Reservoirs of the Bakken Petroleum System: A Core-based Perspective

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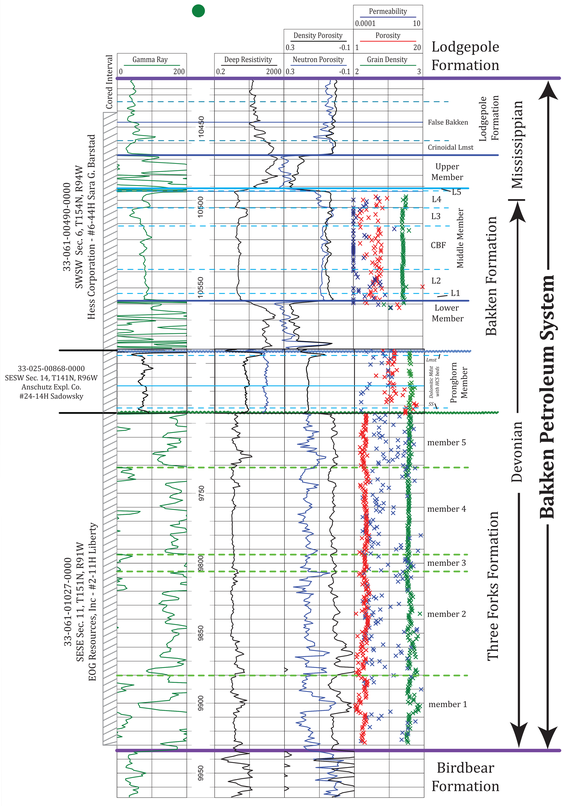
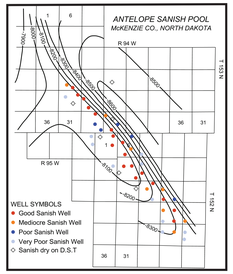
Sheet 1

Composite Log



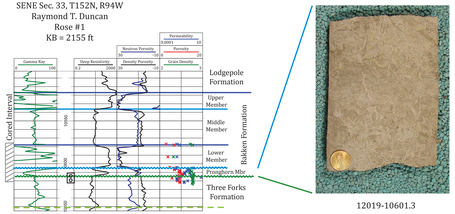
Composite Log – The Bakken Petroleum System was originally described as the lowermost Lodgepole (50 ft), the Bakken, and the top of the Three Forks formations (50 ft). Recent activity has added a new member (Pronghorn) to the Bakken as well as including the entire Three Forks Formation into the source system. In addition to excellent source potential each formation has its own set of unique reservoir rocks.

Antelope Structure - Bakken-Three Forks Formation



Structure map of Antelope Field with wells and their relative production (modified from Murray, 1968). The good wells are associated with the natural fracture network developed along the fault on the northeast flank.

33-053-02163-0000
SENE Sec. 33, T152N, R94W
Raymond T. Duncan
Rose #1
KB = 2155 ft

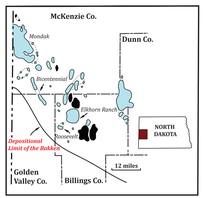


12019-10601.3

Reservoir rocks in Antelope Field are fracture controlled. These fractures opened due to tensile failure along the tightly flexed portion of the steeply-dipping northeastern limb of the anticline and supply an otherwise tight formation with enough oil to be economic. Original formation pressures were significantly above hydrostatic suggesting sourcing from the Bakken. Later attempts in the field to enhance production by additional perforations were generally unsuccessful.

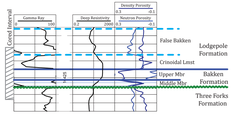
The field produces from the Pronghorn Member of the Bakken and the upper Three Forks section. The Pronghorn in this field reaches a maximum thickness of 24 ft. and consists of a highly burrowed (*Skolithus*), fine-grained sandstone (see photo). It is a transgressive lag deposit and unconformably overlies the apple-green claystones, and tan dolostones of the Three Forks Formation. It is not uncommon for the Pronghorn to be absent; then the uppermost Three Forks becomes the reservoir.

Upper Member - Bakken Shale



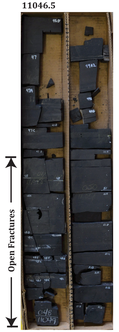
Index Map

33-007-01109-0000
NWSE Sec. 1, T143N, R102W
Meridian Oil, Inc.
MOI Elkhorn #33-11
KB = 2311 ft.



33-007-01185-0000
SWSW Sec. 5, T143N, R99W
Texaco, Inc.
#5-1 Texaco Thompson Unit

Upper Member
11046.5



11052.0

Core with natural vertical fractures stopped above and below by a slight lithologic change.

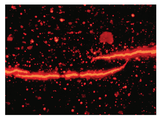
The Bakken Formation exhibits an onlapping relationship. The Three Forks Formation is overlain by stratigraphically higher members of the Bakken. This in turn is overlain by the carbonates of the Lodgepole Formation. The thin shale of the Upper Member overlying regional structures of the area makes it more susceptible to fracturing.

Where it is considered a reservoir, the Upper Member consists of finely laminated shales from a restricted marine setting that are organic-rich. Production is located along the depositional edge from the mature portion of the basin.

The upper shale is divided into 3 parts that have a corresponding gamma-ray log signature. The upper portion of the shale has the highest organic content, the middle portion has the lowest organic content (highest silt content), and the lower portion of the shale is between the upper two. Fracturing is more intense where the organic content is higher. Therefore, the reservoir resides in the upper portion of the shale that has a higher percentage of clay and organic material (Carlisle et al, 1992).

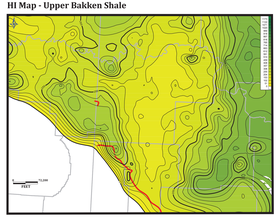
The reservoir is primarily fracture-based. Maturation of the organic-rich shale has resulted in over-pressuring and a system of micro-fractures that are related to generation and expulsion. This network of micro-fractures provides the reservoir with storage and, in conjunction with regional fractures, delivers oil to the wellbore .

Horizontal drilling of the Upper Member (shale) of the Bakken has been actively pursued since 1987 when Meridian Oil drilled and completed the MOI Elkhorn #33-11H well in Billings County, ND. In this area, the members of the Bakken Formation onlap the underlying Three Forks Formation and ultimately pinch-out along a trend commonly referred to as the Bakken fairway. Horizontal drilling targeted areas where the Upper Member was approximately 10 ft thickness which enhanced its ability to fracture over structures.



"Cracked_tip" morphology of horizontal microfractures with widths of 10 to 20 microns. (Carlisle et. al., 1992).

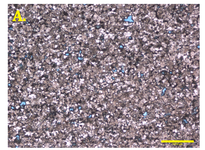
HI Map - Upper Bakken Shale



Maturation map of the Upper Member along the "Bakken Fairway". Lighter colors indicate an increase in maturation leading to an increase in fracturing. Red line indicates the depositional edge of the Upper Member.

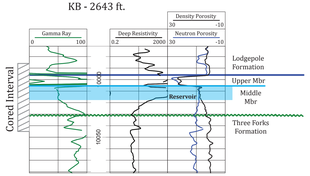
Elm Coulee - Bakken Formation

Balcron Oil - 44-24 Vaira (SESE Sec 24, T24N, R54E) – Depths 10,005.5 to 10019.5 ft. - Base of the Upper Member through the reservoir section (Log below; USGS Photograph).

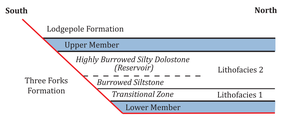


Balcron Oil – 44-24 Vaira (SESE Sec. 24, T24N, R54E) – Depth 10,011.0 ft. – Plane light photomicrographs of the reservoir consisting of a quartz dolostone with minor amounts of feldspars and clay. Intergranular porosity ranges from 10 – 13%. A. 4X; B. 10X.

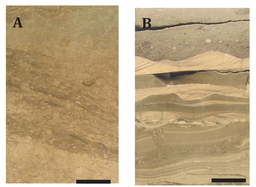
25-083-21775-0000
SESE Sec. 24, T24N, R54E
Balcron Oil Company
#44-24 Vaira
KB = 2643 ft.



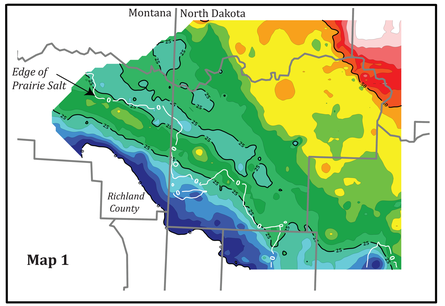
Wireline logs for the overlying core and thin-section photographs. Reservoir section for Elm Coulee is shown in blue.



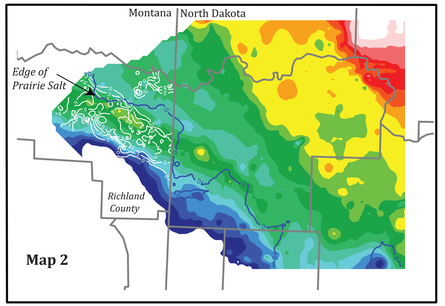
The onlap relationship of the Middle and Upper Bakken Formation in the Elm Coulee area is shown in this schematic diagram. The red line represents an unconformity.



Representative core samples of the highly burrowed silty dolostone that comprises the reservoir (A) and unconformity between the Middle Member and Three Forks Formation (B). American Hunter Exploration Ltd. - #1 H8 Nevins (SESW Sec. 13, T23N, R56W). Scale Bar = 1 inch.



Map 1 - The isopach of the Middle Member of the Bakken Formation shows a noticeable northwest-southeast trend in the Elm Coulee area of Richland County, Montana. This trend is approximately 2 to 3 townships wide and is by 72 miles long. It reaches a maximum thickness of 35 ft before decreasing in thickness towards the depositional limit. It gradually thickens towards the center of the basin. The white zero edge line represents the present edge of the Devonian Prairie salt. The section responsible for the increase in thickness is shown in blue on the log of the Balcron Oil Co. – #44-24H Vaira well.



Map 2 - The porosity along this trend is mapped in white and overlain on the isopach. Notice how the porosity lies immediately southwest of the zero edge of the salt.

Elm Coulee Field was discovered in 2000 with the drilling and completion of the Kelly/Prospector - #2-33 Albin FLB well in the Middle Member of the Bakken Formation. The Bakken Formation in this area consists of the Upper and Middle Members (facies L1 and L2), onlapping the underlying Three Forks Formation. In turn, they are overlain by the dense carbonates of the Lodgepole Formation forming a stratigraphic trap. Only the lowermost facies, L1 and L2 are present in the field. The maximum thickness of the Bakken Formation is 50 ft.

The field is developed along the northwest-southeast trending isopach thick. The reservoir consists of a dolomitized carbonate shoal complex. It has low matrix porosity, typically 3 to 9 %, and low permeabilities averaging .04 md. The field is slightly overpressured at .53 psi/ft.

Elm Coulee also depends on fracturing. Besides providing accommodation space, dissolution of the underlying Prairie salt probably provided a fracture network that allowed dolomitizing fluids to move through the carbonate shoal.