THE POWDER RIVER OIL FIELD, WYOMING.

By CARROLL H. WEGEMANN.

INTRODUCTION.

The field work on which this report is based was done in October and November, 1910, the writer being assisted by C. J. Hares, William Mulholland, and O. B. Hopkins. The area under consideration (about 200 square miles) lies just southeast of the Bighorn Mountains of Wyoming, in Tps. 40, 41, and 42 N., R. 81 W., and portions of adjoining townships. Practically all the indications of oil occur in T. 41 N., R. 81 W., and in the northern part of T. 40 N., R. 81 W. The distribution of the oil is controlled by a structural dome much resembling that of the Salt Creek oil field,[1] which lies some 15 miles to the southeast, but the strata in which oil occurs in the Powder River field are lower in the geologic column and thus older than those which bear oil at Salt Creek.

The oil of the Powder River field is a heavy lubricating oil somewhat higher in specific gravity than the heaviest oil at Salt Creek. It is black and contains over 2 per cent of asphalt and about 20 per cent of kerosene, but no naphtha. It could be used either as a fuel oil in its crude state or for the manufacture of lubricants.

The Powder River field may be reached from Casper, on the Chicago & Northwestern Railway, a distance of about 55 miles, by private conveyance, or from Sheridan or Clearmont, on the Chicago, Burlington & Quincy Railroad, by stage to Buffalo and Kaycee and thence by private conveyance, the total distance from the railroad by this route being 100 miles. There is also a wagon road from Shannon, on Salt Creek, to the Powder River field.

HISTORY OF THE FIELD.

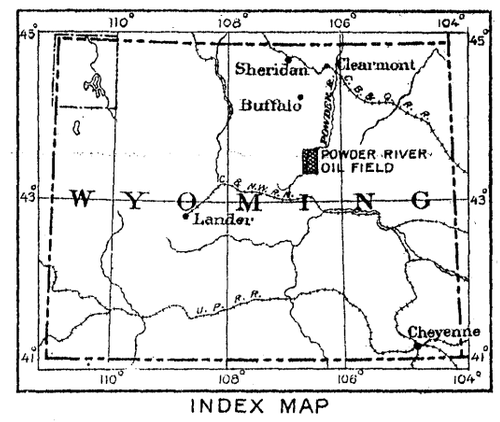
The Powder River oil field has been known since the early eighties. It was described by Samuel Aughey, Territorial geologist of Wyoming, in his annual report for the year 1885, and is mentioned by his successor, Louis D. Ricketts, in his annual report for 1889. The most extended account is given by W. C. Knight in a bulletin of the University of Wyoming, entitled "The Dutton, Rattlesnake, Arago, Oil Mountain, and Powder River oil fields," published in 1901.

[1] Wegemann, C. H., The Salt Creek oil field, Natrona County: Bull. U. S. Geol. Survey No. 452, 1911, pp. 37-82.

R.82 W. R.81 W. R.80 W.

T.42 N. T.41 N. T.40 N.

INDEX MAP



POWDER RIVER

ROAD TO KAYCEE

Frewens Castle

SOUTH FORK

Wall Creek

Old Tisdale Ranch

TRAIL CANYON

OIL CANYON

OIL TUNNEL

SALT CANYON

LONG CANYON

Quinn

L.F.Kelley

JOHNSON CO
NATRONA CO
5° BOUNDARY LINE

FAULT

Lone Bear Creek

Deadhorse Creek

Willow Creek

ROAD TO CASPER

ROAD TO SHANNON

A B

MAP OF POWDER RIVER OIL FIELD, WYOMING

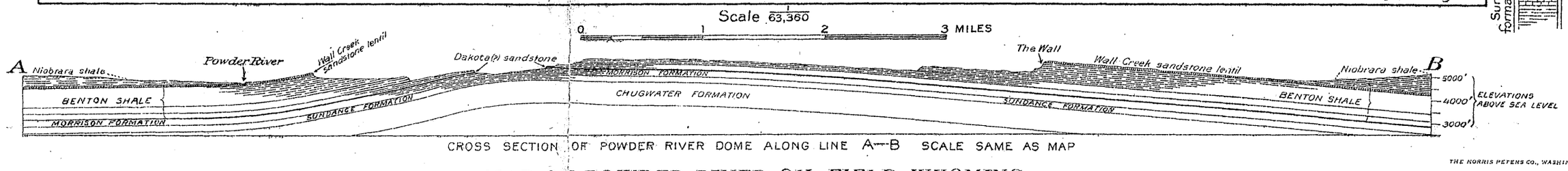
By Carroll H. Wegemann

Assisted by C. J. Hares and Wm. Mulholland

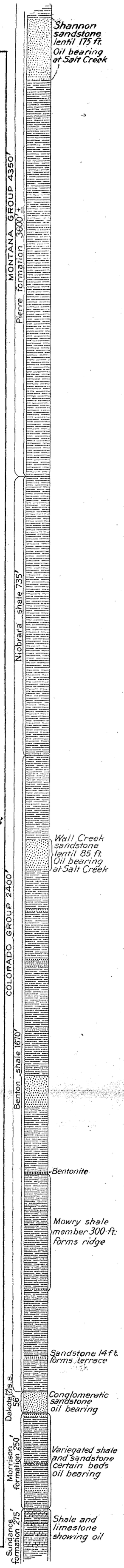
LEGEND

- Pierre formation
- Niobrara shale
- Wall Creek sandstone lentil
- Undifferentiated Benton (including areas not patterned)
- Mowry shale member
- Dakota(?) sandstone
- Morrison formation
- Sundance formation
- Oil well
- Water well
- Oil seep
- Structure contours
- Government land corner
- Instrumental location and altitude
- Local anticline
- Wagon road
- Strike and dip reading

Scale 1/63,360 — 0 1 2 3 MILES



CROSS SECTION OF POWDER RIVER DOME ALONG LINE A—B SCALE SAME AS MAP



Although considerable prospecting and drilling has been done in the Powder River field almost from the time of its discovery, comparatively little oil has been obtained, and the field has not up to this time been of commercial importance.

The first wells in the field and the only ones which obtained more than a showing of oil were open wells 6 or 8 feet square and 30 or 40 feet in depth, which were sunk in a coarse sandstone rather doubtfully correlated with the Dakota. These were dug in the early eighties by the Central Wyoming Oil Association. The same company also dug several tunnels into the sandstone beds which occur in the lower portion of the Morrison formation and from them obtained traces of oil. On their discoveries they received from the Government patent to 1,200 acres of land. About 1886 this company drilled the upper well in Oil Canyon, known as the Bothwell well, which obtained a flow of sulphur water but no oil. The well is said to be 1,000 feet in depth and to have reached the red beds.

In 1893 a Kansas City company drilled several wells on the river flat about three-fourths of a mile below the Tisdale ranch. They obtained a flow of sulphur water in two of the wells but no oil.

In 1896 a well was drilled by the French Oil Co. on Dugout Creek in the SW. ¼ sec. 16, T. 40 N., R. 80 W., to a depth of more than 1,200 feet. No oil was encountered, but a flow of lukewarm sulphur water with a little gas was obtained, which has continued up to the present time.

In 1902–3 the Peoria Oil Co. drilled two wells on the south fork of Salt Canyon to a depth of about 700 feet. Artesian water was encountered near the bottom of each hole and seriously interfered with the drilling, but no oil was struck, although a small amount of gas was obtained in the south well.

In 1902 the Powder River Oil Co. drilled the west well in Oil Canyon, in the NW. ¼ sec. 29, to a reported depth of 700 feet. No oil was struck. In 1903 the same company sunk an open shaft about 7 feet square to a depth of 40 or 50 feet in the Dakota (?) sandstone, in the NE. ¼ sec. 20, T. 41 N., R. 81 W. Apparently no oil was obtained. In 1904 a well was drilled in Oil Canyon in the SW. ¼ sec. 20 by the same company. It is reported that when this well was down between 300 and 400 feet a small showing of oil was encountered. The Dakota (?) sandstone was not reached.

In 1907 H. W. Davis drilled in Trail Canyon, in the SW. ¼ sec. 17, T. 41 N., R. 81 W., a well which reached the Dakota (?) sandstone at about 775 feet. The well was continued to a depth of about 900 feet without striking oil. The Dakota (?) sandstone here carries water that contains sodium salts, but no sulphur.

TOPOGRAPHY.

The Powder River oil field (see Pl. VII) is situated on a dome or anticline of Cretaceous rocks which, although it has undergone consid-

erable erosion, still rises to a height of 800 or 900 feet above the comparatively level country that surrounds it. The dome itself is outlined by the escarpment of a heavy sandstone occurring near the top of the Benton shale, which, dipping away on all sides from the anticlinal axis, practically encircles the dome. Within this escarpment the shale carrying fish scales known as the Mowry shale member forms a wooded ridge with a gradual dip slope on the east and an abrupt escarpment on the west, extending from north to south across the middle of the field. West of this the small streams draining the dome have cut deep canyons in the Dakota (?) sandstone and the underlying Morrison formation.

The principal stream of the region is the South Fork of Powder River, which flows northward along the west side of the dome and then, turning to the northeast, cuts across the upturned edges of the strata and continues in a northeasterly direction to join the main Powder River in T. 43 N., R. 80 W. Four intermittent streams, tributaries of Powder River, drain the dome—Wall Creek, which flows northward just inside the sandstone rim on the east, and Salt Canyon, Oil Canyon, and Trail Canyon, draining the west side of the dome and flowing westward into South Fork of Powder River.

WATER SUPPLY.

The only perennial stream in the area is the South Fork of Powder River and most of its water is used for irrigation.

The best drinking water in the vicinity of the field occurs in the Wall Creek sandstone lentil, which forms the escarpment encircling the dome. The house belonging to L. C. Kelley, at the east side of the dome, stands close to a spring which flows from this sand, and another smaller spring is situated in the bed of a gulch near the crest of "the wall" in sec. 19, T. 41 N., R. 80 W. Other springs are reported from the same sandstone. The well drilled for oil on the east flank of the dome in the SW. ¼ sec. 16, T. 40 N., R. 80 W., passed through the Wall Creek sandstone lentil, but whether the lukewarm sulphur water which flows from the well is derived from this sandstone or not is uncertain. A good spring occurs near a deserted cabin in the SW. ¼ sec. 20, T. 41 N., R. 81 W., in the bed of a gulch which enters Oil Canyon from the north. The underlying rock is the Mowry shale member. Several springs also occur along the east slope of the ridge formed of the Mowry shale, and the water is said to be palatable. The only salt water noted in the field is that in the lower portion of Salt Canyon. Its origin is not known.

The water from the Dakota(?), as noted in the well drilled by H. W. Davis in Trail Canyon, is alkaline, but does not give off the odor of sulphur. Sulphur water obtained in the wells on the south branch of Salt Canyon, in sec. 5, T. 40 N., R. 81 W., put a stop to the drilling.

The wells are reported to be 500 or 600 feet in depth, and if the information is correct, the source of the sulphur water is either the Dakota(?) sandstone or the underlying Morrison formation. The water flowing from the old Bothwell well in Oil Canyon carries considerable sulphur, but the source of the water is not known.

In the SW. ¼ sec. 33, T. 41 N., R. 81 W., a small sulphur spring rises from the Sundance formation, which is here brought to the surface along the bed of the gulch by a sharp fold.

METHODS OF FIELD WORK.

The greater part of the mapping in the Powder River field was done on a 15-inch planetable, on a scale of 1 inch to the mile, a telescopic alidade being used. In beginning the work a base line, 4,650 feet in length, was measured on the ridge of the Mowry shale member from the SW. ¼ sec. 23 to the SE. ¼ sec. 27, T. 41 N., R. 81 W. From the ends of this base line triangulation was expanded on a scale of 2 inches to the mile, and two monuments were located, the northern of these being a pile of stones on "the wall" in the NW. ¼ sec. 18, T. 41 N., R. 80 W., and the southern being the large monument built by the topographers of the Geological Survey in the NW. ¼ sec. 13, T. 40 N., R. 81 W. The distance between these two monuments being established, it was divided in half and the points transferred to a new sheet. From them as the ends of a new base line, control was expanded over the Powder River field on a scale of 1 inch to the mile. Altitudes were carried to the field from a United States Geological Survey bench mark in sec. 12, T. 47 N., R. 82 W., by means of vertical angles measured with the telescopic alidade. Such altitudes are generally accurate within 10 feet and may often be counted on within 2 or 3 feet. In carrying altitudes over long distances, however, as in the present case, the errors may be cumulative and the final error considerably greater than that stated. In the valleys of Salt Canyon, Oil Canyon, and Trail Canyon, where much more detail in mapping was required than in other parts of the area, a scale of 4 inches to the mile was used. Stadia traverse was run up the principal valleys and checked by triangulation.

LAND SURVEYS.

From the few original land corners which were found (represented on Pl. VII by circles), and others in adjoining areas the land lines have been projected according to the Land Office notes. Careful search for original corners was not made throughout the area, and many corners not represented on the map doubtless exist. The location on the map of land lines at a distance from known corners is only approximate, as many irregularities exist in the old surveys which are not recorded on the township plats submitted by the surveyors and so could not be shown on the present map.

STRATIGRAPHY.

GENERAL SECTION.

The following rock formations occur in or near the Powder River field:

Geologic formations in or near Powder River oil field, Wyoming.

System.	Series.	Group.	Formations and members.		Description.	Thickness (feet).
Cretaceous.	Upper Cretaceous.	Montana (4,350 feet).	Fox Hills sandstone.		White sandstone and shale. Marine.	700?
			Pierre formation (3,650 feet).		Shale with several sandstone beds, including that which forms Little Pine Ridge. Marine.	1,000
				Parkman sandstone member.	Massive buff sandstone overlain by shale and thin coal beds. Marine and fresh water.	350
					Shale with sandstone stratum 250 feet above its base. Marine.	1,100
				Shannon sandstone lentil.	Oil-bearing horizon near base. Marine.	175
					Gray shale. Marine.	1,025
		Colorado (2,405 feet).	Niobrara shale.		Light-colored shale, in parts somewhat arenaceous. Marine.	735
			Benton shale (1,670 feet).		Dark shale, several calcareous beds. Marine.	220
				Wall Creek sandstone lentil.	Buff sandstone, ripple marked and cross-bedded. Petrified wood, marine shells, and fish teeth. The principal oil sand of Salt Creek.	80
					Dark shale, several sandstone beds. Marine.	800
				Mowry shale member.	Firm slaty shale, usually forming escarpment. Weathers light gray and bears numerous fish scales. Marine.	300
					Dark shale with one thin, persistent, strongly ripple-marked sandstone.	270
			Dakota(?)sandstone.		Conglomeratic sandstone, oil bearing. Fresh water.	56
Jurassic(?).			Morrison formation.		Variegated shale with several sandstone beds which in certain localities bear oil. Fresh water.	250
Jurassic.			Sundance formation.		Shale and limestone in upper part; white sandstone in lower part.	275

JURASSIC SYSTEM.

SUNDANCE FORMATION.

The Sundance formation is exposed in the Powder River field at one locality only, in sec. 33, T. 41 N., R. 81 W., along the bed of a canyon which enters Salt Canyon from the north. Here about 10 or 15 feet of the formation is brought to the surface by a sharp minor fold. This exposure consists of argillaceous limestone beds a foot or two in thickness which bear abundant fossils and, interbedded with the limestone layers, numerous beds of dark-gray shale. At the top of the formation is an 8-foot bed of shale having fossils in its lower part but none in the upper 3 or 4 feet. It probably represents a transition from the Sundance below to the Morrison above. The Sundance as exposed along the Bighorn uplift to the northwest is about 150 feet in thickness. It is underlain by Triassic or Permian red beds (Chugwater formation). Oil is present in the Sundance in small quantities at least, as is evidenced by an oil seep which occurs in the SW. ¼ sec. 33, T. 41 N., R. 81 W., along the sharp fold mentioned above.

The following fossils were collected in the SW. ¼ sec. 33, T. 41 N., R. 81 W., and identified by T. W. Stanton.

Pentacrinus asteriscus M. and H.
Ostrea strigilecula White.
Ostrea engelmanni Meek.
Camptonectes bellistriatus Meek.
Pleuromya subcompressa [Meek].
Dentalium subquadratum Meek.
Belemnites densus M. and H.

JURASSIC (?) SYSTEM.

MORRISON FORMATION.

The Morrison formation, which is doubtfully referred to the Jurassic, overlies the Sundance conformably. It represents, however, fresh-water conditions of sedimentation, whereas the Sundance represents marine conditions. The Morrison consists of shale with a few hard sandstone beds from 3 to 8 feet in thickness. The shale in the lower part of the formation has a greenish tinge, but in the upper part it is maroon. The colors are by no means pronounced and the term variegated might well be applied to this formation. The Morrison in this locality is 250 feet in thickness. The hard sandstone strata mentioned are four or five in number and always form ledges where the formation is exposed by erosion. Oil occurs in small quantity in at least two of these sandstone beds in the Powder River field.

Saurian remains and fossil leaves are reported by N. H. Darton[1] from the Morrison formation along the Bighorn uplift. The only fossils found in the present investigation belong to a species of *Unio*

[1] Geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906.

which occur in considerable numbers in the NE. ¼ sec. 33, T. 41 N., R. 81 W., in a sandstone near the base of the formation. The specimens were identified by T. W. Stanton as *Unio felchii*.

CRETACEOUS SYSTEM.

DAKOTA (?) SANDSTONE.

Overlying the Morrison is a coarse conglomeratic sandstone 56 feet in thickness with a thin bed of coal at its base, which in certain localities suffered from erosion before the sandstone was laid down. Bits of coal occur throughout the mass of the sandstone itself and cross bedding is marked. In the Powder River field the sandstone is a lithologic unit, but 25 miles to the north, where it outcrops along the Bighorn uplift, it consists of numerous thin layers of sandstone with interbedded shale, some of which is pink in color and is not very different in appearance from the underlying Morrison. The Dakota (?) sandstone, so far as known, is the principal oil-bearing formation of the Powder River field. It is from this sandstone that the oil obtained in the open wells of Trail Canyon and Oil Canyon is derived, and in this sandstone most of the oil seeps occur.

Near the top of the sandstone are numerous shaly layers in which stems, bark, and a few small leaves of ferns were found. Fossils are rare, however, and were not collected in sufficient number for a definite determination of the age of the sandstone. It is here provisionally called the Dakota (which is Upper Cretaceous in age), but it may represent the Lakota (Lower Cretaceous) of the Black Hills. The question as to the age of the formation can not be settled without further field study.

COLORADO GROUP.

BENTON SHALE.

Above the Dakota (?) sandstone is the Benton shale, about 1,700 feet in thickness. It is not in this region a lithologic unit, and its several divisions are worthy of detailed description.

Lower beds.—Resting upon the Dakota (?) sandstone with a sharp line of demarcation between the two is about 80 feet of dark shale, which is apparently barren of animal remains. It contains numerous plant stems, which are not of value, however, in determining its age. The shale is capped by a shaly sandstone 14 feet in thickness, which in most places forms a marked terrace. The sandstone bears plant remains similar to those of the shale below and, like it, may be Benton in age or may be older. The sandstone is strongly ripple marked and apparently is persistent throughout a considerable area, as it has been observed along the Bighorn Mountains 40 miles north of the field. Above this sandstone is 175 feet of dark shale very similar to that below and also bearing plant stems. Fifteen feet above its base

were found, in a thin, calcareous layer, the teeth of a species of Lamna (shark). The shale is capped by a thin sandstone stratum, which in certain places increases to 8 or 10 feet in thickness and usually forms a small terrace. Just below it was found, near the center of sec. 28, T. 41 N., R. 81 W., a fragment of petrified wood, and at about this horizon in the SE. ¼ sec. 32, T. 42 N., R. 81 W., in the bank of Powder River, occur several thin carbonaceous beds, one of which contains a few inches of subbituminous coal. The shark teeth found in the lower part of this shale probably indicate marine or brackish water conditions during deposition, whereas the petrified wood and coal occurring at its top suggest a short period at least of fresh-water deposition. The plant stems occurring throughout the shale may belong to either a fresh-water or a salt-water flora.

Mowry shale member.—Above the variable sandstone with which is associated the coal bed just described the shale is lighter in color and harder. It also contains throughout its mass numerous fish scales. For a thickness of 300 feet the shale may be regarded as a lithologic unit, and is called the Mowry shale member. In its upper portion the fish scales are less abundant, but the shale itself is easily recognized by its lithologic character. In its lower part are several beds of bentonite (hydrous silicate of alumina), and at its top is a bed of the same material 5 or 6 feet thick. The upper bed of bentonite forms a conspicuous white band along the foot of the dip slope usually formed by the Mowry member and is easily recognized, especially after a rain, when it is exceedingly slippery.

Beds above the Mowry.—Overlying the Mowry is 800 feet of shale with several sandstone beds in its upper part. In contrast to the Mowry, which can be traced over a great area and is very uniform in character, these beds are most variable. In the southern part of the Powder River dome four distinct sandstone strata occur below the outcrop of the Wall Creek sandstone lentil, which rims the dome. In the northern part only two of these sandstone beds are represented, the others apparently having been replaced by shale.

Wall Creek sandstone lentil.—Overlying the shale and sandstone beds just described is a sandstone about 80 feet in thickness, which is the most important oil-bearing sand of the Salt Creek dome, but which in the Powder River field is barren of oil. It is called the Wall Creek sandstone lentil, from its exposures along Wall Creek. The sandstone is dirty buff in color, is cross-bedded, and in its lowest 5 or 6 feet contains numerous small lenses of shale, which give to that portion a peculiar mottled appearance. It bears fragments of petrified wood, large shark teeth, and numerous shells of invertebrates, and, although of marine origin, was probably laid down not far from some land mass.

Uppermost beds.—The part of the Benton shale above the Wall Creek sandstone lentil is somewhat darker than the part below, and contains four thin beds of ferruginous limestone separated by intervals of 50 or 60 feet. The topmost bed is about 220 feet above the Wall Creek lentil, and may be considered as marking the top of the Benton shale.

Fossils.—The fossils named below were collected from the Benton. The invertebrates were identified by T. W. Stanton and the plant remains by F. H. Knowlton.

Arenaceous stratum 4 feet above Dakota (?) sandstone, SW. ¼ sec. 20, T. 41 N., R. 81 W.:
- Trails.
- Burrows.
- Stem imprints.

Sandstone at base of Mowry shale member, NE. ¼ sec. 28, T. 41 N., R. 81 W.:
- Gastropods.
- Dicotyledonous leaves.
- Rootlets.

Middle portion of Mowry shale member, SE. ¼ sec. 32, T. 41 N., R. 81 W.:
- Inoceramus labiatus Schloth.?
- Fish scales.
- Benton fauna.

Sandstone 100 feet below Wall Creek sandstone lentil, SW. ¼ sec. 19, T. 41 N., R. 80 W.:
- Inoceramus fragilis H. and M.?
- Metoicoceras sp.
- Benton fauna.

Dark shale just below Wall Creek sandstone lentil, SE. ¼ sec. 19, T. 41 N., R. 80 W.:
- Inoceramus fragilis H. and M.?
- Scaphites sp.
- Prionocyclus wyomingensis Meek.
- Benton fauna.

Arenaceous shale 137 feet below the Wall Creek sandstone lentil, NW. ¼ sec. 13, T. 40 N., R. 81 W., near large monument:
- Metoicoceras.
- Benton fauna.

Argillaceous sandstone 86 feet below Wall Creek sandstone lentil, NW. ¼ sec. 13, T. 40 N., R. 81 W., near large monument:
- Inoceramus labiatus Schloth.
- Pachydiscus? sp.
- Benton fauna.

Sandy shale just below Wall Creek sandstone lentil, NW. ¼ sec. 13, T. 40 N., R. 81 W., near large monument:
- Inoceramus labiatus Schloth.?
- Scaphites ventricosus M. and H.?
- Benton fauna.

Middle portion of Wall Creek sandstone lentil, sec. 23, T. 42 N., R. 81 W.
- Inoceramus fragilis H. and M.?
- Martesia? sp. Burrow in wood.
- Fragmentary fish bones.
- Benton fauna.

About 25 feet above base of Wall Creek sandstone lentil, SE. ¼ sec. 19, T. 41 N. R. 80 W.:
Inoceramus fragilis H. and M.?
Benton fauna.

Top of Wall Creek sandstone lentil, NW. ¼ sec. 30, T. 41 N., R. 81 W.:
Turnus? sp.

Wall Creek sandstone lentil, SE. ¼ sec. 14, T. 40 N., R. 82 W.:
Inoceramus sp.
Benton (?) fauna.

Top of Wall Creek sandstone lentil, NW. ¼ sec. 31, T. 41 N., R. 81 W.:
Exogyra sp.
Crassatellites? sp.
Benton fauna.

Wall Creek sandstone lentil, SW. ¼ sec. 30, T. 41 N., R. 81 W.:
Halymenites major Lesq.
Petrified wood occurring as water-worn pebbles 2 inches in diameter embedded in the sandstone.

Wall Creek sandstone lentil, NE. ¼ sec. 1, T. 40 N., R. 81 W.:
Inoceramus fragilis H. and M.?
Turnus? sp.
Lunatia sp.
Baculites gracilis Shumard?
Scaphites warreni M. and H.
Prionocyclus wyomingensis Meek.
Benton fauna.

Concretionary masses in shale about 200 feet above Wall Creek sandstone lentil, sec. 21, T. 41 N., R. 80 W.
Ostrea sp. Possibly O. congesta Con.
Inoceramus sp. Related to I. deformis Meek.
Probably near contact between Benton and Niobrara.

Concretionary limestone 150 feet above the Wall Creek sandstone lentil, sec. 10, T. 42 N., R. 81 W.:
Ostrea sp.
Inoceramus sp.
Tapes? sp.
Turritella sp.
Volutoderma? sp.
Scaphites ventricosus M. and H.
Benton fauna.

Concretionary limestone 75 to 100 feet above Wall Creek sandstone lentil, sec. 23, T. 42 N., R. 81 W.:
Exogyra sp.
Avicula sp.
Inoceramus fragilis H. and M.
Turritella sp.
Fusus? sp.
Benton fauna.

Calcareous layer 40 feet above Wall Creek sandstone lentil, NW. ¼ sec. 15, T. 42 N., R. 81 W.:
Exogyra sp.
Inoceramus sp.
Scaphites ventricosus M. and H.
Benton fauna.

Shale about 20 to 50 feet above Wall Creek sandstone lentil, SE. ¼ sec. 11, T. 40 N., R. 81 W.:

Ostrea sp.
Inoceramus fragilis H. and M.?
Inoceramus sp.
Scaphites ventricosus H. and M.?
Benton fauna.

Limestone concretions between Wall Creek sandstone lentil and Niobrara shale, SW. ¼ sec. 29, T. 40 N., R. 80 W.:

Exogyra sp.
Ostrea sp.
Fasciolaria? sp.
Probably from upper Colorado.

About 100 feet above Wall Creek sandstone lentil, NW. ¼ sec. 9, T. 40 N., R. 80 W.:

Ostrea congesta Conrad?
Exogyra sp.
Inoceramus fragilis H. and M.?
Inoceramus sp.
Probably upper part of Benton.

Interval between Wall Creek sandstone lentil and the Niobrara, NE. ¼ sec. 21, T. 41 N., R. 80 W.:

Ostrea sp.
Leda? sp.
Lunatia sp.
Fasciolaria? sp.
Baculites gracilis Shumard?
Benton fauna.

Top of Benton shale, NE. ¼ sec. 3, T. 42 N., R. 81 W.:

Scaphites sp.
Baculites sp.
Probably Colorado.

Dark shales of Colorado group, NE. ¼ sec. 3, T. 42 N., R. 81 W.:

Ostrea sp.
Inoceramus sp.
Baculites sp.
Scaphites sp.
Fish bones.
Probably upper part of Colorado.

Uppermost ledge of concretionary limestone, about 200 feet above Wall Creek sandstone lentil, sec. 15, T. 42 N., R. 81 W.:

Ostrea congesta Conrad.

NIOBRARA SHALE.

About 220 feet above the top of the Wall Creek sandstone lentil the dark shale of the Benton gives place to the buff or bluish-gray shale of the Niobrara. The latter contains fragments of very thick shelled Inocerami, to which are attached in clusters numerous shells of *Ostrea congesta*. The association of these two fossils is typical of this formation. Exposures of the Niobrara shale are usually concealed in a broad valley, and the limits of the formation are somewhat difficult to establish and trace. The lower limit, as already mentioned, is placed a little over 200 feet above the top of the Wall Creek sandstone lentil, where the shale changes abruptly from dark to light in color and is

somewhat sandy in composition. At this point also *Ostrea congesta* appears in considerable numbers; below it only isolated specimens can be found.

At the top of the formation are two or three beds of limestone only a few inches in thickness. *Ostrea congesta* is fairly abundant in the shale below these beds of limestone, but above them none occur, and many large baculites distinctive of the Montana group are found. At the limestone horizon, also, there is a slight change in lithologic character of the shale; above the limestones are numerous very thin beds of reddish calcareous shale and the structure known as cone-in-cone is abundant, whereas below them neither occurs. Also the amount of alkali in the Montana group is apparently greater than in the Niobrara shale, as indicated by the white alkali deposited on the surface by evaporation. These differences, although perhaps unimportant in themselves, furnish convenient means, where fossils can not be found, of separating the Niobrara from the overlying Montana.

Owing to the lack of exposures the thickness of the Niobrara shale is difficult to determine. Three sections made along the outcrop from 1 to 4 miles northwest of Kaycee give an average of 735 feet. Another section measured on the southeast side of the Powder River dome, about 4 miles southwest of Scott's ranch, gives a thickness of 1,025 feet, which is unusually large. Exposures in this locality are good and there seems to be little chance of error unless concealed faults have duplicated the beds. Even if this section is disregarded, however, it is evident that the Niobrara in this general region is of unusual thickness as compared with other localities, although much less distinct in lithologic character.

The following fossils were collected from the Niobrara shale and identified by T. W. Stanton.

Shale about 300 feet above Wall Creek sandstone lentil, sec. 10, T. 42 N., R. 81 W.:
Ostrea congesta Conrad.
Inoceramus sp. Fragments of a large, thick-shelled species with Ostrea shells attached.
Niobrara.

Limestone and shale, sec. 3, T. 40 N., R. 82 W.:
Ostrea congesta Conrad.
Inoceramus.
Probably Niobrara.

Limestone stratum, SW. ¼ sec. 32, T. 40 N., R. 80 W.:
Ostrea congesta Conrad.
Probably Niobrara.

Shale, NW. ¼ sec. 32, T. 40 N., R. 80 W.:
Ostrea congesta Conrad.
Inoceramus sp.
Probably Niobrara.

Shale, NW. ¼ sec. 32, T. 40 N., R. 80 W.:
Ostrea congesta Conrad.
Probably Niobrara.

MONTANA GROUP.

PIERRE FORMATION.

Above the Niobrara the gray shale of the Pierre extends for 1,000 feet to the upper oil-bearing sandstone of Salt Creek, which is known as the Shannon sandstone lentil and which outcrops just east of the area shown on the map (Pl. VII). A further description of the Montana group is given in the writer's report on the Salt Creek oil field.[1]

The following fossils were collected from the lower part of the Pierre and examined by T. W. Stanton and C. W. Gilmore.

Dark-gray shale, NW. ¼ sec. 25, T. 41 N., R. 80 W.:
Baculites ovatus Say.
Montana fauna.
Dark-gray shale, sec. 35, T. 41 N., R. 80 W.:
Fragment of reptile bone.
Undeterminable.

FOX HILLS SANDSTONE.

The Fox Hills sandstone, which overlies the Pierre formation in apparent conformity, outcrops some distance northeast of the Powder River field. It consists of a series of white sandstones with interbedded shale and local coal beds, usually of little economic importance. The whole series is about 700 feet in thickness, but the lower limit has not been defined with certainty. At the top, immediately below the Lance formation, is a white sandstone from 150 to 200 feet in thickness, which is a constant feature in the vicinity of the Salt Creek field but is not prominent farther north. For a more complete description see the writer's report cited above.

STRUCTURE.

The horizontal plan of the Powder River dome is roughly outlined by the outcrop of the Wall Creek sandstone lentil. As thus defined, the dome is a somewhat irregular oval structure 16 miles in length from north to south and 10 miles in width from east to west, its axis trending approximately north and south and being much nearer its west than its east side. About 15 miles north and a little west of the highest point of the dome is a smaller but similar dome, which lies just west of the village of Kaycee. The two domes are connected by a low anticlinal arch and may be considered as parts of a single structure—an anticline 30 miles in length by 15 miles in width.

To the northeast the strata dip away from the anticline at various angles until, at a distance of 15 miles from the axis, they are practically horizontal in the broad basin which lies between the Black Hills and the Bighorn Mountains. On the southeast they dip at low angles into a shallow syncline which intervenes between the

[1] Bull. U. S. Geol. Survey No. 452, 1911.

Powder River and Salt Creek domes and rise again in the Salt Creek dome, only to drop once more into a great basin on the east, the dip gradually decreasing until at a distance of 30 miles from the Powder River field the strata are practically horizontal.

West of the Powder River dome the strata dip abruptly into a syncline and rise once more beyond, along the Bighorn uplift. South of the dome the structure gradually flattens until the anticline merges with the synclines on either side and the folds are replaced by a monocline with gentle dip to the east.[1]

The axis of the Powder River dome trends north and south and is approximately parallel to that of the Kaycee dome, but the latter structure is 4 or 5 miles west of the former, the axis of the anticline connecting the two domes being bent rather abruptly to the west at the north end of the Powder River dome. The whole structure is a duplication of the anticline at Salt Creek, except that in the Salt Creek anticline the northern dome is the larger and produces the oil. In the Salt Creek dome only rocks of the Montana group are brought to the surface, whereas in the Powder River dome older formations are exposed. In other respects the two anticlines are very similar and apparently were produced contemporaneously by the same forces acting in the same way. In the vast thickness of strata (almost 15,000 feet) exposed from the top of the Sundance formation in the Powder River field to the upper strata of the Fort Union formation in Pumpkin Buttes, 40 miles to the northeast, no marked unconformity of dip has as yet been observed. The lower strata of the Fort Union are upturned along the eastern margins of the anticline of Salt Creek and Powder River at angles in some places as high as 30°. No dips higher than these occur in the oldest rocks exposed in the Powder River dome. It seems probable, therefore, that at least the major part of the folding which produced the anticlines of Salt Creek and Powder River occurred after the deposition of the Fort Union formation.

A better conception of the general shape of the Powder River dome can be gained from a study of the structure contours shown on the accompanying map (Pl. VII) than can be given in words. Several points, however, deserve special mention. The crest of the dome throughout the central part of the area is broad, with gentle dips to the east and west. In secs. 16 and 20, T. 41 N., R. 81 W., however, a minor fold 20 or 30 feet in width and 5 to 10 feet in height is developed just west of the axis of the dome and parallel to it. In the SW. ¼ SW. ¼ sec. 16, at the location of the oil pits in Trail Canyon, this fold occurs at the very crest of the dome and the axes of the two coincide, but north and south of this point the axes diverge so

[1] Since the completion of the field work on which this report is based a small dome has been reported about 10 miles south of the Powder River dome. It has not been seen by the writer.

that the fold exists as a minor irregularity on the west flank of the dome near its crest. It generally marks the line at which the strata begin to dip steeply to the west.

In sec. 33, T. 41 N., R. 81 W., occurs a small but sharp fold which extends for over half a mile in a direction N. 32° E. Its axis thus makes a considerable angle with the axis of the dome in this locality. The fold is not over 15 or 20 feet in width and 8 or 10 feet in height—is so small, in fact, that it does not influence the direction of the structure contours drawn at intervals of 100 feet, which are shown on the general map. The fold dies out rapidly on the northeast and southwest. It is particularly interesting, as it brings to the surface the only exposure of the Sundance formation in the area. On the crest of this fold a small oil seep occurs, the oil being derived from the Sundance formation.

Another fold similar to the one just described occurs in sec. 32, T. 41 N., R. 81 W., and extends into sec. 5, T. 40 N., R. 81 W., in a direction parallel to the general strike of the rocks in this locality. This fold is perhaps 50 or 75 feet in width and 15 to 25 feet in height, but is not large enough to be represented by the structure contours, and a special symbol is therefore used on the map to indicate it. Two wells have been drilled upon this fold, in one of which a small quantity of gas was struck, but no oil was obtained in either well. No trace of the fold was found on the north side of Salt Canyon, and it dies out rather abruptly at its southeastern extremity. It is in all about a mile in length.

In the SE. ¼ sec. 6, T. 41 N., R. 81 W., a cross section of a symmetrical anticline in the Mowry shale member is exposed in the south bank of Powder River. This anticline is of about the same width as that described above and is only local in extent.

The structure contours on Plate VII represent elevations above sea level and are drawn at intervals of 100 feet on the upper surface of the Dakota (?) sandstone. Altitudes on the Dakota (?) were obtained in two ways—by vertical-angle readings on exposures of the sandstone and by vertical-angle readings on other strata whose stratigraphic distance above the Dakota (?) was known. Where it was impossible to obtain altitudes on the sandstone by the methods just mentioned the contours were spaced according to dip readings taken at the surface. A stratum dipping 10° falls 100 feet in a certain horizontal distance. If it dips only 5° it falls 100 feet in a much greater distance. It is possible to make a scale by which the horizontal distance between 100-foot contours can be read for any given dip. The final check on the work was the accordance of the contours thus spaced between points of known altitude. The contours as given on the map are most accurate within the outcrop of the Wall Creek sandstone lentil, for here observations both of dip and altitude

were made at many more points than in the area outside of this outcrop. The other contours are only approximately accurate, but are given more to show the general structure of the region than to furnish exact information as to the depths at which certain strata can be struck in wells. The principal economic use to which the structure contours given on the map can be put is the estimation of depth of any given stratum where the altitude of the surface is known. For example, if at a certain point the surface altitude is 5,200 feet and the point falls on the map near the 4,800-foot contour, it is evident that the Dakota (?) sandstone at this point is about 400 feet below the surface. By reference to the geologic column given at the side of the map the distance between the Dakota (?) and any other formation, such as the Sundance, may be determined and this amount added to or subtracted from the altitude of the Dakota (?), thus giving the elevation above sea level of the other formation.

DISTRIBUTION OF THE OIL.

Oil has been found in five different beds in the Powder River field. Of these the lowest is in the Sundance, a small quantity of oil, along with brackish water, rising from the upper strata of that formation in the SW. ¼ sec. 33, T. 41 N., R. 81 W.[1] A massive sandstone about 6 or 7 feet thick near the base of the Morrison formation contains a small quantity of oil in the NE. ¼ sec. 33, T. 41 N., R. 81 W., where a tunnel has been driven into the sandstone.[2] In Oil Canyon, in the NW. ¼ sec. 28, T. 41 N., R. 81 W., a small oil seep was noted in a sandstone near the middle of the Morrison. In the Mowry shale member oil is reported in small quantity in the well in Oil Canyon, where a few quarts was obtained at a depth of about 300 feet. The principal reservoir of oil in the field, however, is the coarse conglomeratic sandstone, 56 feet thick, which is in this report doubtfully called Dakota. On account of its character and thickness this is an excellent reservoir for the storage of oil. It has been prospected with results that have not been altogether encouraging. A glance at the map, however, will show that while the west side of the dome has been prospected fairly well, no drilling has been done on the east side, which is, under any theory of oil accumulation, the more promising of the two.

The open wells in Trail Canyon, situated on the crest of a secondary fold previously described, which here forms also the axis of the anticline, obtain oil from the Dakota (?) sandstone,[3] but the well in the small canyon half a mile to the south, situated a short distance

[1] See second analysis from Powder River field, p. 75
[2] See third analysis from Powder River field, p. 75.
[3] See fourth analysis from Powder River field, p. 75.

farther down the western slope of the dome, struck water only in the sand. It seems probable that in this locality the small secondary fold has brought about a local accumulation of oil that does not extend beyond the limits of this fold. Oil was reached in the open well in Oil Canyon[1] at a point somewhat lower on the anticline than the well last mentioned, which obtained water, yet the old Bothwell well, drilled on the same contour on the dome, did not strike oil in the Dakota (?). Oil seeps occur in the Dakota (?) sandstone near the point where its outcrop crosses Salt Canyon and also considerably to the east, near the head of one of the south branches of the same canyon, but it is to be noted that no seeps occur east of the axis of the anticline.

It is evident that here, as in most other western oil fields, the accumulation of oil is controlled in part by structural conditions, but it is also apparent that other conditions affect the shape of the oil pool. Some authorities believe that the accumulation of oil takes place because of water pressure which drives the oil before it. This pressure may be due in part to artesian head, but in greater measure to the difference in capillary action between oil and water, that of water being much stronger. If we assume this theory to be correct and apply it to the Powder River field, we must look for a gathering ground for the water which evidently exists in the Dakota (?) below the oil on the western limb of the anticline. There is only one area where the strata involved come to the surface outside of the dome itself; that is along the Bighorn uplift some 8 or 10 miles west of the crest of the dome. The water which here enters the Dakota (?) sandstone, being confined above by the overlying shale, must pass downward into the syncline, which lies just west of the Powder River dome, to a depth of 1,600 to 1,800 feet and rise again toward the outcrop of the sandstone, where it is exposed in the oil dome. Thence it works its way gradually north and south around the ends of the dome, driving before it the oil globules disseminated through the sandstone. It reaches the west side of the dome first and by the most direct route, and so exerts more pressure at that point than it can after its journey around the ends of the dome, consequently the oil on the west side of the dome is pushed up nearer the axis of the anticline. Where minor folds exist it may be caught and retained in them, though the folds themselves may be completely surrounded by the water which has worked its way into the sandstone reservoir. The water which travels around the north and south ends of the dome, driving the oil particles before it, gradually loses headway and at some point on the east side of the dome comes to a standstill. At this point, which is more likely to be at some minor undulation or fold, the accumulation of oil probably takes place.

[1] See first analysis from Powder River field, p. 75.

If, with an older school of oil men, we believe that the accumulation of oil is due principally to the difference in specific gravity between oil and water, the oil gradually working its way upward because of its lower specific gravity, the east side of the dome still appears to offer the more promising field for prospecting, for on this side, owing to the gentle dip of the rocks, the gathering ground for the oil is extremely large, especially on the northeast. On the southeast the gathering ground is limited by the axis of the syncline which lies between the Powder River and Salt Creek domes. On the west side of the Powder River dome, because of the steep dip of the rocks the axis of the syncline lies not far distant from the outcrop of the oil-bearing sandstone, and hence the gathering ground for the oil is limited in extent, for the oil west of the axis of the syncline rises not toward the Powder River dome but toward the Bighorn uplift. It seems probable, then, that the possibilities of the Dakota (?) sandstone in the Powder River field will not have been thoroughly tested until wells are put down on the north and south ends of the dome and at some point on the east side, preferably at locations such as the minor roll which is present in secs. 2 and 3, T. 41 N., R. 81 W., on the northeastern slope of the dome. If in such wells a strong head of water is encountered in the Dakota (?) sandstone it is probable that the area containing oil in the Powder River dome is comparatively small and the very crest of the anticline should be tested.

Even should the Dakota (?) sandstone and the other beds near it prove unproductive throughout the dome, another possible oil stratum exists which has never been tested in this general region. This is the Embar formation, a division of the upper part of the Carboniferous, which is the probable source of oil in the Lander field, although the productive strata in that area are, for the most part, in the Chugwater red beds, which overlie the Embar.[1]

N. H. Darton[2] describes the Embar formation, which outcrops west of the Powder River field, as follows:

> On the east slope of the Bighorn Mountains the formation appears at intervals in the valley of Buffalo Creek, near the Hole-in-the-Wall. The limestone is 20 feet thick, with a 2-foot massive layer at the top, and with thinner-bedded slabby limestones of greenish-gray color and green shale below, lying on the Tensleep sandstone. The formation is traceable continuously northward to the Red Fork of Powder River, but gradually thins in that direction.

The presence of oil in two sands in the Morrison and its existence in the Sundance formation, as well as its presence in the Dakota (?) (at four horizons in a stratigraphic distance of 300 feet), would seem to indicate a common origin for the oil. It does not seem unreasonable to suppose that it is working its way upward from some source

[1] Woodruff, E. G., The Lander oil field, Fremont County: Bull. U. S. Geol. Survey No. 452, 1911.
[2] Darton, N. H., Geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906, p. 36.

as yet undiscovered, and that it collects in any sandstone which forms a convenient reservoir. The Embar formation and the overlying red beds are both within the reach of the drill in the Powder River field. The Sundance is about 300 feet thick and the Chugwater red beds about 1,000 feet thick. These estimates are made from exposures along the Bighorn Mountains to the northwest. The top of the Embar or base of the Chugwater should lie about 1,350 feet below the top of the Dakota (?) sandstone of this area, or approximately 3,000 feet below the surface at the outcrop of the Wall Creek sandstone lentil. The fact that the Chugwater and Embar formations bear oil in the Lander field is no proof that they carry oil in the Powder River dome, yet the possibility appears to be worth testing.

CHARACTER OF THE OIL.

A table of analyses of Powder River oils, made in the laboratory of the United States Geological Survey under the direction of David T. Day, is appended. Analyses of the oils from Salt Creek and Lander are also given for the sake of comparison. Concerning the character and value of the Powder River oils, Mr. Day says:

> These oils resemble the heavy oils from Natrona County, but are somewhat different in their character, containing very considerable amounts of asphalt, while the Salt Creek oils show none. The samples here submitted show less than 2.5 per cent, whereas the Lander oils run as high as 15 per cent. In general, these oils are intermediate in their character between the Lander and the Salt Creek oils. As to their utilization, they could be used with profit if no better oils were at hand for the production of illuminants, but they are by no means as good for this purpose as the light Salt Creek oils. It is evident that these oils would ordinarily be used first for fuel, for which they would require practically no preliminary treatment, although the fuel oil would also be good after the illuminating fraction was first distilled off, or after the oils were "skimmed," as this process is called in the trade. There is no doubt that these oils, besides being valuable for fuel, would yield the fine lubricants characteristic of most refining oils. For this, the small amount of asphalt would be only slightly detrimental. Cylinder oils of good grade can be obtained by distilling off carefully the lighter parts of the oil. Ordinary machine oils and other lubricants could be obtained by distilling the oil down to dryness and cutting the distillants according to specific gravity, extracting any paraffin wax which might develop, and then purifying the oil by treatment with sulphuric acid, filtration, etc., in the ordinary way.

Analyses of Wyoming oils.

[Made in the laboratory of the United States Geological Survey, David T. Day, in charge.]

Well or location.	Physical properties.			Distillation by Engler's method.							Water.	Sulphur.	Paraffin.	Asphalt.	Unsaturated hydrocarbons.	
	Gravity at 60° F.		Color.	Begins to boil.	By volume.											
					To 150° C. (naphtha, gasoline, benzine).		150–300° C. (water-white oil).		Residuum (lubricating oil, paraffin, and tar).		Total cubic centimeters.					
	Specific.	Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.					Crude.	150–300° C.
Lander field.		°		°C.								P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
Wyoming No. 3	0.9198	22.2	Dark brown.	93	2.5	.....	22.0	(a)	(a)	(a)	(a)	.....	.....	(a)	(a)	50.4	(a)
Wyoming No. 4	.9126	23.4	.....do.....	120	2.0	.....	23.5	0.8041	69.9	0.9543	95.4	.....	.....	0.91	4.02	46.4	4
Wyoming No. 5	.9121	23.5	.....do.....	93	2.0	.....	21.0	.8067	75.2	.9589	98.2	.....	.....	1.27	5.69	50.8	4
Wyoming No. 6	.9126	23.4	.....do.....	105	1.5	.....	24.0	.8018	73.9	.9605	99.4	.....	.....	.90	11.04	58.0	4
Wyoming No. 7	.9091	24.0	.....do.....	108	2.5	.....	23.0	.8047	73.1	.9589	98.6	.....	.....	.62	15.26	50.8	9
Wyoming No. 8	.8121	42.4	Green.....	77	14.0	0.7244	41.0	.7994	41.1	.8755	96.1	.....	.....	5.85	.00	10.4	5
Salt Creek field.																	
Dutch No. 1 (sample 1)	.8221	40.3	Green.....	76	8.0	.7220	38.0	.7881	49.3	.8963	95.3	.....	.....	4.97	.....	16.4	4
Dutch No. 1 (sample 2)	.8255	39.6	.....do.....	76	11.0	.7210	36.0	.7934	50.0	.9088	97.0	.....	.....	4.91	.....	13.2	4
Dutch No. 1 (sample 3)	.8221	40.3	.....do.....	66	16.0	.7114	29.0	.7911	52.4	.8861	97.4	.....	.....	6.44	.....	14.4	5
Shannon No. 10	.9097	23.9	Olive green..	204	.....	.....	12.5	.7673	86.9	.9192	99.4	.....	.....	1.14	.....	15.2	6
Shannon No. 12	.9085	24.1	Green.....	213	.....	.....	10.0	.8673	86.6	.9211	96.6	.....	.....	.....	.....	14.8	8
Iba	.8314	38.4	.....do.....	84	11.0	.7215	34.0	.7875	54.0	.8923	99.0	.....	.....	5.56	.....	13.2	4
Stock	.8563	33.5	Dark green..	126	1.0	.....	36.0	.7854	62.4	.9032	99.4	.....	.....	5.63	.....	13.2	4
Powder River field.																	
Open pit in Oil Canyon	.9180	22.5	Black.....	190	.....	.....	14.0	.8546	84.3	.9302	98.5	0.19	0.38	.0	2.31	33.2	6
Oil seep in Salt Canyon	.9056	24.6	.....do.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.27	.....	.....	.....	.....
Tunnel in Salt Canyon	.9106	23.75	.....do.....	240	.....	.....	16.5	.8498	80.6	.9226	99.5	2.42	.55	3.12	2.30	27.2	8
Open pit in Trail Canyon	.9150	23.0	.....do.....	210	.....	.....	20.5	.8541	78.7	.9356	99.3	.10	.38	.0	2.58	31.6	8

[a] Flask broke during distillation. Water in the oil.