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REVIEW OF REPORTED TAR SAND OCCURRENCES AND RECENT PROJECTS IN WYOMING.

by

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INTRODUCTION

Wyoming may hold significant oil resources in the form of tar sands. In recent years, with continuing concerns over availability of petroleum, some of these tar sand occurrences have been reexamined and exploitation attempted. Hence, evaluation of reported tar sand deposits in Wyoming becomes increasingly important.

This report provides a synopsis of 78 reported occurrences of shallow, oil-impregnated rocks in Wyoming many of which may be tar sands. (Appendices A and B). In most cases, there are only sketchy descriptions of these occurrences, scattered throughout the literature. This paper is a prelude to much needed studies and evaluations of these individual deposits.

In addition, brief descriptions of three recent extractive operations are presented.

DEFINITIONS

As recently as 1979, an international conference on heavy crude and tar sands failed to resolve the question of how best to define and classify a variety of native bitumens variously called tar sands, heavy oils, natural bitumen, oil sands, bituminous sands, asphaltic earth, asphaltic rock, and natural asphalts (Meyer, 1981). This classification problem has persisted over the years, partially because petroleum occurrences are chemically gradational and often indistinguishable without standardized tests or analyses. Consequently, the boundaries between these substances are of necessity somewhat arbitrary, thus prompting different individuals or organizations to set different boundary criteria.

Major steps toward resolving these classification problems were taken in 1981 and 1982 when The U.S. Department of Energy, The United Nations, The Interstate Oil Compact Commission (IOCC), and The American Petroleum Institute (API) each recommended the adoption of similar or noncontradictory definitions for tar sand (Ball, Marchant, and Goldburg, 1982). These definitions establish a concensus distinction between tar sand and heavy oil occurrences. The noncontradictory definitions recommended by these four entities are provided below:

U.S. Department of Energy

> Tar sand is any consolidated or unconsolidated rock (other than coal, oil shale, or gilsonite) that contains a hydrocarbonaceous material with a gas-free viscosity, at reservoir temperature, greater than 10,000 centipoise,

or contains a hydrocarbonaceous material that is extracted from the mined or quarried rock (Lee Marchant, Laramie Energy Technology Center, U.S. Department of Energy, personal communication, December 1982).

United Nations

Tar sand oil has a gas-free viscosity greater than 10,000 mPa.s (centipoise) at original reservoir temperature or a density greater than 1,000 kg/m^3 (less than 10° API gravity)[1] at 15.6° C (60°F) at atmospheric pressure (IOCC, 1981).

Interstate Oil Compact Commission

Tar sand is any consolidated or unconsolidated rock containing a crude oil which is too viscous at natural reservoir temperature to be commercially producible by conventional primary recovery methods (IOCC, 1981).

American Petroleum Institute

A general definition of tar sands might be:

Tar sands are rocks containing highly viscous hydrocarbons (other than coal, oil shale, or gilsonite) that are not recoverable at reservoir conditions by primary production methods (i.e. capability for primary production cannot be established). That is, the hydrocarbons in tar sands cannot readily move as a fluid under their own reservoir energy. The hydrocarbons in heavy oil sands, in contrast, will flow slowly under their own energy.

In determining the international resource base, they recommend that viscosity be used to define tar sands and heavy oil and that API gravity be used where viscosity measurements are not available.

They recommend the following limits or ranges for tar and heavy oil:

Tar: Greater than 10,000 centipoise at original reservoir temperature or less than 10° API gravity at 60°F and atmospheric pressure (IOCC, 1981).

[1]API gravity is a measure of petroleum density, modeled after a Baume scale for comparing lighter liquids with water. This density, in degrees API, is equal to 141.5/P-131.5; where P is the specific gravity of the petroleum measured at 15.6° C (American Geological Institute, 1976).

On the bases of viscosity or API gravity limits set by these recommended definitions, the multitude of native bitumens listed above are now most simply divided into tar sands or heavy oil occurrences. Obviously, there will still be some problems separating the two if no viscosity or API gravity determinations are available. In these cases, the presence or absence of visibly flowing oil must suffice to separate tar sands from heavy oils until the necessary physical tests are performed on the oil.

OCCURRENCES

There are references to at least 78 possible tar sand occurrences in Wyoming. Although the existence of many of these occurrences is well known, there is often very little published information about their characteristics and specific locations. In most cases, these occurrences cannot be identified as tar sands or heavy oils because there is no information on the viscosity or API gravity of the native bitumen. Appendix A summarizes what is available on each of these 78 occurrences.

A review of the published literature on these reported tar sand or heavy oil occurrences in Wyoming indicates that these occurrences are apparently more common or more extensive in the following geologic formations than in others (refer to Appendix B for details):

Cretaceous	Frontier Formation Aspen Shale
Jurassic	Morrison Formation
Triassic	Chugwater Formation
Permian	Phosphoria Formation
Pennsylvanian	Minnelusa Formation Tensleep Formation
Mississippian	Madison Limestone

HISTORICAL USES AND RECENT PROJECTS

In the past, many oil seeps, some of which may qualify as tar sands, 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. However, with the discovery and development of conventional petroleum resources, interest in less conventional resources such as tar sands disappeared. Also, with increased technology, 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 has focused some attention back to the tar sands of the State. Three recent attempts to exploit "tar sands" in Wyoming are discussed below:

Brent Exploration

On the east flank of the Bighorn Basin (locality 11, Plate 1), Brent Exploration is experimenting with an enhanced oil recovery project in Ts. 53-56 N., Rs. 91-93W. (Gill, 1982). Reserves in Phosphoria Formation carbonates are estimated at 0.9 billion barrels of 10° 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, inverted 5-spot pattern.[2] 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. Within 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. According to Brent Exploration, 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 the slowly migrating bank of oil was broken. The injected fluids found a "path of least resistance" through the oil bank and flowed through the 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 number 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, reviving migration. Introduction of the polymer resulted in abrupt pressure reduction in well number 2. The pressure drop indicated that the leak in the fluid-oil front had been plugged; injected fluid was no longer escaping.

Brent's investigators suggest 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 the produced barrel of oil, while

[2]Four peripheral wells arranged in rectangular outline with the fifth well in the center, all within a 10-acre area; in 1982.

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 Deposit

In Crook County (locality 2, Plate 1), 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 of Houston, Texas, initiated the Burnt Hollow pilot tar sand oil recovery project in 1981. The Burnt Hollow deposits consist of 9° API gravity and 1,000,000 centipoise bitumen in the Minnelusa Formation. The formation reservoir averages 24 feet thick at a depth of 900 feet. This *in situ* commerical pilot project was estimated capable of producing 50 BOPD per well by injecting steam and caustic chemicals in a two-acre inverted five-spot array.[3] Total reserves are estimated at 364 million barrels, of which 182 million barrels are estimated recoverable, over an area of 12,800 acres (Marchant, 1981).

Trapper Canyon Deposit

In Big Horn County, east of Shell, Wyoming (locality 9, Plate 1), in secs. 32 and 33, T.52N., R.89W., Big Horn Oil Company from Salt Lake City, along with SPC Enterprises, had operated the Trapper Canyon tar sand oil recovery project in the Tensleep Sandstone. This deposit consisted of an estimated 1.96 million barrels of original oil in place. Properties of these hydrocarbons vary from 5.6° API gravity and over 10,000 centipoise viscosity at the outcrop to as much as 23.6° API gravity and undetermined viscosity in the subsurface, determined by coring. Although bitumen in outcrop has been degraded more than in the subsurface, the down-dip extent of this degradation is currently undefined. The formation reservoir is 18 feet thick and crops out in the area of interest. The tar sand (in this case) had

[3] 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 while the peripheral four wells are produced. In "conventional" techniques, the peripheral four wells are injectors and the single center well is the producer.

been mined. The ore then was taken to a processing plant, with the petroleum extracted via the modified Brimhall Cold Water technique. [4] 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 (Marchant, 1981).

In the summer of 1982, geologists from the Geological Survey of Wyoming initiated an independent geologic study of the Trapper Canyon deposit. Results of this study will be completed and published by mid-1983.

[4]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 with water and solvent to extract the desired hydrocarbons.

APPENDIX A

Appendix A provides brief summary descriptions of 78 reported occurrences of shallow, oil-impregnated rocks in Wyoming. Based on existing information, these deposits or occurrences are divided into probable tar sand, probable heavy oil, and unspecified type deposits. Unfortunately, with very few exceptions, accurate classification of these occurrences must await more detailed investigations.

Appendix A is organized into three sections. In the first section, probable tar sand occurrences are listed by basin; the second section lists probable heavy oil occurrences arranged by basin; and the third section lists unspecified occurrences also arranged by basin. All these occurrences are indexed by reference numbers that correspond to similarly identified locations on the accompanying map (Plate 1).

PROBABLE TAR SAND DEPOSITS--POWDER RIVER BASIN

Location: (1)	Formation(s):	Description	Development
Crook Co. sec. 2-T.51N.-R.67W.	Fuson Shale Mbr. Assoc. Field(s): Moorcroft Reference(s): Barnett, 1914b, p. 86.	Bud Spring oil seep. Thin film on water, asphalt bed above spring.	
Location: (2) Crook Co. Ts. 53&54N.-R.66W.	**Formation(s):** Minnelusa Fm. **Assoc. Field(s):** **Reference(s):** Kirkwood O & G Co., personal comm., 1982.	**Description** Left Creek Deposit. Petroleum is mostly 9° API gravity; but ranges from 9 to 16° API gravity.	**Development** Kirkwood Oil and Gas Co. estimates 184 million barrels of oil in reserves. The accumulation is currently being assessed.
Location: (3) Crook Co. sec. 35-T.55N.-R.64W.	**Formation(s):** Minnelusa Fm. **Assoc. Field(s):** **Reference(s):** Marchant, 1981.	**Description** Burnt Hollow. 9° API gravity and 1,000,000 centipoise oil at a depth of 900 feet. Reservoir is a 25-feet thick sandstone in Minnelusa Fm.	**Development** In situ, commercial pilot. Steam drive with caustic 2-acre inverted 5-spots. Currently operating pilot flood plant is in sec. 35-T.55N.-R.64W. Estimated 184 million barrels reserve. W.C. Kirkwood Oil & Gas Co.
Location: (4) Natrona Co. secs. 3,10-T.38N.-R.78W.	**Formation(s):** Shannon Sandstone Mbr. **Assoc. Field(s):** Salt Creek Field AST Teapot Unit. **Reference(s):** Wegemann, 1918, p. 39.	**Description** Located on the crest of the Salt Creek Anticline. Deposit is in shale, originating in the Shannon Ss. Ozocerite deposits.	**Development**

PROBABLE TAR SAND DEPOSITS--POWDER RIVER BASIN

Location: (5)	Formation(s):	Description	Development
Natrona Co. secs. 11-13,23,25 T.40N.-R.79W.	Niobrara Fm. Shannon Sandstone Mbr. Assoc. Field(s): Salt Creek Field AST Teapot Unit Reference(s): Woodruff & Wegemann,1911; Wegemann, 1918,p.39.	Oil seeps and ozocerite in coarse, cross-bedded sandstone, 8 feet thick, at the base of the Shannon Ss. Also, ozokerite is found in fractures and fissures in the Niobrara Shale; thought to be the result of lighter volatiles evaporating from the parent petroleum.	
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

PROBABLE TAR SAND DEPOSITS--WIND RIVER BASIN

Location: (6)	Formation(s):	Description	Development
Fremont Co. secs. 2,3,4,5,10, 11-T.32N.-R.94W.	Wagon Bed Fm. Assoc. Field(s): Reference(s): Van Houten, 1954; Love, 1970.	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.	
Location: (7)	**Formation(s):**	**Description**	**Development**
Fremont Co. secs. 3,10,11-T.32N.-R.94W.	White River Fm. Assoc. Field(s): Reference(s): Hares, 1916; Bell, 1960.	Minor asphalt in "rhyolite bombs" in upper part of White River Fm. In Section 3, asphalt of lower White River is uraniferous. "Bombs" are actually tuffaceous concretions (J.D. Love, pers. comm., 1982).	A pit was dug into lower White River strata in sec. 3, on west flank of Conant Creek Anticline, and a small amount of asphalt was recovered as uranium ore.
Location: (8)	**Formation(s):**	**Description**	**Development**
Fremont Co. secs. 12,13-T.32N. R.99W.	Chugwater Fm. Assoc. Field(s): Dallas Dome Reference(s): Jameson, 1911; Krampert, 1948.	Asphalt deposit resulting from an active oil seep.	Led to discovery of the Dallas Dome Field in 1884.
Location:	**Formation(s):**	**Description**	**Development**
	Assoc. Field(s): Reference(s):		

PROBABLE HEAVY OIL ACCUMULATIONS--BIGHORN BASIN

Location: (9)	Formation(s):	Description	Development
Big Horn Co. secs. 28,29,32, 33-T.52N.-R.89W.	Tensleep Sandstone Assoc. Field(s): Reference(s): Darton, 1906; Hares, 1947.	Trapper Canyon Deposit (formerly called Battle Creek). Oil sand dips 3° SW and is about 1500 feet long, 2000 feet wide, and 20 feet thick (proved by core drilling). Gravity varies from 5.6° API in outcrop to possibly 23.6° API in subsurface.	Mining and extraction, using Modified Brimhall Cold Water Technique. Estimated 1.96 x 10^6 bbl. in place in 66 acres. Bronco Oil and Gas (Marchant, 1981).
Location: (10)	**Formation(s):**	**Description**	**Development**
Big Horn Co. secs. 28,29,32, 33-T.52N.-R.90W.	Tensleep Ss. (top) and Phosphoria Fm. (btm). Assoc. Field(s): Reference(s): Clabaugh, et al., 1946; Washburne, 1908, p.361.	Extensive and heavy oil impregnation. Outcrop is on steep-dipping southwest flank of sharp, asymmetric anticline. Bed is about 10 feet thick and lies under 10 feet of mantle. (Possibly a duplicate of preceding entry, but with mistaken location.)	Washburne filed for quarrying, but no production recorded; possibly commercial occurrence.
Location: (11)	**Formation(s):**	**Description**	**Development**
Big Horn Co. sec. 13-T.54N.-R.92W.	Phosphoria Fm. Assoc. Field(s): Reference(s): Gill, 1982.	10° API gravity petroleum in the subsurface. Possibly three producing horizons within the Phosphoria Fm.	In situ test, began in mid-January, 1982. Ten-acre, 5-spot pattern. Expected 50% recovery of 280,000 bbl. in place under the 10-acre pattern. Brent Exploration.
Location: (12)	**Formation(s):**	**Description**	**Development**
Hot Springs Co. sec. 29-T.43N.-R.93W.	Chugwater Fm. Assoc. Field(s): Red Springs, Warm Spgs., Wild Horse Butte fields Reference(s): Hewett & Lupton, 1917, p. 133.	Small seep of heavy oil located on the crest of Red Spring Anticline.	

PROBABLE HEAVY OIL ACCUMULATIONS--GREEN RIVER BASIN

Location: (13)	Formation(s):	Description	Development
Uinta Co. sec. 12-T.14N.-R.119W.	Aspen Shale Assoc. Field(s): between Sulphur Creek and Aspen fields Reference(s): Veatch, 1907.	Oil found in several springs on Hilliard Flat. Absaroka Thrust cuts through this section.	Union Pacific's Aspen Tunnel, sec. 7-T.14N.-R.118W., flowed 200-300 gallons per day for 30 to 40 days in 1901. Petroleum claims were staked and some lubricating oil was sold.
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

PROBABLE HEAVY OIL ACCUMULATIONS--WIND RIVER BASIN

Location: (14)	Formation(s):	Description	Development
Fremont Co. sec. 6-T.39N.-R.91W.	Flathead Sandstone. Assoc. Field(s): Reference(s): Tourtelot, 1953.	Oil seep in the vicinity of north dipping thrust fault, 13.2° API.	
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

UNSPECIFIED TYPE DEPOSITS--BIGHORN BASIN

Location: (15)	Formation(s):	Description	Development
Big Horn Co. sec. 24-T.51N.-R.93W.	Soil Assoc. Field(s): Torchlight Field Reference(s): Washburne, 1908.	Bitumen in soil located near crest of Torchlight Anticline.	
Location: (16)	Formation(s):	Description	Development
Big Horn Co. secs. 34,35-T.54N R.94W. and sec. 12-T.53N.-R.94W.	Madison Limestone Assoc. Field(s): Crystal Creek Field Reference(s): Washburne, 1908; Clabaugh et. al., 1946.	Limestone is lightly and variably impregnated with asphaltic oil on the crest of Sheep Mountain Anticline. Reported to have been a nearby seep, now covered by railroad track. Bitumen in cavities and cracks.	
Location: (17)	Formation(s):	Description	Development
Hot Springs Co. sec. 21-T.42N.-R.90W.	Frontier Fm. Assoc. Field(s): Reference(s): Hewett & Lupton, 1917, p. 122.	Small seep located on the crest of Lysite Mountain Anticline.	15 dry holes in township.
Location: (18)	Formation(s):	Description	Development
Park Co. SW NW sec. 12-T.52N.-R.103W.	Tensleep Sandstone(?) Assoc. Field(s): none Reference(s): Love & Good, 1970; Spencer & Dersch, 1981.	Cedar Mountain. John Colter's "boiling tar springs" (Harris, 1952). Many nearby hot springs. Petroleum is described as "tar" and "asphaltum." Obliterated in 1970 by Buffalo Bill Reservoir.	

UNSPECIFIED TYPE DEPOSITS --BIGHORN BASIN (CONT.)

Location: (19)	Formation(s):	Description	Development
Park Co. sec. 21(?)-T.53N.-R.101W.	Colorado Group Assoc. Field(s): Reference(s): Hewett, 1914a.	Oil seep from sandstones in the Colorado Group. The Colorado Group includes strata from the top of Cody Shale through the bottom of Thermopolis Shale.	Oil impregnated sandstones were encountered by a well drilled by Shoshone Oil Co. in 1909-1912. All oil produced was stored locally and used for lubricating. Maximum production was 200 barrels.
Location: (20)	**Formation(s):**	**Description**	**Development**
Park Co. Shoshone National Forest 44°31'N.-109°39'W.	Eocene breccia Assoc. Field(s): Reference(s): Hewett, 1914b; Love & Good, 1970.	Sweetwater Mineral Springs. Hydrocarbon seeps are near cold water mineral springs. Test pits yielded only minor oil. Alluvial sand in pits was dark brown, with asphaltic odor.	
Location: (21)	**Formation(s):**	**Description**	**Development**
Washakie Co. sec. 19(?)-T.47N.-R.89W.	Madison Fm. (?) Assoc. Field(s): Shoal Unit Reference(s): Hewett & Lupton, 1917, p. 105.	Small seep on Sherard or Cottonwood Anticline.	Six dry holes in township.
Location: (22)	**Formation(s):**	**Description**	**Development**
Washakie Co. sec. 29-T.47N.-R.90W.	? Assoc. Field(s): Cottonwood Creek Field Reference(s): Washburne, 1908.	Oil in a mud spring, located on crest of anticline.	

UNSPECIFIED TYPE DEPOSITS--GREEN RIVER BASIN

Location: (23)	Formation(s):	Description	Development
Carbon Co. sec. 9-T.15N.-R.88W.	Browns Park Fm. Assoc. Field(s): Reference(s): Love, pers. comm.,1982		
Location: (24) Carbon Co. secs. 3,10,15,16, 22,27-T.17N.-R.92W. and sec. 34-T.18N.-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 feet wide and up to 50 feet thick.	**Development**
Location: (25) Carbon Co. sec. 8-T.19N.-R.79W.	**Formation(s):** basal Hanna Fm. **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: (26) Carbon Co. SE NW sec. 20-T.14N.-R.89W.; SW SE NW sec. 14, NW sec. 24-T.13N.-R.87W.; NW SE NE sec. 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**

UNSPECIFIED TYPE DEPOSITS--GREEN RIVER BASIN (CONT.)

Location: (27)	Formation(s):	Description	Development
Lincoln-Sublette Counties, east of LaBarge Ridge.	Wasatch Fm. Assoc. Field(s): Reference(s): Schultz, 1914.	Oil springs.	
Location: (28)	Formation(s): Assoc. Field(s): LaBarge Unit Reference(s): Schultz, 1907.	Description Oil in deep pit, oozed from surface rocks.	Development
Location: (29)	Formation(s): Darby Fm. Assoc. Field(s): Reference(s): Baker, 1946.	Description Oil stain along NW tip of Wind River Range.	Development
Location: (30)	Formation(s): Mesozoic strata Assoc. Field(s): Reference(s): Love, pers. comm., 1982.	Description Oil seep reported, not actually seen by Love.	Development
Sublette Co. sec. 34-T.27N.-R.113W.			
Sublette Co. T.38N.-R.109W.			
Sublette Co. T.37N.-R.110W.			

Location: (31)	Formation(s):	Description	Development
Sweetwater Co. W½ sec. 9-T.12N.-R.97W.	Green River Fm. Assoc. Field(s): Reference(s): Sears, 1924.	Slight impregnation in a thin sandstone. Beds are dragged up sharply along fault near Shell Point.	
Location: (32)	**Formation(s):**	**Description**	**Development**
Sweetwater Co. sec. 9-T.12N.-R.98W.	Green River or Browns Park fms. Assoc. Field(s): Reference(s): Sears, 1924.	Slightly saturated sandstone on upthrown side of a normal fault.	
Location: (33)	**Formation(s):**	**Description**	**Development**
Teton Co. T.39N.-R.116W.	? Assoc. Field(s): Reference(s): Schultz, 1914.	Oil on water, within northern tip of thrust belt.	
Location: (34)	**Formation(s):**	**Description**	**Development**
Uinta Co. sec. 4-T.13N.-T.119W.	Aspen Shale Assoc. Field(s): Reference(s): Veatch, 1907.	Oil in springs on Hilliard Flat, flanked by west adjacent Absaroka Thrust, in an overturned syncline.	

UNSPECIFIED DEPOSIT TYPES--GREEN RIVER BASIN (CONT.)

Location: (35)	Formation(s):	Description	Development
Uinta Co. sec. 7-T.14N.-R.118W.	Aspen Shale Assoc. Field(s): Aspen, Spring Valley, Sulphur Creek fields Reference(s): Veatch, 1907.	Oil in springs on Hilliard Flats on the south end of Lazeart Syncline, flanked by Absaroka Thrust on west, near Oil Spring Fault.	
Location: (36)	Formation(s):	Description	Development
Uinta Co. sec. 33-T.14N.-R.119W.	Aspen Shale Assoc. Field(s): Sulphur Creek Field Reference(s): Veatch, 1907.	Oil in springs on Hilliard Flat in syncline hinge area cut by subsidiary thrusts from the Absaroka Thrust.	
Location: (37)	Formation(s):	Description	Development
Uinta Co. sec. 31-T.15N.-R.118W.	Aspen Shale Assoc. Field(s): Sulphur Creek Field Reference(s): Veatch, 1907.	Carter Spring on west flank of Lazeart Syncline, cut by Absaroka Thrust, near Oil Spring Fault.	
Location: (38)	Formation(s):	Description	Development
Uinta Co. T.21N.-R.117W.	Wasatch Fm. Assoc. Field(s): Fossil Field Reference(s): Veatch, 1907.	Group of springs on a gentle anticline.	

UNSPECIFIED TYPE DEPOSITS--POWDER RIVER BASIN

Location: (39)	Formation(s):	Description	Development
Converse Co. sec. 16-T.32N.-R.73W.	Cloverly Fm. Assoc. Field(s): Browning Basin and Douglas Creek fields Reference(s): Barnett, 1914a, p. 68.	Located on north flank of large, steeply dipping limb of NW trending anticline. Sandstone more or less saturated with "heavy oil" was encountered in construction of an irrigation tunnel in sec. 16-T.32N. R.73W.	
Location: (40) Converse Co. sec. 6-T.32N.-R.74W.	Formation(s): upper Casper Fm. Assoc. Field(s): Douglas Creek Field Reference(s): Barnett, 1914a, p. 68.	Description In Boxelder Creek bed, oil seeps from the top of the Casper Formation, appearing on the water surface.	Development
Location: (41) 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 & 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 of oil between 1887-1957 from NW¼ sec. 34-T.52N.-R.67W.
Location: (42) Crook Co. sec. 9-T.52N.-R.61W.	Formation(s): upper Minnelusa Fm. Assoc. Field(s): Rocky Ford Field (abnd) Reference(s): Brady, 1958, p. 47; Trotter, 1963, p. 117.	Description Dead oil stain, northwest flank of Black Hills Uplift. A 100-foot sandstone in the Upper Minnelusa Fm. is impregnated with oil in canyon of Rocky Ford Creek, not readily apparent. Other localities are indicated nearby, but not described by Clabaugh, et al., (1946).	Development

UNSPECIFIED TYPE DEPOSIT--POWDER RIVER BASIN (CONT.)

Location: (43)	Formation(s):	Description	Development
Crook Co. sec. 22-T.52N.-R.67W.	Granerous Fm. Assoc. Field(s): Moorcroft Field Reference(s): Barnett, 1914b, p. 86.	Stain. The Granerous Formation includes strata from Skull Creek Shale through Belle Fourche Shale. (W.G.S. Guidebook, 1958, p. 306).	
Location: (44)	**Formation(s):**	**Description**	**Development**
Crook Co. sec. 27-T.52N.-R.67W.	Granerous Fm. Assoc. Field(s): Moorcroft Field Reference(s): Barnett, 1914b, p. 86.	Spring and two seeps. The Granerous Formation includes strata from Skull Creek Shale through Belle Fourche Shale. (W.G.A. Guidebook, 1958, p. 306).	
Location: (45)	**Formation(s):**	**Description**	**Development**
Crook Co. sec. 34-T.52N.-R.67W.	Granerous Fm. Assoc. Field(s): Moorcroft Field Reference(s): Barnett, 1914b, p. 86.	Small seep, heavily stained. Small outcrop. The Granerous Formation includes strata from Skull Creek Shale through Belle Fourche Shale. (W.G.A. Guidebook, 1958, p. 306).	
Location: (46)	**Formation(s):**	**Description**	**Development**
Johnson and Natrona Cos. secs. 16,17,20, 28,29,32,33-T.41N.-R.81W.	Morrison, Sundance, Cloverly fms. Assoc. Field(s): Powder River Field, Tilsdale Field Reference(s): Knight & Slossen, 1901; Wegemann, 1912,p.61,71-74.	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.	North Tilsdale is four miles north and has produced more than a million barrels of oil since 1952.

Location: (47)	Formation(s):	Description	Development
Natrona Co. sec. 23-T.38N.-R.87W.	Frontier Fm. Assoc. Field(s): Reference(s): Tourtelot, 1953.	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.	Tar sands, oil and gas seeps led to discovery of Shannon Pool in 1889 and Salt Creek Field in 1908.
Location: (48)	Formation(s):	Description	Development
Natrona Co. secs. 28,33-T.41N. R.81W.	Sundance, Morrison fms. and Dakota Sandstone Assoc. Field(s): Tilsdale Unit Reference(s): Wegemann, 1912.	Oil seeps, located on the crest of an anticline.	
Location: (49)	Formation(s):	Description	Development
Natrona Co. sec. 33-T.41N.-R.81W.	Morrison Fm. Assoc. Field(s): Tilsdale Unit Reference(s): Love, pers. comm., 1982; Wegemann, 1912.	Oil impregnation in a massive sandstone, 6 to 7 feet thick, near base of Morrison Fm. Located on the crest of an anticline. Sixteen % of oil produced was 35° API and 81% of oil was 21.9° API residuum.	Oil produced by tunneling, prior to 1912.
Location: (50)	Formation(s):	Description	Development
Platte Co. sec. 1-T.27N.-R.68W.	Tertiary rocks Assoc. Field(s): Reference(s): Denson & Botinelly, 1949.	Associated with the Hartville Uplift; located on the west flank of a N-S trending anticline.	

UNSPECIFIED TYPE DEPOSITS--POWDER RIVER BASIN (CONT.)

Location: (51)	Formation(s):	Description	Development
Weston Co. sec. 2-T.44N.-R.61W. and secs. 23,25-T.45N R.62W.	Newcastle Sandstone Assoc. Field(s): Skull Creek Field Reference(s): Darton, 1905, p. 385.	Newcastle Sandstone is stained with oil along Salt Creek. Unit dips 20° to 25° southwest. Staining is confined to the top of the formation.	Seeps near Newcastle once furnished small amounts of lubricating oil for many years, at least, before Darton's 1905 report.
Location: (52)	**Formation(s):**	**Description**	**Development**
Weston Co. secs. 3,4-T.48N.-R.66W. and secs. 33,34-T.49N R.66W.	Turner Sandy Member of Carlile Shale Assoc. Field(s): Thornton Field Reference(s): Hancock, 1920, p. 31.	The Turner Sandy Member dips 25° southwest into the Powder River Basin.	Led to the discovery of the Upton-Thornton Field in 1917. 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**

UNSPECIFIED TYPE DEPOSITS--WIND RIVER BASIN

Location: (53)	Formation(s):	Description	Development
Fremont Co. sec. 7-T.1S.-R.1E.	? Assoc. Field(s): Reference(s): Jameson, 1911.	Oil saturated sandstone and shale on anticlines on leading edge of allochthon of NE dipping thrust.	
Location: (54)	**Formation(s):**	**Description**	**Development**
Fremont Co. sec. 26-T.1S.-R.1E.	Mancos Shale (?) Assoc. Field(s): Plunkett Field Reference(s): Jameson, 1911.	Oil springs on small dome in allochthon of east dipping thrust fault. The Mancos Shale is equivalent to lower Mesaverde Group and upper Cody Shale.	
Location: (55)	**Formation(s):**	**Description**	**Development**
Fremont Co. sec. 1-T.1S.-R.1W.	? Assoc. Field(s): Reference(s): Jameson, 1911.	On anticline on leading edge of allochthon of NE dipping thrust. Bubbles of oil arising in the bed of Trout Creek.	
Location: (56)	**Formation(s):**	**Description**	**Development**
Fremont Co. secs. 22,25-T.1N.-R.1W.	? Assoc. Field(s): Sage Creek Field Reference(s): Jameson, 1911.	Oil springs on NE flank of NW trending anticline. An extremely heavy, thick oil, containing 84.9 percent "asphaltum."	

UNSPECIFIED TYPE DEPOSITS--WIND RIVER BASIN (CONT.)

Location: (57)	Formation(s):	Description	Development
Fremont Co. secs. 27,32-T.1N.-R.1W.	? Assoc. Field(s): Sage Creek Field Reference(s): Jameson, 1911.	Oil saturated sandstone and shale on allochthon of NE dipping thrust. Section 27 is located on the south end of Sage Creek Field.	
Location: (58) Fremont Co. sec. 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 Sandstone 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: (59) Fremont Co. sec. 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: (60) Fremont Co. sec. 13-T.27N.-R.95W.	Formation(s): Wasatch Fm. Assoc. Field(s): Reference(s): Love, pers. comm., 1982.	Description Oil seep, aromatic oil.	Development

UNSPECIFIED TYPE DEPOSITS--WIND RIVER BASIN (CONT.)

Location: (61)	Formation(s):	Description	Development
Fremont Co. sec. 8-T.31N.-R.99W.	Phosphoria Fm. Assoc. Field(s): Reference(s): Woodruff & Wegemann, 1911.	Five to ten feet of bituminous sandstone in the upper third of the Phosphoria Fm. in the canyon of the Little Popo Agie River.	
Location: (62)	**Formation(s):**	**Description**	**Development**
Fremont Co. secs. 17,18-T.34N.-R.92W.	Fort Union Fm. Assoc. Field(s): Reference(s): Thompson & White, 1952; Keefer & Rich, 1957.	Asphaltic oil variably impregnates Fort Union sandstones and conglomerates. Oil is immediately above the Fort Union-Mesaverde unconformity.	
Location: (63)	**Formation(s):**	**Description**	**Development**
Fremont Co. secs. 3,13,22,24-T.33N.-R.90W.	Frontier, Mowry Shale, Chugwater, Wind R. fms. Assoc. Field(s): Reference(s): Hares, 1916; Zeller, et al., 1956.	Oil impregnated ss. of lower 2/3 of Chugwater near crest of Dutton Basin Anticline in secs. 13 and 22. Also in sandstones of Frontier Fm. and sand lenses in Mowry Fm. and in sandstones and conglomerates of Wind River Fm. Located in the Gas Hills uranium district.	
Location: (64)	**Formation(s):**	**Description**	**Development**
Fremont Co. T.33N.-R.94W.	Frontier Fm. Assoc. Field(s): Reference(s): Hares, 1916.	Small seeps associated with the Alkali Butte Anticline.	Fifteen dry holes in the township.

UNSPECIFIED TYPE DEPOSITS--WIND RIVER BASIN (CONT.)

Location: (65)	Formation(s):	Description	Development
Fremont Co. T.34N.-R.95W. and Ts.1 and 2S.-R.6E.	Cody Shale, Mesaverde, Fort Union, Wind R. fms. Assoc. Field(s): Reference(s): Thompson & White, 1952	Sandstones in upper Cody Shale, sandstones in basal Mesaverde, basal Ft. Union sandstones and conglomerates, basal Wind River sandstones and conglomerates.	
Location: (66)	**Formation(s):**	**Description**	**Development**
Fremont Co. N½ NE¼ sec. 10-T.39N.-R.91W. and NE¼ sec. 2-T.39N.-R.90W.	Cretaceous and Tertiary rocks. Assoc. Field(s): Reference(s): Tourtelot, 1953.	Two oil impregnated outcrops along Cedar Ridge Fault. The first is in overturned beds of late Cretaceous-Paleocene age south of fault. The second is in Upper Eocene andesite tuffs north of the fault..	
Location: (67)	**Formation(s):**	**Description**	**Development**
Fremont Co. T.39N.-R.92W.	Wind River Fm. Assoc. Field(s): Reference(s): Hares, 1916.	Traces of oil.	Two dry holes in township.
Location: (68)	**Formation(s):**	**Description**	**Development**
Fremont Co. SW¼ NE¼ sec. 3-T.39N.-R.93W. and NE¼ SW¼ sec. 16-T.39N.-R.92W.	Upper Eocene tuffs and tuffaceous sandstones. Assoc. Field(s): Reference(s): Tourtelot, 1953; Tourtelot & Thompson, 1948.	Two oil impregnated areas of tuffaceous sandstones 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.	

UNSPECIFIED TYPE DEPOSITS--WIND RIVER BASIN (CONT.)

Location: (69)	Formation(s):	Description	Development
Natrona Co. sec. 28-T.33N.-R.82W.	Lower Cretaceous conglomerate Assoc. Field(s): Oil Mountain Field Reference(s): Hares, 1916.	Oil spring issuing from a fault plane along crest of an anticline.	
Location: (70)	**Formation(s):**	**Description**	**Development**
Natrona Co. secs. 4,5,9-T.33N. R.87W.	Teapot Ss. Mbr.(?) of Mesaverde Fm. Assoc. Field(s): Grieve Field Reference(s): Hares, 1916; Hail, 1957.	Saturated sandstone, Fales Member of Mesaverde Fm., in the Wallace Dome. Teapot Sandstone Mbr., saturated with asphalt, forms a prominent hogback on the east flank of Rattlesnake Range.	
Location: (71)	**Formation(s):**	**Description**	**Development**
Natrona Co. sec. 28-T.33N.-R.87W. to sec. 34-T.34N.-R.88W.	Chugwater Fm. and Dakota Sandstone Assoc. Field(s): Reference(s): Hares, 1916.	Many seeps from units in section from Chugwater to Dakota fms., located on NE flank of Rattlesnake Mountains.	
Location: (72)	**Formation(s):**	**Description**	**Development**
Natrona Co. near Ervay, in Ts.32,33,34N.-Rs.86,87,88W.	Chugwater, Sundance, Morrison fms., Cret. sands Assoc. Field(s): Reference(s): Barwin, 1961; Paape, 1961; and Ball, 1965.	Varied and extensive outcrops of petroleum impregnated sandstones along the northeast flank of the Rattlesnake Hills in Cretaceous sands, Morrison and Sundance and Chugwater fms. Among the largest deposits in Wyoming.	

UNSPECIFIED TYPE DEPOSITS--WIND RIVER BASIN (CONT.)

Location: (73)	Formation(s):	Description	Development
Teton Co. sec. 11-T.38N.-R.110W.	Phosphoria and Amsden fms., Tensleep Ss. Assoc. Field(s): Reference(s): Bell, 1960; Richmond, 1945.	Phosphoria sandstones impregnated with asphaltic oil. Scattered occurrences in this area in Tensleep Sandstone and Amsden Fm. One sample yielded 3.2% oil.	
Location: (74)	**Formation(s):**	**Description**	**Development**
Teton Co. T.42N.-R.114W.	Phosphoria Fm. Assoc. Field(s): Reference(s): Love, et al., 1951.	Oil filled vugs in strata on Red Hills Anticline.	One dry hole.
Location: (75)	**Formation(s):**	**Description**	**Development**
Along east and southeast side of Gros Ventre Range.	Bighorn Dol., Madison, Darby, Phosphoria and Frontier fms. Assoc. Field(s): Reference(s): Love, et al., 1951.	Oil staining.	
Location:	**Formation(s):**	**Description**	**Development**
	Assoc. Field(s): Reference(s):		

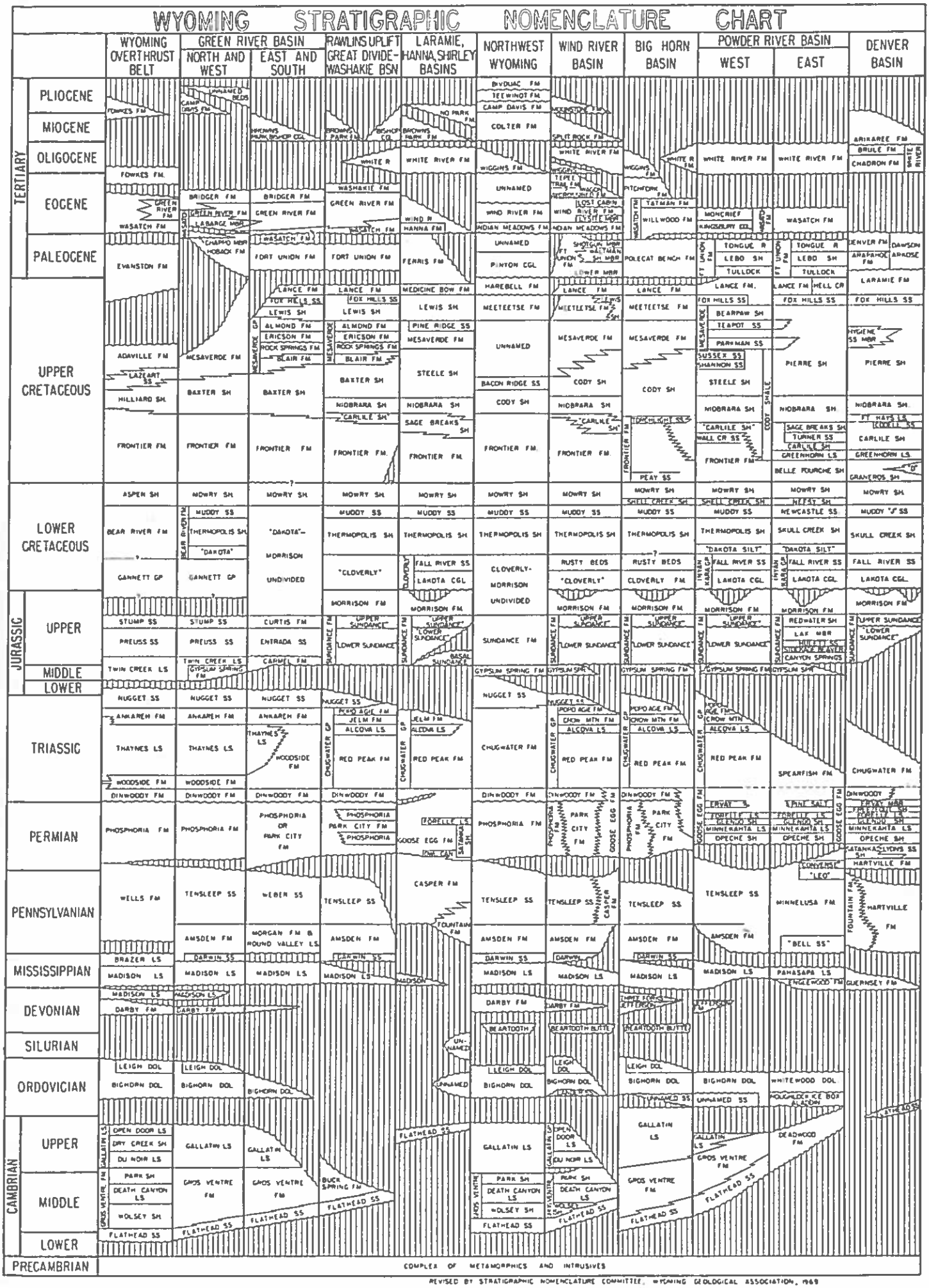
UNSPECIFIED TYPE DEPOSITS (CONT.)--YELLOWSTONE NATIONAL PARK

Location: (76)	Formation(s):	Description	Development
Yellowstone National Park in Yellowstone Grand Canyon	Eocene breccia Assoc. Field(s): none Reference(s): Love & Good, 1970; Spencer & Dersch, 1981.	Calcite springs. Oil emerges from orifices along fractures in soil and rock. Oil heated to 80-85°C. Sulfurous gas and steam and cool water accompany oil in various vents.	
Location: (77)	Formation(s):	Description	Development
Yellowstone National Park near Tower Junction	Lower Cathedral Cliffs Fm. Assoc. Field(s): none Reference(s): Love & Good, 1970; Spencer & Dersch, 1981.	Tower Bridge. Oil seep in walls of pit dug for bridge construction. Original source of oil is unknown.	
Location: (78)	Formation(s):	Description	Development
Yellowstone National Park along Sunlight Creek, east of Mt. Washburn.	Pleistocene strata Assoc. Field(s): none Reference(s): Love & Good, 1970; Spencer & Dersch, 1981.	Rainbow Springs. Many oil seeps from lower claystone and mudstone sequence. Possible Pleistocene origin. Heated oil issues by itself and mixed with water in various seeps.	
Location:	Formation(s): Assoc. Field(s): Reference(s):	Description	Development

A P P E N D I X B

Appendix B lists and describes the geologic formations in which there is some indication or inference of tar sand occurrence in Wyoming. The Wyoming Stratigraphic Nomenclature Chart on page is provided as an aid to understanding the nomenclature and correlation of geologic formations within the State.

WYOMING STRATIGRAPHIC NOMENCLATURE CHART



REVISED BY STRATIGRAPHIC NOMENCLATURE COMMITTEE, WYOMING GEOLOGICAL ASSOCIATION, 1969

Amsden Formation

Map location - 73

Age: Upper Mississippian to Lower and Middle Pennsylvanian

Lithology: upper dolomite; middle brownish limestone; lower red shales and sandstone.

Petroleum: scattered occurrences of "asphaltic oil" in sec. 11-T.38N.-R.110W.

References: Richmond, 1945; Bell, 1960.

Andesite Tuffs

Map locations - 66, 68

Age: Upper Eocene

Lithology: coarse-grained tuffs and equivalent tuffaceous sandstones in lower portion of an andesite tuff sequence.

Petroleum: oil seeps along Cedar Ridge Fault and in West Dry Creek Graben; sec. 2-T.39N.-R.90W., sec. 16-T.39N.-R.92W., and sec. 3-T.39N.-R.93W.

References: Tourtelot, 1953; Tourtelot and Thompson, 1948.

Aspen Shale

Map locations - 13, 34, 35, 36, 37

Age: Lower Cretaceous

Lithology: gray to dark gray, hard, siliceous, fissile shale, occasionally bentonitic.

Petroleum: petroleum in Hilliard Flats springs, secs. 12,33-T.14N.-R.119W., sec. 4-T.13N.-R.119W., and sec. 7-T.14N.-R.118W. Also in Carter Spring, west flank of Lazeart Syncline, near Oil Spring Fault, sec. 31-T.15N.-R.118W.

Reference: Veatch, 1907.

Bighorn Dolomite

Map location - 75

Age: Ordovician

Lithology: light gray, massive, homogeneous dolomite

Petroleum: oil staining along east and southeast side of Gros Ventre Range.

Reference: Love, et al., 1951.

Breccia

Map locations - 20, 76

Age: Eocene

Lithology: at location 76--drab green to brown mafic tuff, conglomerate and possibly basalt flows; all altered yellow by hydrothermal action.
at location 20--thick brown mafic volcanic conglomerate and agglomerate with large angular blocks of Paleozoic limestone and dolomite.

Petroleum: at location 76--warmed oil emerges from spouts and orifices along fractures in soil and rock. Oil often accompanied by sulfurous gas and steam from hotter vents and water from cooler areas.
at location 20--petroleum seeps are close by cold water mineral springs. Alluvial sand in test pits was stained dark brown, with asphaltic odor.

References: Hewett, 1914b; Love and Good, 1970; Spencer and Dersch, 1981.

Browns Park Formation

Map locations - 23, 32

Age: Miocene

Lithology: upper chalk white and grayish white sandstone, tuffaceous sandstone, thin chert beds, occasional vitric tuff and freshwater limestone; lower conglomerates, dominantly of Precambrian cobbles.

Petroleum: slightly saturated sandstone on upthrown side of a normal fault in sec. 9-T.12N.-T.98W.

References: Love, pers. comm., 1982; Sears, 1924.

Cathedral Cliffs Formation

Map location - 77

Age: Eocene

Lithology: dark green to dark brown coarse-grained mafic tuff, conglomerate, and basaltic breccia with minor gray claystone partings. Often altered by hydrothermal activity to white, yellow and light green.

Petroleum: oil seeped from walls of a pit dug for bridge construction. Original source is unknown.

References: Love and Good, 1970; Spencer and Dersch, 1981.

Casper Formation

Map location - 40

Age: Pennsylvanian-Permian

Lithology: upper sandstone and chalky limestone and dolomite; middle carbonate and thin interbedded sandstones; lower arkose, sandstone, shale and limestone.

Petroleum: oil seeps in bed of Box Elder Creek in sec. 6-T.32N.-R.74W.

Reference: Barnett, 1914a.

Chugwater Formation

Map locations - 8, 12, 58, 59, 65, 71, 72

Age: Triassic

Lithology: comprised of four members, in descending order: Popo Agie Member--red sandstone, siltstone, and shale; partly calcareous. Crow Mountain Sandstone--buff to gray, medium grained, slightly calcareous sandstone. Alcova Limestone--buff to pink, finely crystalline limestone. Red Peak Shale--red siltstone and shale with nodules of anhydrite and gypsum in the lower half.

Petroleum: heavy oil seep on crest of Red Springs Anticline, sec. 29-T.43N.-R.93W.; sandstones are variably impregnated on the crest of Sage Creek Anticline, sec. 36-T.1N.-R.1W.; on Circle Ridge Dome, sec. 36-T.7N.-R.3W.; on Dutton Basin Anticline, T.33N.-R.90W.; many seeps on northeast flank of Rattlesnake Mountains.

References: Ball, 1965; Barwin, 1961; Clabaugh, et al., 1946; Collier, 1920; Hares, 1916; Hewett and Lupton, 1917; Paape, 1916; Sharkey, 1946; Zeller, et al., 1956.

Cloverly Formation

Map location - 39

Age: Lower Cretaceous

Lithology: sandstones, chert-pebble conglomerate, siltstones and black to gray or variegated shale.

Petroleum: sandstone saturated in irrigation tunnel in sec. 16-T.32N.-R.73W.

Reference: Barnett, 1914a.

Cody Shale

Map location - 65

Age: Upper Cretaceous

Lithology: soft, gray, marine shales and silty shales with lenses of gray, fine-grained sandstone.

Petroleum: upper sandstones are oil impregnated in region of T.34N.-R.95W. and Ts. 1&2S., R.6E., outcrops on the flanks of Alkali Buttes Anticline.

References: Thompson and White, 1952.

Colorado Group

Map location - 19

Age: Upper Cretaceous

Lithology: includes strata from top of Cody Shale through Thermopolis Shale--upper dark green fossiliferous marine shale, sandy shale, carbonaceous shale, coal and bentonite; lower gray to black shale interbedded with sandstones and bentonites and contains some marine fossils and fish scales.

Petroleum: oil seep from sandstones in the Colorado Group. Apparently, these oil impregnated sandstones were penetrated by a well of Shoshone Oil Co. All oil was stored locally and used for lubricating.

Reference: Hewett, 1914a.

Dakota Sandstone

Map locations - 41, 48, 71

Age: Lower Cretaceous

Lithology: subangular, fine-grained, thin bedded to tabular cross laminated, buff to brown weathering sandstone.

Petroleum: oil impregnated sandstone in secs. 1,12-T.51N.-R.67W. Oil seeps in crest of anticline in secs. 28,33-T.41N.-R.81W. Many seeps scattered for several miles from outcrops on the northeast flank of the Rattlesnake Mountains, most concentrated in the Wallace Creek area in central T.39N.-R.87W.

References: Barnett, 1914b; Biggs and Espach, 1960; Hares, 1916; Wegemann, 1912.

Darby Formation

Map locations - 29, 75

Age: Upper Devonian

Lithology: dark, fine to medium crystalline dolomite ledges separated by beds of shale, mudstone, siltstone and sandstone.

Petroleum: oil staining along northwest tip of Wind River Range and along southwest side of the Gros Ventre Range.

References: Baker, 1946; Love, et al., 1951.

Fales Member (of Mesaverde Formation)

Map locations - 65, 72

Age: Upper Cretaceous

Lithology: upper sequence of interbedded sandstone, siltstone, claystone and shale; middle calcareous shale; and basal light gray, fine- to medium grained sandstone.

Petroleum: outcrops are extensively oil stained in Ts. 32,33&34N.-Rs. 86,87&88W. and in T.34N.-R.95W., Ts. 1&2S.-R.6E.

References: Ball, 1965; Barwin, 1961; Paape, 1961; Thompson and White, 1952.

Flathead Sandstone

Map location - 14

Age: Cambrian

Lithology: red and gray sandstone and quartzite, usually arkosic at base.

Petroleum: oil seep in the vicinity of thrust fault in sec. 6,-T.39N.-R.91W.

Reference: Tourtelot, 1953

Fort Union Formation

Map locations - 62, 65

Age: Paleocene

Lithology: friable gray to yellowish-gray sandstone, dark to light gray shale and sandy shale, brown carbonaceous shale and thin beds of coal.

Petroleum: asphaltic oil impregnated sandstone and conglomerate immediately above the Fort Union-Mesaverde unconformity in secs. 17,18-T.34N.-R.92W. Basal Fort Union is impregnated in T.34N.-R.95W. and Ts. 1&2S.-6E., also.

References: Keefer and Rich, 1957; Thompson and White, 1952.

Frontier Formation

Map locations - 17, 47, 63, 64, 75

Age: Upper Cretaceous

Lithology: buff, brown to tan sandstones interbedded with brown and black to dark gray shales, local coal beds.

Petroleum: seep on Lysite Mountain Anticline, sec. 21-T.42N.-R.90W.; oil impregnated sandstone in allochthon, sec. 23-T.38N.-R.87W.; Dutton Basin Anticline seep, secs. 3,13,22,24-T.33N.-R.90W.; small seeps associated with Alkali Butte Anticline, T.33N.-R.94W.; and oil staining along east and southwest side of Gros Ventre Range.

References: Hares, 1916; Hewett and Lupton, 1917; Love, et al., 1951; Tourtelot, 1953; Zeller, et al., 1956.

Fuson Shale

Map location - 1

Age: Lower Cretaceous

Lithology: variegated and black massive shales and clays with varying amounts of sandstone.

Petroleum: Bud Spring oil seep in sec. 2-T.51N.-R.67W., thin film on water, asphalt bed above spring.

Reference: Barnett, 1914b.

Graneros Shale

Map locations - 43, 44, 45

Age: Upper Cretaceous

Lithology: laminated argillaceous gray shales with very little limy or sandy material. Includes Belle Fourche, Mowry, Nefsy shales, Newcastle Sandstone, and Skull Creek Shale.

Petroleum: staining, seeps and springs in secs. 22,27,34-T.52N.-R.67W.

Reference: Barnett, 1914b.

Green River Formation

Map locations - 31, 32

Age: Eocene

Lithology: brown to yellowish-gray chalky shales, buff-brown sandstones, algal limestones and oil shales.

Petroleum: slight impregnation in a thin sandstone along a fault near Shell Point, sec. 9-T.12N.-R.97W. and sec. 9-T.12N.-R.98W.

Reference: Sears, 1924.

Hanna Formation

Map location - 25

Age: Eocene

Lithology: alternating beds of dark gray, yellowish and carbonaceous shale, white to gray and brown massive to cross-bedded and thin bedded sandstone, pebble conglomerate and conglomeratic sandstone and numerous coal beds.

Petroleum: asphaltic oil in sandstone on northeast flank of anticline cut by Arlington Thrust Fault in sec. 8-T.19N.-R.79W.

Reference: Ver Ploeg, A.J., Wyo. Geol. Surv., personal comm., 1982.

Lakota Formation

Map location - 71

Age: Upper Cretaceous

Lithology: massive, coarse, and cross-bedded sandstone, often conglomeratic and containing chert pebbles.

Petroleum: varied and extensive petroleum impregnation above the northeast flank of Rattlesnake Hills.

Reference: Hares, 1916.

Madison Limestone

Map locations - 16, 21, 26, 75

Age: Mississippian

Lithology: cherty limestone and dolomite

Petroleum: impregnated with asphaltic oil in crest of Sheep Mountain Anticline in secs. 34,45-T.54N.-R.93W. and sec. 12-T.53N.-R.94W. Small seep in Sherard (or Cottonwood) Anticline in sec. 19(?)-T.47N.-R.89W. Black asphaltic oil in fractures, vugs and disseminated through outcrops. Also, oil stained along east and southeast side of Gros Ventre Range.

References: Clabaugh, et al., 1946; Hewett and Lupton, 1917; Love, et al., 1951; Ritzma, 1951; Washburne, 1908.

Mancos Shale

Map location - 54

Age: Upper Cretaceous

Lithology: shale, sandy shale, thin bedded sandstones. Includes upper Cody Shale through lower Mesaverde strata.

Petroleum: oil springs on small dome in allochthon of east dipping thrust fault.

Reference: Jameson, 1911.

Mesaverde Formation

Map locations - 65, 72

Age: Upper Cretaceous

Lithology: commonly massive to thin bedded sandstones above and below a medial shale and coal sequence of both marine and non-marine origin.

Petroleum: impregnated basal sandstones in areas of T.34N.-R.95W. and Ts. 1&2S.-R.6E.; and Ts. 32,33&34N.-Rs. 86,87&88W. Refer also to Fales and Teapot members.

References: Ball, 1965; Barwin, 1961; Paape, 1961; Thompson and White, 1952.

Minnelusa Formation

Map locations - 2, 3, 42

Age: Pennsylvanian and Lower Permian

Lithology: white, crystalline, subsacchroidal sandstone; anhydrite, shale and limestone.

Petroleum: Burnt Hollow deposit, 9^{o} API gravity at depth of 900 feet in a reservoir sandstone 25 feet thick, sec. 35-T.55N.-R.64W. One hundred feet thick upper Minnelusa sandstone apparently oil impregnated in canyon of Rocky Ford Creek, sec. 9-T.52N.-R.61W.

References: Brady, 1958; Marchant, 1981; Trotter, 1963.

Morrison Formation

Map locations - 46, 48, 49, 72

Age: Upper Jurassic

Lithology: waxy, dull, drab and variegated shales and sandy shales interbedded with sandstones, siltstones and thin limestones.

Petroleum: sandstones near base of Morrison are lightly impregnated with oil in T.41N.-R.81W. Varied and extensive outcrops of petroleum impregnated sandstones on northeast flank of Rattlesnake Hills in Ts. 32,33&34N.-Rs. 86,87&88W.

References: Ball, 1965; Barwin, 1961; Knight and Slossen, 1901; Paape, 1961; Wegemann, 1912.

Mowry Shale

Map locations - 41, 63

Age: Lower Cretaceous

Lithology: hard, chunky, dark gray to black siliceous shales with abundant fish scales interbedded with thin sandstones and siltstones and bentonite. Weathers to light silvery gray.

Petroleum: sand lenses impregnated with oil at several localities in NE¼ T.51N.-R.67W., SE¼ T.52N.-R.67W. and secs. 3,13,22,24-T.33N.-R.90W.

References: Brady, 1958; Hares, 1916; Trotter, 1963; Zeller, et al., 1956.

Muddy Sandstone

Map location - 41

Age: Lower Cretaceous

Lithology: white, salt and pepper sandstone; occasionally glauconitic.

Petroleum: impregnated at several locations in NE¼ T.51N.-R.67W. and SE¼ T.52N.-R.67W.

References: Barnett, 1914b; Biggs and Espach, 1960.

Niobrara Formation

Map location - 5

Age: Upper Cretaceous

Lithology: gray marine shale with tiny tan to white calcareous lenses. Appears as a "speckled" shale.

Petroleum: ozocerite in fissures within the shales, associated with the Salt Creek Field; secs. 11,12,13,23,25-T.40N.-R.79W. Thought to be the result of the lighter volatiles evaporating from parent oil.

References: Wegemann, 1918; Woodruff and Wegemann, 1911.

Newcastle Sandstone

Map location - 51

Age: Lower Cretaceous

Lithology: reddish to light yellow sandstone associated with black carbonaceous shale.

Petroleum: stained with oil along Salt Creek. Staining is confined to top of formation, sec. 2-T.44N.-R.61W. and secs. 23,25-T.45N.-R.62W.

Reference: Darton, 1905.

Nugget Sandstone

Map location - 58

Age: Lower Jurassic to Upper Triassic

Lithology: light brown to white sandstone, cross-bedded, frosted quartz grains; locally calcareous or dolomitic.

Petroleum: scattered impregnations on crest of Sage Creek Anticline in sec. 36-T.1N.-R.1W.

References: Clabaugh, et al., 1946; Sharkey, 1946.

Phosphoria Formation

Map locations - 10, 11, 61, 73, 74, 75

Age: Middle Permian

Lithology: gray to tan cherty dolomite and limestone with thin gray dolomitic and phosphatic shale and siltstone.

Petroleum: extensive heavy oil impregnated outcrops in T.52N.-R.90W. and T.52N.-R.89W. Five to ten feet of bituminous sandstone in the upper two-thirds of the unit in canyon of Little Popo Agie River. Asphaltic oil impregnation in sec. 11-T.38N.-R.110W. Oil filled vugs in strata in Red Hills Anticline, T.42N.-R.114W. Oil staining along east and southeast side of Gros Ventre Range. 10° API gravity in subsurface, possibly three producing horizons in sec. 13-T.54N.-R.92W.

References: Bell, 1960; Clabaugh, et al., 1946; Love, et al., 1951; Richmond, 1945; Washburne, 1908, Woodruff and Wegemann, 1911.

Pleistocene Strata

Map location - 78

Age: Quaternary

Lithology: upper pebbly sandstone and sand unit, at least 125 feet thick; lower blue-gray claystone and mudstone, about 75 feet thick.

Petroleum: many oil seeps from lower in the unit. Oil issues from springs both pure and mixed with water in various locations. Pleistocene origin of oil has been mentioned.

References: Love and Good, 1970; Spencer and Dersch, 1981.

Quaternary alluvium

Map location - 15

Age: Quaternary

Lithology: soil

Petroleum: bitumen in soil, near crest of Torchlight Anticline.

Reference: Washburne, 1908.

Shannon Sandstone Member (of Cody Shale)

Map locations - 4, 5

Age: Upper Cretaceous

Lithology: fine-grained, clean to argillaceous, commonly glauconitic sandstone interbedded with thin dark gray shale laminae.

Petroleum: ozocerite deposits on crest of Salt Creek Anticline; deposit is in shale, but originated in the Shannon; secs. 3,10-T.38N.-R.78W. Oil seeps and ozocerite in coarse, cross-bedded sandstone, eight feet thick at base of Shannon sequence, secs. 11,12,13,23,25-T.40N.-R.79W.

References: Wegemann, 1918; Woodruff and Wegemann, 1911.

Sundance Formation

Map locations - 48, 72

Age: Upper Jurassic

Lithology: upper highly glauconitic greenish shales, calcareous sandstones and thin limestone, all fossiliferous.

Petroleum: oil seeps on crest of anticline in secs. 28,33-T.41N.-R.81W. Petroleum impregnated outcrops along northeast flank of Rattlesnake Hills, Ts.32,33&34N.-Rs.86,87&88W.

References: Ball, 1965; Barwin, 1961; Paape, 1961; Wegemann, 1912.

Teapot Sandstone Member (of Mesaverde Formation)

Map location - 70

Age: Upper Cretaceous

Lithology: gray, soft sandstone, with some carbonaceous shale.

Petroleum: saturated with asphalt, forms prominent hogback on the east flank of Rattlesnake Range; secs. 4,5,9-T.33N.-R.87W.

References: Hail, 1957; Hares, 1916.

Tensleep Sandstone

Map locations - 9, 10, 18, 73

Age: Middle and Upper Pennsylvanian

Lithology: massive, medium-grained, cross-bedded, tan to gray sandstone with minor interbedded thin, cherty dolomite and limestone.

Petroleum: Trapper Canyon (formerly Battle Creek) deposit; 23.6° API gravity in 20 feet of sandstone in secs. 28,29,32,33-T.52N.-R.89W. Heavy oil impregnated outcrops on steeply dipping southwest flank of sharp asymmetric anticline in secs. 28, 29,32,33-T.52N.-R.89W. John Colter's famous "boiling tar spring" was near Cedar Mountain, SW NW sec. 12-T.52N.-R.103W., now swamped by Buffalo Bill Reservoir.

References: Bell, 1960; Clabaugh, et al., 1946; Darton, 1906; Hares, 1947; Love and Good, 1970; Richmond, 1945; Washburne, 1908.

Turner Sandy Member (of Carlile Shale)

Map location - 52

Age: Upper Cretaceous

Lithology: sandy shale and siltstone with iron concretions and persistent thin sandstone. Sandstones are locally conglomeratic and phosphatic. Abundant shark teeth in lower portion.

Petroleum: oil impregnated outcrops in secs. 3,4-T.48N.-R.66W. led to discovery of Upton-Thornton Field.

Reference: Hancock, 1921.

Wagon Bed Formation

Map location - 6

Age: Middle and Upper Eocene

Lithology: bentonitic greenish-yellow to yellowish-gray, locally tuffaceous zeolitic mudstone and sandstone in persistent beds. Also volcanic sandstone and conglomerate, interbedded.

Petroleum: asphalt residue on east flank of Burly Anticline in secs. 2,3,4,5,10,11-T.32N.-R.94W.

References: Love, 1970; Van Houten, 1954.

Wasatch Formation

Map locations - 24

Age: Lower Eocene

Lithology: red, gray, brown variegated mudstones, siltstones, sandstones and conglomerates.

Petroleum: oil impregnated sandstone lenses in basal Wasatch along outcrops in secs. 3,10,15,16,22,27-T.17N.-R.92W. Oil saturated sandstones of basal Wasatch on west dipping monocline, sec. 34-T.18N.-R.92W.

References: Bell, 1960; Jameson, 1913.

White River Formation

Map location - 6

Age: Oligocene

Lithology: lacustrine, fluviatile and volcaniclastics with abundant mammalian fossils.

Petroleum: uranium and asphalt on west flank of Conant Creek Anticline in SW SE sec. 3-T.32N.-R.94W.

References: Bell, 1960; Hares, 1916.

Wind River Formation

Map locations - 63, 65, 67

Age: Eocene

Lithology: red shales, carbonaceous shales, variegated tuffaceous and bentonitic claystone; variegated siltstone, tuffaceous siltstone; buff, fine-grained shaly sandstones and sandstones, fine to coarse tuffaceous sandstones; and white to buff cobble and pebble conglomerates.

Petroleum: oil impregnated sandstones and conglomerates near crest of Dutton Basin Anticline in sec. 3,13,22,24-T.33N.-R.90W.

References: Hares, 1916; Thompson and White, 1952; Zeller, et al., 1956.

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THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

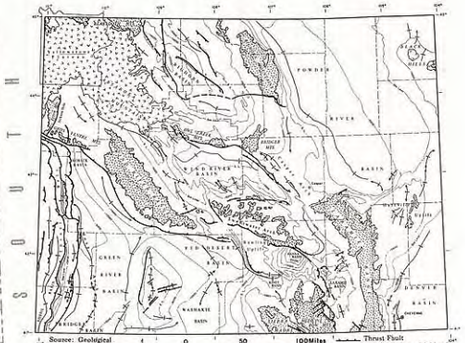
TAR AND HEAVY OIL DEPOSITS IN WYOMING
1982

Compiled by Michael Clark

0 10 Miles

SCALE 1:1,000,000
1 inch equals approximately 16 miles

STRUCTURAL INDEX MAP



EXPLANATION

- Tar sands
- Heavy oil deposits
- Unspecified type deposits
- Unspecified type deposits (locations are approximate)
  Location numbers refer to indexed descriptions in appendix A of the accompanying report
- Field with predominately oil production
- Field with predominately gas production
- Field with significant oil and gas production
- Oil shale-bearing strata
- Approximate location of basin axis

OPEN FILE REPORT 82-5/Plate 1