. The quantity of phosphate is much greater in the oolitic than in the nonoolitic shale, which suggests that there may be some relation between oolitic texture and phosphate content. Another feature is the fact that the content of phosphoric acid is not affected by burning the shale, for the quantity of phosphate in the ash is almost exactly the same as that in the original sample. The phosphate seems to be present as a mineral and not as an organic compound, its form being probably a result of the metamorphism of the rocks. The fact that the phosphate occurs as a mineral and is not decomposed by the heat required to distill the shale may have an important technologic application, as the oil in the shale might be used as fuel to calcine the phosphate if calcination is desirable. A more promising investigation, however, would be directed to the utilization of the ammonia in the oil to produce ammonium phosphate, a small quantity of oil being obtained as a by-product. Unless some such combination can be worked out the samples tested are not rich enough in either phosphate or oil to be of present value. However, as the shale was sampled at only one place in each locality and as its phosphatic character was not surmised at that time but was discovered later in the office, it is possible that richer material may be discovered, especially material richer in phosphate, as high-grade phosphate occurs at Melrose, about 30 miles north of Dillon.

Considered as to their oil content these are true oil shales for they contain no free oil. The oil is obtained from them by the destructive distillation of their vegetable matter, almost no oil having been obtained by extraction tests. Furthermore, as noted by Chase Palmer, the ethereal extract seems to be of mineral rather than vegetable composition—that is, it probably exists as some form of mineral wax or other hydrocarbon produced by the distillation of a part of the original organic matter in the shale. This distillation could have been effected by the metamorphism to which the rocks have been subjected, shown by the folding, faulting, and squeezing manifest at many places and by the crystallization of the limestone. A considerable part of the organic matter that was originally in the shale may therefore have undergone partial distillation, a supposition that in turn may account for the relatively small quantity of oil obtained from these shales. If the shales have already undergone partial distillation, what has become of the distillate? Obviously one of two things has happened. Either the oil has escaped into the atmosphere or it is still retained in the rocks. Where the shales are exposed, as in Muddy Creek basin, the oil has undoubtedly escaped, and this may account for the slight yield on extraction from shale that gives off a strong odor of petroleum. Where the shales are not exposed they may have been a source of supply of petroleum in areas where the structural conditions are favorable to its accumulation. It may therefore be possible that commercial accumulations of oil have been formed in these older (Paleozoic) rocks. If this should prove to be true, it would open up a new field for exploration in the West. Thus far the Lander oil field, in Wyoming, seems to be the only place where oil has been obtained in commercial quantities from the Paleozoic rocks in the Rocky Mountain region, though indications of oil have been noted at several other places in Wyoming and in southern Utah.

DISTRIBUTION.

In the preliminary examination here described no attempt was made to trace these shales and determine their distribution. The writer received numerous reports of the occurrence of similar shale in other places, particularly around Lima and in Horse Prairie. As the shale at the lower horizon is interbedded in Paleozoic rocks and is closely related to if not identical with the shale at the phosphate horizon it is probably widely distributed. Whether or not it is equally petroliferous throughout the known phosphate area remains to be determined, for the phosphate shales at other localities have not yet been tested for oil.

The shale in the Tertiary lake beds is probably much less widely distributed than that in the Paleozoic rocks, for the lake beds, which show considerable variation in lithology, were probably deposited in small areas.

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CONTRIBUTIONS TO ECONOMIC GEOLOGY

(SHORT PAPERS AND PRELIMINARY REPORTS)

1917

PART II.—MINERAL FUELS

DAVID WHITE
GEOLOGIST IN CHARGE

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NOTE.—The Survey's annual volumes entitled " Contributions to economic geology " are issued in parts, and the last part will include a volume title-page, table of contents, and index for the use of those who may wish to bind the separate parts. A small edition of the bound volume will also be issued, but copies can not be supplied to those who have received all the parts.

CONTENTS.

[The letters in parentheses preceding the titles are those used to designate the papers for advance publication.]

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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1917.

PART II. MINERAL FUELS.

DAVID WHITE, *Geologist in charge.*

INTRODUCTION.

The Survey's "Contributions to economic geology" have been published annually since 1902. In 1906 the increase in the number of papers coming under this classification made it necessary to divide the contributions into two parts, one including papers on metals and nonmetals except fuels and the other including papers on mineral fuels. In 1915 the year included in the title was changed from the year in which the field work reported in these papers was done to the year of publication, and in consequence there was no volume entitled "Contributions to economic geology, 1914." The subjoined table gives a summary of these bulletins.

United States Geological Survey "Contributions to economic geology."

Date in title.	Date of publication.[a]	Bulletin No.	Date in title.	Date of publication.[a]	Bulletin No.
1902	1903	213	1911, Part I	1913	530
1903	1904	225	Part II	1913	531
1904	1905	260	1912, Part I	1914	540
1905	1906	285	Part II	1914	541
1906, Part I	1907	315	1913, Part I	1915	580
Part II	1907	316	Part II	1915	581
1907, Part I	1908	340	1915, Part I	1916	620
Part II	1909	341	Part II	1916	621
1908, Part I	1909	380	1916, Part I	1917	640
Part II	1910	381	Part II	1917	641
1909, Part I	1910	430	1917, Part I	1918	660
Part II	1911	431	Part II	1918	661
1910, Part I	1911	470			
Part II	1912	471			

[a] The date given is that of the complete volume; beginning with Bulletin 285 the papers have been issued as advance chapters as soon as they were ready.

As the subtitle indicates, the papers included in these volumes are of two classes—(1) short papers giving comparatively detailed descriptions of occurrences that have economic interest but are not of sufficient importance to warrant a more extended description; (2) preliminary reports on economic investigations the results of which are to be published later in more detailed form. These papers are such only as have a direct economic bearing, all topics of purely scientific interest being excluded.

Brief abstracts of the publications of the year are given in the annual report of the Director. The complete list of Survey publications affords, by means of finding lists of subjects and of authors, further aid in ascertaining the extent of the Survey's work in economic geology.

The reports on work in Alaska have been printed in a separate series since 1904, the volumes so far issued being Bulletins 259, 284, 314, 345, 379, 442, 480, 520, 542, 592, 622, 642, and 662.

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