ROCK ASPHALT

An Unconventional
Petroleum Resource
in Wyoming

by

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INTRODUCTION

Wyoming may hold significant marginal oil resources in the form of asphalt and heavy oil impregnated rocks. In the past, limited attention has been afforded to Wyoming's unconventional petroleum deposits. Today, with continuing concerns over availability of petroleum, these marginal resources may require re-evaluation. During the 1982 Summer field season, the Wyoming Geological Survey is planning to investigate the Trapper Canyon tar sand deposit (referred to as Battle Creek in accompanying tables) in secs. 32 and 33, T.52N., R. 89W., Big Horn County, Wyoming.

Currently, a definition of asphalt and heavy oil impregnated rocks and a synopsis of known rock asphalt deposits in Wyoming is presented. Knowledge of these deposits individually is found widely scattered throughout the literature and is scarce in many cases. There are a number of fields that produce heavy oil (refer to Thorton, 1979), however, this introduction is concerned primarily with deposits of asphalt impregnated rocks. With better understanding of deposits and recovery techniques, new field evaluations of known deposits is recommended for precise evaluation of Wyoming's rock asphalt accummulations.

DEFINITION OF ASPHALT AND HEAVY OIL

More exotic techniques are required to produce hydrocarbons from rock asphalt and heavy oil impregnated rocks than are required for strata containing conventional crude oil. Because of higher natural viscosities, heavy oil and asphalt ooze out of their host rocks at a rate too slow for economical production. Definitive characteristics of heavy oil are: a) between 20^o and 10^o API gravity*, and b) between 100 and 10,000 centipoise gas-free viscosity at original reservoir pressure and temperature (Guerand, 1982). Asphalt is defined by: a) less than 10^o API gravity, and b) greater than 10,000 centipoise gas-free viscosity (Guerard, 1982). In addition to the extreme viscosity that makes these petroleum varieties practically irrecoverable by conventional methods, most contain excessive amounts of sulphur compounds and metals, increasing refining problems. Further, their low distillation yield makes them less desirable to refine (Hallmark, 1979).

Evans (1975) reasoned that heavier oil and asphalt are evolved from crude oil when the lighter petroleum is subject to higher temperatures and pressures for a time. Processes involved in the metamorphosis include (refer to Evans, 1975): a) evaporation of volatile fractions, b) condensation, c) oxidation, d) sulfurization, and e) polymerization. These processes may operate individually or in combination on a deposit of lighter oil to produce the observed variety of native bituminous substances. Varieties of bitumen result from hydrocarbons compounded with other substances that alter normal hydrocarbon properties, including: a) sulphur, b) oxygen, c) nitrogen, and, sometimes d) various metallic elements. Hunt (1979) adds that, while some solid bitumens in rock

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*API gravity is a method for specifying the density of crude petroleum, modeled after a Baume scale for comparing lighter liquids with water. This density, in degrees API, equals $\frac{141.5}{P} - 131.5$. P is the specific gravity of the petroleum measured at 15.6^o C (American Geological Inst., 1976).

result from the physical, chemical and biological degradation of normal crudes; others are simply immature heavy asphalt that probably never existed as light oils.

Asphalts occur in several types of "Bituminous rock," commonly referred to as rock asphalt (including tar sand), ozokerite and asphaltite. The following descriptions are summarized primarily from Evans (1975):

a) Rock asphalt includes asphaltic limestones, sandstones and porous rocks with similar lithologies. Solid to semi-solid bituminous material in these rocks is typically reddish-brown to black and often soluble in carbon disulfide. A variety of rock asphalt, referred to often, is tar sand. Tar sand, as defined by API, includes rocks from unconsolidated sand to lithified sandstone that contain highly viscous hydrocarbons (other than coal and oil shale) which are not recoverable by primary methods. Bitumen characteristics in tar sand conform to those previously presented for asphalt; i.e., greater than 10,000 centipoise viscosity or less than 10^{o} API gravity at 60^{o} F and normal atmospheric pressure.* This definition is conformable with descriptions by the IOCC,

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*A specific temperature and normal atmosphere pressure are often assigned to the definition, rather than simply "at original reservoir pressure and temperature," in order to compare separate deposits.

U.S.D.O.E., and the United Nations. Merchant, et al., (1979), adds that the bitumen in tar sand is so viscous and immobile as to prevent displacement and production by primary methods, while heavy oil impregnated sandstones can be produced from, but not at economical rates.

b) Ozokerite (mineral wax) is thought to result from metamorphosis or polymerization of predominately paraffinaceous petroleum; a process involving more than simple evaporation of volatiles from crude oil. Hunt (1979) states it is possible to derive such waxes from inspissation of almost any high wax petroleum. Characteristics of ozokerite include yellow to dark brown color, moderate hardness, fusion temperature between 60 and 95^{o} C and specific gravity between 0.926 and 0.928. Native mineral wax and associated mineral matters occur either as distinct vein fillings or as interstitial material in rock pores. Hunt (1979) adds that ozokerite also represents the natural residuum of high wax oils exposed to the surface.

c) Asphaltite is derived from rock asphalt. Relatively pure asphalt is thought to become "harder," or less soluble and having higher temperatures of fusion, with continuing metamorphism. The product is asphaltite. Even further metamorphism results in asphaltoids; infusable, less soluble derivatives of asphaltites. Hunt (1979) reports other asphaltites are indurated bitumens formed by polymerization and gelation of asphaltic components.

Asphalts and asphaltite deposits occur worldwide. Most deposits are often found associated with structural uplifts where oil producing sandstones crop out. Asphalts are most apt to be associated with active seeps. Breached and fractured crude oil reservoirs are a common source of asphalt deposits (Hunt, 1979).

IMPORTANCE IN WYOMING

In the past, many oil seeps have played a role in the exploration and settlement of the West and early oil exploration in Wyoming (Ball, 1965). The hydrocarbons were initially used as axle grease for wagons and fuel for lanterns. With increased technology, the petroleum demand switched to highly refined petroleum products to power automobiles, trains, aircraft, spacecraft, etc. Today and in the foreseeable future, petroleum deposits that lend themselves to easy and economic refining are becoming less available. This trend will focus some attention back to the rock asphalt from which oil oozed in the early days.

Several formations are reportedly variably oil impregnated over wide areas. These occurrences are widely known by local populations, but there is often scant published information about their characteristics and specific localities. Notable formations variably impregnated with oil throughout Wyoming include the following (Ball, 1965):

Phosphoria Formation - sandy members interbedded with limestone and dolomite commonly contain asphaltic residue and are impregnated with tarry oil as well as light oil over large areas on the northeast flank of the Wind River Range and on the north and south flanks of the Owl Creek Mountains.

Dinwoody Formation - thin bedded, slabby sandstones in this unit are commonly oil stained in the northwest Wind River Basin.

Chugwater Formation - the Red Peak Member is commonly impregnated with heavy oil in outcrops over large areas in the northwestern Wind River Basin and in southwestern Big Horn Basin. Massive gray sandstones of the Crow Mountain Member are heavy oil impregnated over wide areas in northwestern Wind River Basin, and, to a lesser extent, in southwestern Big Horn Basin.

Mesaverde Formation - basal sandstones, especially at the Mesaverde-upper Cody Shale interface, are impregnated with light colored and high gravity oil in wide outcrops in southern and southwestern Wind River Basin.

Wasatch Formation - sandstones are variably impregnated with heavy oil on the southwest flank of the Rock Springs Uplift.

The table at the end of this report shows the heavy oil and rock asphalt deposits known to the Wyoming Geological Survey through readily accessible sources. More detailed information is available, but scattered through the literature.

RECOVERY AND PRODUCTION

A VARIETY OF TECHNIQUES

Techniques for recovering desired petroleum from asphalt and heavy oil impregnated rocks and their success vary with the characteristics of each deposit; involving viscosity of the hydrocarbon, potential quality of the product as well as composition and character of the host rock. Hallmark (1979) describes several techniques that have been applied in California:

a) Cyclic steam stimulation at the Vaca Tar Sand deposit, Ventura County.

b) Mining and subsequent processing of ore for several discontinuous outcrops of rich tar sand in the Sisquoc area, Santa Barbara County.

c) In-situ retorting (vaporizing the hydrocarbons in the reservoir) at tar sand deposits in the Santa Cruz area, Santa Cruz County.

Evans (1975) reports that the recovery of bitumens is possible through other physical extraction and pyrolysis techniques. A type of physical extraction involves introducing solvents, such as carbon disulphide, into the reservoir rock; recovering the resulting oil rich solution; and separating the solvent from the oil. Solvent recovery expenses, however, have prohibited economic competition with hot water techniques. Pyrolysis, described in depth by Rammler (1970), involves subjecting the source rock to high temperatures; decomposing the more volatile components; and recovering the desired products.

In Labette County, Kansas, the EOR Petroleum Company has experimented with a combination mining and in-situ process that they term "flip-flop." The reservoir top is accessed by shafts and tunnels. A heated surfactant solution is pumped into the exposed reservoir formation top. The solution is then absorbed, with the aid of gravity, into the reservoir and displaces lighter oil upward. The displaced oil is then skimmed off the top of the reservoir and pumped to the surface (Merchant and Koch, 1981).

Other recovery projects briefly described by Merchant and Koch (1981) utilize solution by hot water solvents and explosive fracturing of a reservoir prior to in-situ combustion. Reservoirs are also heated with radio waves. The less viscous fluid is then collected in a chamber below the reservoir strata by gravity drainage.

OPERATIONS IN WYOMING

Big Horn Basin

On the east flank of the Big Horn Basin, Brent Exploration is experimenting with an enhanced oil recovery project in Ts. 53-56 N., Rs. 91-93 W. (Gill, 1982). Reserves in Phosphoria Formation carbonates are estimated at 0.9 billion barrels of 10^{o} API gravity, 1,300 centipoise heavy oil. Recovery operations in July and August involved initial steam injection through a center well in a 10 acre, 5 spot pattern.* The injected steam then builds a "front" against the oil within the reservoir. The steam, under high pressure, begins to push a bank of oil away from the injection point. A high pressure zone spreads outward from the injection point as the bank of hydrocarbons moves toward the outlying producer wells. With 60 days of injection, significant pressure increases were noted in the four peripheral wells. Although no oil was produced, significant volumes of more mobile water and gas were produced. The gas rose in methane concentration from 0 to 80% during the experiment.

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*Four peripheral wells arranged in rectangular outline with the fifth well in the center; all within a 10 acre area.

According to the enhanced-oil-recovery consultant on site,this methane increase indicates that hydrocarbons were displaced and that an oil bank was forming between the injector and producer wells, with the water and gas being moved first.

After steam flooding, hot water was injected over the same interval. The same pattern of water and gas displacement was maintained. Then, perhaps due to irregularities in the reservoir, the front between injected fluids and slowly migrating bank of oil was broken. The injected fluids found a "path of least resistance" through the oil bank and flowed through to producing well number 2. With this subsurface leak, the pressure that was driving the oil bank was reduced and oil migration presumably slowed. After the breakthrough was detected at the no. 2 producing well, a polymer was added to the hot water. The polymer, polyacrylamide, was designed to increase the injected fluid viscosity and otherwise modify its properties in hopes of plugging the hole in the front between the injected fluid and the oil bank. Once accomplished, driving pressure could be restored behind the oil bank, reviving migration. Introduction of the polymer resulted in abrupt pressure reduction in well no. 2. The pressure drop indicated that the leak in the fluid-oil front had been plugged; injected fluid was no longer escaping.

The recovery consultant suggested that the preceding results prove that the polymer would be useful in controlling injected fluid mobility and may be useful for future recovery projects. In addition to being more effective than steam, Brent Exploration officials note that hot water and polymer injection adds only $5 to the cost of a produced barrel of oil, while steam injection adds $15 to each barrel. Further, with the hot water and polymer injection, Brent suggested that the existing 10 acre pattern could immediately become a commercial operation and would produce 20 barrels of oil per day per well, for a total of 80 bopd. Full scale tests using hot water and polymer injection began in mid-January, 1982 (Gill, 1982).

Burnt Hollow

In Crook County, 24 miles northwest of Hulett in T.55N., R.64W. (20 sections), Kirkwood Oil and Gas from Casper, Wyoming, along with Glenda Exploration and Development Company and Pogo Producing Company initiated a pilot tar sand oil recovery project in 1981. The deposits consist of 9^{o} API gravity and 1,000,000 centipoise asphalt in the Minnelusa Formation. The formation reservoir averages 25 feet thick at a depth of 900 feet. This in-situ commercial pilot project was estimated capable of producing 50 bopd per well through injecting steam and caustic chemicals in a two acre inverted five spot array.* Total reserves are estimated at 364 million barrels, of which 182 million barrels are estimated recoverable, over an area of 12,800 acres (Merchant, 1981).

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*Four wells are arranged in rectangular outline with the remaining well in the center, all within an area of two acres. "Inverted" indicates that material is injected into the center well as the peripheral four wells are producers. In "conventional" techniques, the peripheral four wells are injectors and the single center well is the producer.

Trapper Canyon

In Big Horn County east of Shell, Wyoming, in secs. 32 and 33, T.52N., R.89W., Big Horn Oil Company from Salt Lake City along with SPC Enterprises had operated another tar sand oil recovery project. This deposit consisted of an estimated 1.96 million barrels of 5.6^{o} API gravity and greater than 10,000 centipoise asphalt over 66 acres in the Pennsylvanian Tensleep Sandstone. The formation reservoir is 18 feet thick and crops out in the area of interest. The rock asphalt (i.e. tar sand, in this case) had been mined. The ore then was taken to a processing plant, with the petroleum extracted via the modified Brimhall Cold Water* technique. This operation is estimated to yield 15 BPH. It has since been shut in by the Wyoming Department of Environmental Quality and the U.S Bureau of Land Management because of lease and environmental concerns (Merchant, 1981).

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*Patented by a member of the Brimhall family of Utah and since improved upon, this technique involves introducing cold water with a petroleum based solvent into the mined tar sand and then processing the mixture to extract the desired petroleum.

A P P E N D I X

The following table is a brief summary of rock asphalt deposits (and some heavy oil) in this state, as readily known to the Wyoming Geological Survey.

Location: (1) Big Horn Co. 23-T.49N.-R.91W.	Formation(s): Thermopolis Fm. and Colorado Group Assoc. Field(s): Bonanza Reference(s): Hares, 1947	Description Oil spring located on the faulted north flank of Bonanza-No Wood Anticline, gravity = 36^o Be.	Development
Location: (2) Big Horn Co. 24-T.51N.-R.93W.	Formation(s): Soil Assoc. Field(s): Torchlight Field Reference(s): Washburne, 1908	Description Bitumen in soil located near crest of Torchlight Anticline.	Development
Location: (3) Big Horn Co. 28,29,32,33-T.52N.-R.89W.	Formation(s): Tensleep Fm. Assoc. Field(s): Reference(s): Darton, 1906 Hares, 1947	Description Tar sand dips 3^o SW about 1500 ft. long, 2000 ft. wide, and 20' thick (proved by core drilling); API 23.6^o, 26% porosity.	Development Possibly a commercial occurrence. Local use as road metal.
Location: (4) Big Horn Co. 28,29,32,33-T.52N.-R.90W.	Formation(s): Tensleep (top) and Phosphoria (btm.) Fms. Assoc. Field(s): Reference(s): Clabaugh, et al., 1946 Washburne, 1908, p.361	Description Extensive and heavy oil impregnation. Outcrop is on steep-dipping southwest flank of sharp, asymmetric anticline. Bed is about 10 ft. thick and lies under 10 feet of mantle.	Development Washburne reports claims filed for quarrying, but no production recorded, possibly commercial occurrence.

Location: (5) Big Horn Co. 34,35-T.45N.-R.97W.	Formation(s): Madison Limestone Assoc. Field(s): Crystal Creek Reference(s): Washburn, 1908	Description Ls is lightly and variably impregnated with asphaltic oil on the crest of Sheep Mountain Anticline. Supposed to have been a nearby seep, now covered by RR track. Bitumen in cavities and cracks.	Development
Location: (6) Hot Springs Co. 21-T.42N.-R.90W.	Formation(s): Frontier Fm. Assoc. Field(s): Reference(s): Hewett and Lupton, 1917, p. 122	Description Small seep located on the crest of Lysite Mtn. Anticline.	Development 15 dry holes in township
Location: (7) Hot Springs Co. 29-T.43N.-R.93W.	Formation(s): Chugwater Fm. Assoc. Field(s): Red Springs, Warm Springs, Wild Horse Butte fields Reference(s): Hewett and Lupton, 1917, p. 133	Description Small seep of heavy oil located on the crest of Red Spring Anticline.	Development
Location: (8) Park Co. 29-T.52N.-R.100W.	Formation(s): Assoc. Field(s): Oregon Basin Field Reference(s): Hares, 1947	Description Gas seep on N-S trending anticline crest.	Development

Location: (9) Park Co. along Sweet- water Creek west of Cody	Formation(s): Tertiary volcanics, Colorado Group Assoc. Field(s): Reference(s): Hewett, 1914	Description Oil seep from sandstones in the Colorado Group.	Development Oil impregnated sandstones were encountered by a well of Shoshone Oil Co. All oil produced was stored locally and used for lubricating. Maximum production was 200 barrels.
Location: (10) Washakie Co. 19(?)-T.47N.- R.89W.	Formation(s): Madison (?) Assoc. Field(s): Shoal Unit Reference(s): Hewett and Lupton, 1917, P. 105	Description Small seep on Sherard or Cottonwood anticline.	Development Six dry holes in the township.
Location: (11) Washakie Co. 29-T.47N.-R.90W.	Formation(s): ? Assoc. Field(s): Cottonwood Creek Field Reference(s): Washburne, 1908	Description Oil in a mud spring, located on crest of anticline.	Development
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development

Location: (12) Carbon Co. 9-T.15N.-R.88W.	Formation(s): Browns Park Assoc. Field(s): Reference(s): Love, pers. comm.	Description	Development
Location: (13) Carbon Co. 3,10,15,16,22, 27-T.17N.-R.92W.	Formation(s): basal Wasatch Fm. Assoc. Field(s): Muddy Creek Field Reference(s): Jameson, 1913 Bell, 1960	Description Massive series of sandstone and conglomerate lenses, oil impregnated for two mile long N-S outcrop; 1,000-2,000 ft. wide and up to 50 ft. thick.	Development
Location: (14) Carbon Co. 34-T.18N.-R.92W.	Formation(s): basal Wasatch Assoc. Field(s): none Reference(s): Jameson, 1913	Description Oil saturated sandstone on west dipping monocline.	Development
Location: (15) Carbon Co. 8-T.19N.-R.79W. near center of T.L. Ranch quad	Formation(s): basal Hanna Assoc. Field(s): Reference(s): Ver Ploeg, pers. comm. 1982	Description Asphaltic oil impregnated sandstone, on NE flank of anticline cut by the SW dipping Arlington thrust fault.	Development

Location: (16) Carbon Co. SE NW 20-T.41N.-R.87W. SW SE NW 14, NW SE 24-T.13N.-R.87W. NW SE NE 8-T.12N.-R.86W.	Formation(s): Madison Fm. Assoc. Field(s): Reference(s): Ritzma, 1951	Description Black asphaltic oil in fractures, vugs and disseminated through outcrops.	Development
Location: (17) Lincoln Co. T.23N.-R.116W.	Formation(s): Assoc. Field(s): Reference(s): Schultz, 1907	Description Gas seep reported, not actually seen by Schultz.	Development
Location: (18) Lincoln - Sublette Co. East of LaBarge Ridge	Formation(s): Wasatch Assoc. Field(s): Reference(s): Schultz, 1907	Description Oil springs.	Development
Location: (19) Sublette Co. 34-T.27N.-R.113W.	Formation(s): Assoc. Field(s): La Barge Unit Reference(s): Schultz, 1907	Description Oil in deep pit, oozed from surface rocks.	Development

Location: (20) Sublette Co. T.37N.-R.110W.	Formation(s): Mesozoic Assoc. Field(s): Reference(s): Love, pers. comm.	Description Oil seep reported, not actually seen by Love.	Development
Location: (21) Sublette Co. T.38N.-R.109W.	Formation(s): Darby Fm. Assoc. Field(s): Reference(s): Baker, 1946	Description Oil stain along NW tip of Wind River Range.	Development
Location: (22) Sweetwater Co. W½ sec. 9-T.12N.-R.97W.	Formation(s): Green River Fm. Assoc. Field(s): Reference(s): Sears, 1924	Description Slight impregnation in a thin sandstone. Beds are dragged up sharply along fault near Shell Point.	Development
Location: (23) Sweetwater Co. 9-T.12N.-R.98W.	Formation(s): Green River or Browns Park Fms. Assoc. Field(s): none Reference(s): Sears, 1924	Description Slightly saturated sandstone on upthrown side of a normal fault.	Development

Location: (24) Teton Co. T.39N.-R.116W.	Formation(s): Assoc. Field(s): Reference(s): Schultz, 1907	Description Oil on water, within northern tip of thrust belt.	Development
Location: (25) Uinta Co. 4-T.13N.-R.119W.	Formation(s): Benton and Aspen shales Assoc. Field(s): Reference(s): Veatch, 1907	Description Hilliard Flat Springs, flanked by west adjacent Absaroka Thrust, in an overturned syncline.	Development
Location: (26) Uinta Co. 7-T.14N.-R.118W.	Formation(s): Benton and Aspen shales Assoc. Field(s): Aspen, Spring Valley, Sulphur Creek Reference(s): Veatch, 1907	Description Hilliard Flat springs on the south end of Lazeart Syncline, flanked by Absaroka thrust on west, near Oil Spring Fault.	Development
Location: (27) Uinta Co. 12-T.14N.-R.119W.	Formation(s): Benton and Aspen shales Assoc. Field(s): between Sulphur Creek and Aspen Fields Reference(s): Veatch, 1907	Description In Hilliard Flat springs, Absaroka thrust cuts through this section.	Development Union Pacific tunnel flowed 2-300 gallons per day in 1901

Location: (28) Uinta Co. 33-T.14N.-R.119W.	Formation(s): Benton and Aspen shales Assoc. Field(s): Sulphur Creek Field Reference(s): Veatch, 1907	Description Hilliard Flat Springs in syncline hinge area cut by subsidiary thrusts from the Absaroka Thrust.	Development
Location: (29) Uinta Co. 31-T.15N.-R.118W.	Formation(s): Benton and Aspen shales Assoc. Field(s): Sulphur Creek Reference(s): Veatch, 1907	Description Carter Spring on west flank of Lazaert Syncline, cut by Absaroka Thrust, near Oil Spring Fault.	Development
Location: (30) Uinta Co. T.21N.-R.117W.	Formation(s): Wasatch Fm. Assoc. Field(s): Fossil Field Reference(s): Veatch, 1907	Description Group of springs on a gentle anticline.	Development
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development

Location: (31) Converse Co. 16-T.32N.-R.73W.	Formation(s): Cloverly Fm. Assoc. Field(s): Browning Basin Douglas Creek Reference(s): Barnett, 1914a, p. 68	Description Located on north flank of large, steeply dipping limb of NW trending anticline. Sandstone saturated in tunnel.	Development
Location: (32) Converse Co. 6-T.32N.-R.74W.	Formation(s): Upper Casper Assoc. Field(s): Douglas Creek Reference(s): Barnett, 1914a, p. 68	Description Small seep.	Development
Location: (33) Crook Co. NE¼ T.51N.-R.67W. and SE¼ T.52N.-R.67W.	Formation(s): Muddy Ss., Mowry Sh., Dakota Ss. Assoc. Field(s): Reference(s): Barnett, 1914b; Biggs and Espach, 1960	Description The Muddy Sandstone and several sandstone lenses in the Mowry Shale are oil impregnated at several localities. One oil impregnated Dakota Ss. outcrop reported in secs. 1,12-T.51N.-R.67W. Several oil seeps are known.	Development Numerous wells close to impregnated outcrops and seeps. Moorcroft oil field produced 58,000 barrels oil between 1887-1957 from NW¼ sec. 34-T.52N.-R.67W.
Location: (34) Crook Co. 2-T.51N.-R.67W.	Formation(s): Fuson Fm. Assoc. Field(s): Moorcroft Reference(s): Barnett, 1914b, p. 86	Description Bud Spring oil seep. Thin film on water, asphalt bed above spring.	Development

Location: (35) Crook Co. 9-T.52N.-R.61W.	Formation(s): Upper Minnelusa Assoc. Field(s): Rocky Ford (abnd.) Reference(s): Brady, 1958; p. 47 Trotter, 1963; p. 117	Description Dead oil stain, northwest flank of Black Hills Uplift. A 100-ft. sandstone in the upper Minnelusa Fm. is impregnated with oil, not readily apparent.	Development
Location: (36) Crook Co. 22-T.52N.-R.67W.	Formation(s): Granerous Assoc. Field(s): Moorcroft Reference(s): Barnett, 1914b; p. 86	Description Stain	Development
Location: (37) Crook Co. 27-T.52N.-R.67W.	Formation(s): Granerous Assoc. Field(s): Moorcroft Reference(s): Barnett, 1914b; p. 86	Description Spring and two seeps	Development Yielded 90 gal./month in 1888
Location: (38) Crook Co. 34-T.52N.-R.67W.	Formation(s): Granerous Assoc. Field(s): Moorcroft Reference(s): Barnett, 1914b; p. 86	Description Small seep, heavily stained. Small outcrop.	Development

Location: (39) Johnson and Natrona Cos. 16,17,20,28,29, 32,33-T.41N.-R.81W.	Formation(s): Morrison Fm. Assoc. Field(s): Powder River oil field Tilsdale field Reference(s): Knight and Slosser, 1901 Wegeman, 1912; p.61,71-4	Description A six- to seven-foot sandstone occurs near the base of the Morrison Fm., lightly impregnated with oil. Several oil seepages from sandstones in the Sundance, Morrison and Cloverly Fms.	Development North Tilsdale is four miles north and has produced more than a million barrels of oil since 1952.
Location: (40) Natrona Co. 3,10-T.38N.-R.78W.	Formation(s): Shannon Sandstone Assoc. Field(s): Salt Creek Field AST Teapot Unit Reference(s): Wegeman, 1918; p. 39	Description Located on the crest of the Salt Creek Anticline. Deposit is in shale, originating in the Shannon Ss. Ozokerite deposits.	Development
Location: (41) Natrona Co. 23-T.38N.-R.87W.	Formation(s): Frontier Formation Assoc. Field(s): Reference(s): Tourtelot, 1953	Description Oil impregnated sandstones in the Frontier Fm. in the overriding block of a small thrust fault. Other minor impregnated outcrops include the Parkman and Fox Hills ss.	Development Tar sands, oil and gas seeps led to discovery of Shannon Pool in 1889 and Salt Creek Field in 1908.
Location: (42) Natrona Co. 11-13,23,25-T.40N.-R.79W.	Formation(s): Niobrara Shale Shannon Sandstone Assoc. Field(s): Salt Creek Field AST Teapot Unit Reference(s): Woodruff & Wegeman, 1911 Wegeman, 1918; p. 39	Description Oil seeps and ozokerite in coarse, cross-bedded sandstone, eight ft. thick at the base of the Shannon Ss.	Development

Location: (43) Natrona Co. 28,33-T.41N.-R.81W.	Formation(s): Sundance, Morrison, Dakota Fms. Assoc. Field(s): Tilsdale unit Reference(s): Wegeman, 1910	Description Oil seeps, located on the crest of an anticline.	Development
Location: (44) Natrona Co. 33-T.41N.-R.81W.	Formation(s): Morrison Fm. Assoc. Field(s): Tilsdale unit Reference(s): Love, pers. comm. Wegeman, 1910	Description Located on crest of an anticline.	Development Oil produced by tunneling.
Location: (45) Platte Co. 1-T.27N.-R.68W.	Formation(s): Tertiary rocks Assoc. Field(s): none Reference(s): Densen & Botinelly (1949)	Description Associated with the Hartville Uplift; located on the west flank of a N-S trending anticline.	Development
Location: (46) Weston Co. 2-T.44N.-R.61W. and 23,25-T.45N.-R.62W.	Formation(s): Newcastle Sandstone Assoc. Field(s): Skull Creek Field Reference(s): Darton, 1905; p. 385	Description Newcastle Sandstone is stained with oil along Salt Creek. Unit dips 20 to 25° southwest. Staining is confined to the top of the formation.	Development Seeps near Newcastle once furnished small amounts of lubricating oil.

POWDER RIVER BASIN

Location: (47) Weston Co. 3,4-T.48N.-R.66W.	Formation(s): Turner member of the Carlile Shale Assoc. Field(s): Thornton Field Reference(s): Hancock, 1921; p. 31	Description The Turner member dips 25^{o} southwest into the Powder River Basin.	Development Led to the discovery of the Upton-Thornton Field. The field produced less than 1,000 barrels of oil, total.
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development

Location: (48) Fremont Co. 7-T.1S.-R.1E	Formation(s): Ft. Washakie Fm. Assoc. Field(s): Reference(s): Jameson, 1911	Description Oil saturated sandstone and shale on anticlines on leading edge of allochthon of NE dipping thrust.	Development
Location: (49) Fremont Co. 26-T.1S-R.1E.	Formation(s): Mancos Shale(?) Assoc. Field(s): Plunkett Field Reference(s): Jameson, 1911	Description Oil springs on small dome in allochthon of east dipping thrust fault.	Development
Location: (50) Fremont Co. 1-T.1S.-R.1W.	Formation(s): Fort Washakie Fm. Assoc. Field(s): Reference(s): Jameson, 1911	Description On anticline on leading edge of allochthon of NE dipping thrust. Bubbles of oil in spring.	Development
Location: (51) Fremont Co. 22,25-T.1N-R.1W.	Formation(s): ? Assoc. Field(s): Sage Creek Field Reference(s): Jameson, 1911	Description Oil springs on NE flank of NW trending anticline.	Development

Location: (52) Fremont Co. 27,32-T.1N.-R.1W.	Formation(s): Ft. Washakie Fm. Assoc. Field(s): Reference(s): Jameson, 1911	Description Oil saturated sandstone and shale on allochthon of NE dipping thrust.	Development
Location: (53) Fremont Co. 36-T.1N.-R.1W.	Formation(s): Red Peak mbr. of Chugwater Fm. & Nugget Ss. Assoc. Field(s): Sage Creek Field Reference(s): Clabaugh, et al., 1946 Sharkey, 1946	Description Sandstones of Red Peak mbr. and other Chugwater mbrs. are variably impregnated with oil on crest of Sage Creek Anticline. Nugget Sandstone has scattered oil impregnations.	Development Oil seeps led to drilling in the early 1900's, but no sustained commercial production.
Location: (54) Fremont Co. 36-T.7N.-R.3W.	Formation(s): Chugwater Fm. Assoc. Field(s): Circle Ridge Field Reference(s): Collier, 1920	Description Oil stain, Circle Ridge Dome.	Development
Location: (55) Fremont Co. 13-T.27N.-R.95W.	Formation(s): Wasatch Fm. Assoc. Field(s): Reference(s): Love, pers. comm.	Description Oil seep, aromatic oil.	Development

Location: (56) Fremont Co. 8-T.31N.-R.99W.	Formation(s): Embar (or Phosphoria) Fm. Assoc. Field(s): Reference(s): Woodruff & Wegeman, 1911	Description Five to ten feet of bituminous sandstone in the upper third of the Embar (or Phosphoria) Fm. in the canyon of Little Popo Agie River.	Development
Location: (57) Fremont Co. 2,3,4,5,10,11-T.32N.-R.94W.	Formation(s): Wagon Bed Fm. Assoc. Field(s): Reference(s): Van Houten (1954) Love (1970)	Description Asphalt residue. East flank of Burly Anticline. Variable impregnation upward from basal beds to several sandy and cherty beds 100-400 feet above basal unconformity.	Development
Location: (58) Fremont Co. 10,11-T.32N.-R.94W.	Formation(s): White River Fm. Assoc. Field(s): Reference(s): Hares, 1916.	Description Complicated structure. Asphalt in rhyolite.	Development
Location: (59) Fremont Co. 17,18-T.34N.-R.92W.	Formation(s): Fort Union Fm. Assoc. Field(s): Reference(s): Thompson & White, 1952 Keefer & Rich, 1957.	Description Asphaltic oil variably impregnates Fort Union sandstones and conglom-erates. Oil is immediately above the Fort Union-Mesaverde unconformity.	Development

Location: (60) Fremont Co. 3,13,22,24-T.33N. R.90W.	Formation(s): Frontier, Mowry, Chugwater, W. River Fms. Assoc. Field(s): Reference(s): Hares, 1916 Zeller, et al., 1956	Description Oil impregnated ss. of lower 2/3 of Chugwater near crest of Dutton Basin Anticline in secs. 13 & 22. Also in sandstones of Frontier Fm. and in sandstones and conglomerates of Wind River Fm.	Development In the Gas Hills uranium district.
Location: (61) Fremont Co. T.33N.-R.94W.	Formation(s): Frontier Fm. Assoc. Field(s): Reference(s): Hares, 1916	Description Small seeps associated with the Alkali Butte Anticline.	Development Fifteen dry holes in the township.
Location: (62) Fremont Co. 17,18-T.34N.- R.92W.	Formation(s): Fort Union Fm. Assoc. Field(s): Reference(s): Thompson & Rich, 1952 Keefer & Rich, 1957	Description Asphaltic oil variably impregnates Fort Union sandstones and conglomerates. Oil is immediately above the Fort Union-Mesaverde unconformity.	Development
Location: (63) Fremont Co. T.34N.-R.95W. and T.1S,2S.-R.6E	Formation(s): Cody Shale, Mesaverde, Fort Union, Wind R. Fms. Assoc. Field(s): Reference(s): Thompson & White, 1954	Description Sandstones in upper Cody Sh., sandstones in basal Mesaverde, basal Ft. Union and Conglomerate, basal Wind River Ss. and Congl.	Development

Location: (64) Fremont Co. 2-T.39N.-R.90W.	Formation(s): Upper Eocene andesite tuffs. Assoc. Field(s): Reference(s): Tourtelot, 1953.	Description Oil seep near Cedar Ridge Fault.	Development
Location: (65) Fremont Co. 6-T.39N.-R.91W.	Formation(s): Flathead Ss. Assoc. Field(s): Reference(s): Tourtelot, 1953	Description Oil seep in the vicinity of north dipping thrust fault, 13.2^{o} API.	Development
Location: (66) Fremont Co. N½NE¼ sec. 10-T.39N.-R.91W. and NE¼ sec. 2-T.39N.-R.90W.	Formation(s): Cretaceous and Tertiary rocks Assoc. Field(s): Reference(s): Tourtelot, 1953	Description Two oil impregnated outcrops along Cedar Ridge Fault. The first is in overturned beds of late Cret.-Paleocene age south of fault. The second is in Eocene tuffs north of the fault.	Development
Location: (67) Fremont Co. 16-T.39N.-R.92W.	Formation(s): Upper Eocene andesite tuffs Assoc. Field(s): Reference(s): Tourtelot, 1953	Description Oil stain near Cedar Ridge Fault.	Development

Location: (68) Fremont Co. T.39N.-R.92W.	Formation(s): Wind River Fm. Assoc. Field(s): Reference(s): Hares, 1916	Description Traces of oil	Development Two dry holes in township.
Location: (69) Fremont Co. SW¼NE¼ sec. 3-T.39N.-R.93W. and NE¼SW¼ sec. 16-T.39N.-R.92W.	Formation(s): Upper Eocene tuffs and tuffaceous sandstones. Assoc. Field(s): Reference(s): Tourtelot, 1953 Tourtelot & Thompson, 1948	Description Two oil impregnated areas of tuffaceous sandstone and tuffs. The first is along the north margin of the West Dry Creek Graben. The second is along southern marginal faults of West Dry Creek Graben.	Development
Location: (70) Natrona Co. 28-T.33N.-R.82W.	Formation(s): Lower Cretaceous conglomerate Assoc. Field(s): Oil Mountain Reference(s): Hares, 1916	Description Oil spring issuing from a fault plane along crest of an anticline.	Development
Location: (71) Natrona Co. 4,5,9-T.33N.-R.87W.	Formation(s): Teapot Mbr.(?) of Mesaverde Fm. Assoc. Field(s): Grieve Field Reference(s): Hares, 1916	Description Saturated sandstone in the Wallace Dome, Phayles Reef, member of the Mesaverde Fm.	Development

Location: (72) Natrona Co. 28-T.33N.-R.87W. to 34-T.34N.-R.88W.	Formation(s): Chugwater and Dakota Fms. Assoc. Field(s): Reference(s): Hares, 1916	Description Many seeps from units in section from Chugwater to Dakota Fms., located on NE flank of Rattlesnake Mountains.	Development
Location: (73) Natrona Co. near Ervay, in Ts. 32,33,34N.- Rs. 86,87,88W.	Formation(s): Chugwater, Sundance, Morrison & Cret. sands Assoc. Field(s): Reference(s): Barwin, 1961 Paape, 1961	Description Varied and extensive outcrops of petroleum impregnated sandstones along the northeast flank of the Rattlesnake Hills in Cretaceous sands and in Lakota, Dakota mbrs., Frontier and Mesaverde Formations.	Development Most important deposits are in Morrison Fm., Lakota Congl., Dakota Ss., and basal Mesaverde Ss. (Phayles). Among largest deposits in Wyoming.
Location: (74) Natrona Co. 23-T.38N.-R.87W.	Formation(s): Frontier Fm. Assoc. Field(s): Reference(s): Tourtelot, 1953	Description Oil stain on small E-W trending anticline on faulted south flank.	Development
Location: (75) Teton Co. 11-T.38N.-R.110W.	Formation(s): Phosphoria, Tensleep, and Amsden Fms. Assoc. Field(s): Reference(s): Bell, 1960 Richmond, 1945	Description Phosphoria sandstones impregnated with asphaltic oil. Scattered occurrences in this area in Tensleep and Amsden Fms.	Development One sample yielded 3.2% oil.

Location: (76) Teton Co. T.42N.-R.114W.	Formation(s): Phosphoria Fm. Assoc. Field(s): Reference(s): Love, et al., 1951	Description Oil filled vugs in strata on Red Hills Anticline.	Development One dry hole.
Location: (77) Teton Co. 31-T.44N.-R.112W.	Formation(s): Cody Shale Assoc. Field(s): none Reference(s): Love, et al., 1951	Description Gas seep on Spread Creek Anticline.	Development
Location: (78) Teton Co. 3-T.44N.-R.113W.	Formation(s): Bacon Ridge Ss. Assoc. Field(s): none Reference(s): Love, et al., 1951	Description Gas seep on Spread Creek Anticline.	Development
Location: (79) Teton Co. 36-T.44N.-R.113W.	Formation(s): Cody Shale Assoc. Field(s): none Reference(s): Love, et al., 1951	Description Gas seep on Spread Creek Anticline.	Development

Location: (80) Teton Co. T.46N.-R.113W.	Formation(s): Lance Fm. Assoc. Field(s): none Reference(s): Love, et al., 1951	Description Gas seep on Pacific Creek anticline.	Development
Location: (81) Along east and southeast side of Gros Ventre Range	Formation(s): Bighorn, Madison, Darby Phosphoria, Frontier Fms. Assoc. Field(s): Reference(s): Love, et al., 1951	Description Oil staining.	Development
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development

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