**Tar Sand Triangle Bitumen Deposit, Garfield and Wayne Counties, Utah**

Steven Schamel

Search and Discovery Article #50883 (2013)**

Posted October 31, 2013

*Adapted from a poster presentation given at AAPG Rocky Mountain Section Meeting, Salt Lake City, Utah, September 22-24, 2013

**AAPG©2013 Serial rights given by author. For all other rights contact author directly.

1GeoX Consulting, Inc., Salt Lake City, UT (geox-slc@comcast.net)

Abstract

The bitumen in the Tar Sand Triangle deposit is reservoired in a several-hundred-foot-thick eolian sandstone, the White Rim Sandstone (Lower Permian). Across an area of 84 square miles, the thickness of the bitumen-impregnated sandstone exceeds 100 ft. The strata are gently dipping and otherwise unstructured. Average porosity and permeability of the sandstone reservoir are in the range 15-20 % and 200-500 md, respectively. The oil saturation is consistently low, averaging 30-35%. The bitumen has an API gravity less than 8° at the surface and just over 10° in core. It has a high asphaltene and sulfur content, and it is saturate-poor. Although very viscous at reservoir temperatures, the bitumen is a few orders of magnitude less viscous than the Uinta Basin heavy oils. This study estimates a total in-place bitumen resource between 4.25 to 5.15 billion barrels in a deposit less than 200 square miles in size. However, at a commercially viable resource minimal threshold equal and greater than 60 MBO/ac, the in-place bitumen resource is estimated to range between 1.30 and 2.46 billion barrels in an area of 30 to 52 square miles, respectively. The Tar Sand Triangle deposit has several drawbacks that will make commercial bitumen recovery operations difficult and expensive, but not impossible. These include the relatively low grade of the resource and the apparent low oil saturations; the generally poor quality of the oil due to high sulfur content and high viscosity at reservoir temperatures; the difficult access by existing unimproved roads, all of which pass through the Glen Canyon NRA; potentially complicated and/or expensive process water access; the lack of petroleum service vendors and other support services in southeast Utah; and the proximity to environmentally-protected and visually stunning public lands.
Tar Sand Triangle Bitumen Deposit, Garfield and Wayne Counties, Utah

Steven Schamel
GeoX Consulting Inc.

Summary

The bitumen in the Tar Sand Triangle deposit is reservoired in a several-hundred-foot-thick eolian sandstone, the White Rim Sandstone (Lower Permian). Across an area of 84 square miles, the thickness of the bitumen-impregnated sandstone exceeds 100 ft. The strata are gently dipping and otherwise unstructured. Average porosity and permeability of the sandstone reservoir are in the range 15-20% and 200-500 md, respectively. The oil saturation is consistently low, averaging 30-35%. The bitumen has an API gravity less than 8º at the surface and just over 10º in core. It has a high asphaltene and sulfur content, and it is saturate-poor. Although very viscous at reservoir temperatures, the bitumen is a few orders of magnitude less viscous than the Uinta Basin heavy oils. This study estimates a total in-place bitumen resource between 4.25 to 5.15 billion barrels in a deposit less than 200 square miles in size. However, at a commercially viable resource minimal threshold equal and greater than 60 MBO/acre, the in-place bitumen resource is estimated to range between 1.30 and 2.46 billion barrels in an area of 30 to 52 square miles, respectively.

The Tar Sand Triangle deposit has several drawbacks that will make commercial bitumen recovery operations difficult and expensive, but not impossible. These include the relatively low grade of the resource and the apparent low oil saturations; the generally poor quality of the oil due to high sulfur content and high viscosity at reservoir temperatures; the difficult access by existing unimproved roads, all of which pass through the Glen Canyon NRA; the proximity to environmentally-protected and visually stunning public lands.

Geologic Setting of the Deposit

The bitumen in the White Rim Sandstone occupies a conventional stratigraphic trap in which the up-dip edge is truncated by the base-Triassic unconformity. Within this trap an inclined oil-water contact at elevations of 4200 to 4650 ft relative to mean sea level (msl) is recognized in wells. The oil-water contact (OWC) establishes the western and northwestern down-dip tapered edge of the deposit. The eastern up-dip edge is defined either by the basal Triassic unconformity cut-off or by the modern land surface in the canyon of the Colorado River. At the location of the deposit, stratification is nearly flat-lying, dipping to the northwest at just 120 ft per mile.

The combination of erosional beveling and stratigraphic position above the westward thinning tongue of the Organ Rock Shale has resulted in the thinning of the White Rim Sandstone towards the southeast and east. In the area of the Tar Sand Triangle deposit, the White Rim Sandstone is less than 350 ft thick. The source of the oil and the direction of charge are unknown.

The Tar Sand Triangle deposit is thought to be part of a much larger oil accumulation on the Colorado Plateau in the tectonic position of either the southwest rim of the Paradox Basin (Pennsylvanian) or the up dip edge of the Sevier foredeep basin (Cretaceous), or both. It may be a remnant of a 30-40 billion barrel oil (BBO) field in which the original oil evolved into a bitumen within the reservoir after emplacement by a combination of biodegradation, water washing and near-surface oxidation. The degradation of the oil probably occurred as the Colorado Plateau uplifted in the late Cenozoic and the oil pool was exhumed.

Figures after Dana and others (1984)

Author's address: GeoX Consulting Inc., 1265 Yale Avenue, Salt Lake City, UT 84105, Tel. 801 583-1146, geox-slc@comcast.net
Character of the Sandstone Reservoir and Bitumen

Twenty-eight wells provide control on the thickness of the White Rim Sandstone in the Tar Sand Triangle deposit and the thickness of the reservoir interval that is bitumen-impregnated (see map and table on the right). The average reservoir thickness is 236.8 ft (median = 232.5 ft), which is consistent with the regional isopach map in Dana and others (1984) showing the unit thinning southeastward toward the Colorado River. The elevation of the top of the White Rim Sandstone in the set of wells ranges from a high of 5464 ft in 315-16E-16 to a low of 4601 ft in 315-15E-8. Across the deposit, the average bitumen-impregnated interval constitutes only about half of total unit thickness, 124.9 ft (median = 124.5 ft). The range of thicknesses of the bitumen-impregnated interval encountered in the wells is 14 to 249 ft. The spatial distribution of bitumen-impregnated thicknesses defines a central core of the deposit with bitumen-impregnated interval thickness in excess of 150 ft passing outward in all directions to a bitumen zero-edge within the White Rim reservoir.

Petrophysical data for the White Rim Sandstone, as measured in cores, is displayed in cross-plots and logs below.

As might be expected of eolian sandstone, the porosity and permeability of the White Rim Sandstone, as measured in the cores below, are good for a conventional oil reservoir. Average porosity is in the range 15.3% to 20.2% and permeability is between about 100 and 500 md. In the cores, there is substantial vertical variability in porosity, which likely would be detrimental to the overall effectiveness of in situ oil recovery processes. For all cores, a good correlation exists between porosity and permeability. Note that the majority of core samples have porosity in excess of 15% and permeability greater than 100 md.

Average oil saturation, So, is in the range 24 to 36 vol%; the average water saturation, Sw, is somewhat lower between 4.0 and 26 vol%. The sum of So + Sw is less than the expected 100% indicating that the reservoir is deficient in fluids. Either (a) the reservoir is situated above the local water table, within the vadose zone, and air is also present in the pore space, or (b) the handling of the cores was such that fluid loss occurred before the cores were analyzed. It is most likely that the water drained from the core preferentially to the highly viscous, virtually immobile bitumen. This would mean that the values of So reported closely reflect the actual oil saturations in the reservoir — 50% or less. Successful in situ oil recovery processes, whether thermal, chemical or electrical, normally require oil saturations greater than 60%, preferably in the 70 to 90% range (Schamel, 2009).

The richness of bitumen in the reservoir or "oil grade" is calculated from the values of porosity and oil saturation. The oil grade (in units of barrels of oil per acre foot) is 7758 BO/ac; the volume in barrels of an acre foot, multiplied by the product of porosity times So, both expressed as decimal fractions. The logs below show the large vertical variability of bitumen richness in the White Rim Sandstone reservoir. The oil grade is considerably more variable than porosity, reflecting the important role of oil saturation (see figure above). In the five cores, the average oil grade varies from a low of 360.1 BO/ac ft to a high of 454.7 BO/ac ft. The actual oil grade in BO/ac ft times the net thickness of the reservoir is the product of porosity times So, both expressed as decimal fractions. The logs below show the vertical variability of oil grade (in units of barrels of oil per acre foot) is 7758 BO/ac ft.

Surface bitumen samples are much heavier and more degraded than the 11.1º API oil from core that was analyzed by Bunger and others (1979; see table). The Tar Sand Triangle bitumen is very close in composition and physical properties to the well-known Athabasca bitumen, but it differs substantially from the more saturate-rich heavy oil from Utah's northwest Asphalt Ridge. It has a relatively low (1.44) H/C ratio and high asphaltine (26.0%) and sulfur (4.38%) content, as well as a very high carbon residue. All of these factors will make upgrading the bitumen/heavy oil difficult and expensive. However, the oil does have a favorable nitrogen and metals content. Bitumens extracted from Sagadahoc-Skyline State 1 core has an API gravity of 8.5º and a total sulfur content of 5.47 wt%. Bitumens from this deposit are not well characterized.

The viscosity of the Tar Sand Triangle bitumen is the lowest of any heavy oils and bitumen in Utah, but it is slightly more viscous than the Athabasca oil. At a reservoir temperature of 100ºF, the viscosity of the oil is about 50,000 centipoise (cp). By conventional Andrade extrapolation, a viscosity of 100 cp would be reached in about 100 years. This heavy oil at 23°C (67°F) and 10 cp would be reached at 290ºF. These temperatures are within the range of thermal recovery processes, such as steam stimulation.
To date, the most rigorous estimate of the bitumen resource is a study conducted by the Laramie Energy Technology Center in the early 1980s (Dana and others, 1984). Using public domain and proprietary well data, the thickness of the bitumen-impregnated White Rim Sandstone reservoir was compiled for 28 wells penetrating the full resource interval. For eight of the wells there was adequate oil-grade data from core samples to calculate a bitumen resource value for the well. These values ranged from a high of 244.0 MBO/acre for Gordon Flats 27-1 (305-16E-27) to a low of 29.0 MBO/acre in Saga-Skyline State 1 (305-16E-16). Using the 28 bitumen-impregnated thickness values, a "resource-thickness" isolette map was constructed. The eight bitumen resource values then were used to sketch out four concentric zones having the general shape of the isopaths map.

The approach taken in this study expands on the database and methodology of Dana and others (1984) adding and revising the control wells and adopting a more rigorous analysis of the data. Three additional bitumen resource control wells were added to the original set of eight: Gordon Flat 16-1, Gordon Flat 19-1, and Hatch Canyon 34-16D.

The bitumen in the Tar Sand Triangle deposit is reservoired in a several-hundred-foot-thick eolian sandstone, the White Rim Sandstone. Across an area of 84 square miles, the thickness of the bitumen-impregnated sandstone exceeds 100 ft. The strata are gently dipping and otherwise unstructured. Average porosity and permeability of the sandstone reservoir are in the range of 15-20% and 200-500 md, respectively. The oil saturation is consistently low, averaging 30-35%. The bitumen has an API gravity less than 8° at the surface and just over 10° in core. It has a high asphaltene and sulfur content, and it is saturate-poor. Although very viscous at reservoir temperatures, the bitumen is a few orders of magnitude less viscous than the Uinta Basin heavy oils. This study estimates a total in-place bitumen resource between 4.7 to 5.6 BBO in a deposit exceeding 200 square miles in size.

A large area in which the bitumen-impregnated interval is in excess of 100 ft thick, an apparently homogeneous, relatively porous reservoir, and relatively low viscosity of the oil all would suggest that steam-based thermal recovery methods could be successful in the Tar Sand Triangle (Schamel, 2009). However, the close proximity to a national park and a national recreation area, as well as limited access to water resources, would favor a recovery process that has little water demand. One has a very small surface footprint, and generates minimal air pollutants. THAI™ (toe-to-heel air injection) in situ combustion might be applied very effectively in this deposit, particularly as the deposit has generally low oil saturation. Solvent extraction is an alternative technology, and electrical heating might prove effective on the intermediate benches where the deposit is relatively close to the surface.

The oil resource values are plotted against the resource-thickness for the 11 control wells in the table to the left. While most data points cluster, one well stands far apart from the others. Excluding this clear outlier, Gordon Flats 27-1, the linear regression for the remaining 10 wells has an average oil-grade equivalence of 460.3 BBO/acre, a value exceeding the upper range for all but a few of the control wells. The R2 for this regression is 0.74. By excluding two additional wells, Gordon Flats Fed Unit 1 and Utah 5-Govt 22-19, the linear regression for the remaining eight wells has an average oil-grade equivalence of 386.0 BBO/acre and an R2 of 0.92. The linear regressions serve as the basis for two alternative bitumen resource models. Model A, the more conservative, is based on eight wells and has a very good correlation. Model B, a plausible alternative, is based on 10 wells.

The total in-place bitumen resource estimate may attract the attention of speculators, but is in most respects a meaningless number for an operator. If the resource is too lean for commercial exploitation, it can never become booked reserves and future produced hydrocarbons. With no experience actually producing the Tar Sand Triangle bitumen, it is not presently prudent to speculate on the level of reservoir richness where commercially-viable production is possible. Consequently, the in-place bitumen resource is plotted for specific MBO/acre thresholds. For instance, at the 60 MBO/acre richness threshold, the in-place resource is 60 BBO, and at the 120 MBO/acre richness threshold, the in-place resource is 120 BBO. The areas having the bitumen resource exceed 100 BBO are clustered on the Gordon Flats, the southeast The Big Ridge, and in North Hatch Canyon, reducing the effective data density.

Prospects for Exploitation

The Tar Sand Triangle deposit has several drawbacks that will make commercial bitumen recovery operations difficult and expensive, but not impossible. These include:

1) the relatively low grade of the resource and the apparent low oil saturations.
2) the generally poor quality of the oil due to high sulfur content and high viscosity at reservoir temperatures.
3) the difficult access to the deposit by existing unimproved roads, all of which pass through the Glen Canyon National Recreation Area.
4) potentially complicated and/or expensive process water access.
5) the lack of petroleum service vendors and other support services in southeast Utah.
6) the proximity to environmentally-protected and visually stunning public lands.

Acknowledgements and References

This paper greatly expands on a chapter describing the Tar Sands Triangle bitumen deposit in the Utah Geological Survey Open-File Report 551, Strategies for in situ recovery of Utah’s heavy oil and bitumen resources (Schamel, 2009). That report was prepared, in part, with a UGS research contract managed by Craig Morgan. Wally Gwynn and Gene Van Dyke provided valuable assistance to earlier investigations of the Tar Sand Triangle bitumen deposit enabling the open-file report and this paper.

Dana, G. F., Oliver, R. L., and Elliott, J. R., 1984, Geology and resources of the Tar Sand Triangle, southeastern Utah: Laramie, WY, Western Research Institute, 30 p.
