

Bakken Formation Reserve Estimates

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Executive Summary

Nature of the Controversy

All researchers agree that the Bakken Formation is a tremendous source rock. The controversy lies with how much oil has been generated, what other formations it may have sourced, and how much is ultimately recoverable. Early research on the Bakken started with a 1974 landmark paper by Wallace Dow, a UND Geology graduate, that addressed the oil generation capacity of the Bakken shale. Since that time, several additional papers have re-evaluated the Bakken, each bringing its own controversy over how much oil the Bakken is capable of generating and more importantly, how much of that oil can be economically produced.

The current controversy involves a paper by the late Dr. Leigh Price formerly of the United States Geological Survey in Denver, Colorado. He was an innovative thinker that challenged many of the traditional viewpoints of petroleum geochemistry. After an extensive oil sampling program by the North Dakota Geological Survey showed oil from the Bakken is compositionally distinct, further work, additional analyses, and many discussions with Dr. Price resulted in the controversial paper under review.

The methods used by Price to determine the amount of hydrocarbons generated by the Bakken and the idea that the oil has not migrated out of the Bakken are under dispute.

History of Bakken Oil Generation Estimates

A landmark paper by Dow and a companion paper by Williams (1974) recognized the Bakken as a tremendous source for the oil produced in the Williston Basin. These papers suggested that the Bakken was capable of generating 10 billion barrels of oil (BBbls). Webster (1982, 1984) as part of a Master's Thesis at the University of North Dakota further sampled and analyzed the Bakken and calculated hydrocarbon generation capacities to be about 92 BBbls. This data was updated by Schmoker and Hester (1983) who estimated that the Bakken was capable of generating 132 BBbls of oil in North Dakota and Montana. Price (unpublished) used a more complete database and estimated that the Bakken was capable of generating between 271 and 503 BBbls of oil with an average of 413 BBbls. New estimates of the amount of hydrocarbons generated by the Bakken were presented by Meissner and Banks (2000) and by Flannery and Kraus (2006). The first of these papers tested a newly developed computer model with existing Bakken data to estimate generated oil of 32 BBbls. The second paper used a more sophisticated computer program with extensive data input supplied by the ND Geological Survey and Oil and Gas Division. Early numbers generated from this information placed the value at 200 BBbls later revised to 300 BBbls when the paper was presented in 2006.

North Dakota Geological Survey Input

Dr. Price was impressed by the data available from the State of North Dakota and the extensive oil sampling program conducted by the North Dakota Geological Survey which determined oil from the Bakken is compositionally distinct from oil generated in the Mission Canyon Formation (Madison). The results of this study were published by Price and LeFever in 1994 and showed that the Bakken is "truly dysfunctional" with no evidence in the analysis that Bakken-generated

oil had migrated into the overlying Madison beds, as previously thought. Therefore, the oil generated by the Bakken remains within the Bakken. Considerable input was given to the Price paper by North Dakota Geological Survey geologists concerning the overall geology of the Williston Basin and specifically the Bakken Formation. Price used samples collected for analysis from the ND Geological Survey Core and Sample Library and the well files from the Oil and Gas Division extensively.

North Dakota Geological Survey Evaluation

The geochemistry methods used by Dr. Price are beyond the expertise of the Geological Survey to review; however his methods appear to be supported by the data and are adequately explained. The geological model as presented by Price in his paper appears solid. Use of North Dakota Geological Survey and Oil and Gas Division data along with considerable input from staff geologists adds to the credibility of the geological portion of the model.

Conclusions and Recommendations

The Bakken Formation is a large unconventional resource that underlies most of the western portion of the state of North Dakota.

Shales that comprise the upper and lower members of the Bakken are world class source rocks.

An extensive oil sampling program by the North Dakota Geological Survey shows that the Bakken generated oil remains in the Bakken.

The geological model presented by Price in his paper appears solid and is built upon considerable input by North Dakota Geological Survey geologists, samples from the ND Core and Sample Library, and the well files from the Oil and Gas Division.

A sophisticated computer program with extensive data input supplied by the ND Geological Survey and Oil and Gas Division places the Bakken generated value at 200 – 300 BBbls.

How much of the generated oil is recoverable remains to be determined. Estimates of 50%, 18%, and 3 to 10% have been published.

The Bakken play on the North Dakota side of the basin is still early in the learning curve. Technology and the price of oil will dictate what is potentially recoverable from this formation.

The unpublished manuscript by Dr. Leigh Price entitled “Origins and characteristics of the basin-centered continuous-reservoir unconventional oil-resource base of the Bakken Source System, Williston Basin” contains valuable information and should be published with a disclaimer or perhaps a discussion. The data in the paper is valuable and potentially of great benefit to the state. It should be left to the geological community to determine whether or not they will accept interpretations presented within the report.

Discussion

The Bakken Formation is a large unconventional resource that underlies the western portion of the state of North Dakota. It has been an exploration target several times since oil was discovered in the state. Recent drilling success in the Bakken Formation of

Montana (Wall Street Journal, April 5, 2006) has once again focused interest on this resource. Since the start of the play in Montana in 2001, activity has also increased on the North Dakota side of the Williston Basin where the majority of the formation exists. This activity translates into record lease sales of mineral rights and increased drilling. Information becomes a valuable component of this activity. Drilling results with the increase in oil prices have attracted new companies into the Williston Basin. Existing and new companies commonly have staff with limited or no knowledge of the play. These companies rely on information from the current literature and the state government to quickly answer their questions. The availability of that data is important, part of which is the focus of this paper.

In addition to being an exploration target, the Bakken Formation has also been a focus of research since the early days of exploration. The Williston Basin is the ultimate geologic laboratory, especially the North Dakota portion of the basin. Since the discovery of oil in the state occurred late compared to other states, key legislation was already in place. The state is foremost in data acquisition and storage. The availability of well information, cores and samples makes the state an ideal laboratory. Early research on the Bakken started when a landmark paper was written by Wallace Dow, a graduate from the Geology Department of the University of North Dakota, in 1974 that addressed the oil generation capacity of the Bakken shale. Since that time, several additional papers have added to and further refined the information and re-evaluated the Bakken. Each additional paper brings its own controversy into the discussion of how much oil the Bakken is capable of generating and, more importantly, how much of that generated oil can be economically produced. The following discussion is an in-house review of one of these papers.

As previously stated, the Bakken has been and continues to be a focus of research. The shales that comprise the upper and lower members of the Bakken are world class source rocks. Additionally information that is learned in this basin may be applied to other similar rocks in North America. The fact that the Williston Basin is located in the middle of a continent and is relatively undisturbed structurally makes it more attractive for study. It is a simple, more geologically controlled environment for applied research. All researchers agree that the Bakken Formation is a tremendous source rock. The controversy lies with how much oil has been generated, what it has sourced, and how much is ultimately recoverable. The landmark paper by Dow and a companion paper by Williams (1974) recognized the Bakken as a tremendous source for the oil produced in the Williston. Based on the limited dataset of the time, these papers suggested that the Bakken was capable of generating 10 billion barrels of oil (BBbls). They also suggested that the only 3 BBbls would be recoverable in existing pools. The remainder would be found in some undiscovered pools with a large portion left in the Bakken unable to escape. Webster (1982, 1984) as part of a Master's Thesis at the University of North Dakota further sampled and analyzed the Bakken and calculated hydrocarbon generation capacities to be about 92 BBbls. Once again this data was updated by Schmoker and Hester (1983) who estimated that the Bakken was capable of generating 132 BBbls of oil in North Dakota and Montana. It is easy to see that as new data become available the values shift significantly.

The current controversy involves a paper by Dr. Leigh Price formerly of the United States Geological Survey in Denver, Colorado. Price was a well respected organic geochemist whose primary research interest was the Bakken Formation. He was impressed by the data available from the State of North Dakota citing it in many of his publications, for instance in the current publication under review, he states: “The North Dakota portion of the Williston Basin, which has the larger of the two Bakken HC kitchens in the basin, has the best rock and oil sample base and well-history file for any basin, worldwide.” He was an innovative thinker that challenged many of the traditional viewpoints of petroleum geochemistry. An early paper by Price and others (1984) once again looked at the oil resources of the Bakken in the U.S. side of the Williston Basin. They concluded that this was a significant resource and followed the traditional line of thought that most of the generated oil had been expelled from the formation. Price changed his opinion about the conclusion to this paper. He felt that the data was solid but that they had made some erroneous assumptions in the interpretation of that data. This change occurred when an extensive oil sampling program was done by the North Dakota Geological Survey. Oil from the Bakken is compositionally distinct from oil generated in the Mission Canyon Formation (Madison). The intent of this study was to determine whether oil had migrated from the Bakken into the overlying and very productive Madison beds. The results of this study were published by Price and LeFever in 1994 and showed that the Bakken was “truly dysfunctional”. There was no evidence in the analyses of the oil that Bakken-generated oil had migrated into the overlying Madison beds, as previously thought. Therefore, the oil generated by the Bakken was still within the Bakken. Further work, additional analyses and many discussions later with the author, resulted in the paper under review.

The methods used by Price to determine the amount of hydrocarbons generated by the Bakken are different from the traditional petroleum geochemical practices and are under dispute. Previous estimates were determined directly from available data and did not take into account the changes that had already occurred within the rock. These estimates are calculated from the area (measured) times the thickness (measured) times the total organic content (TOC, measured by RockEval pyrolysis in the laboratory) times the percent of organic carbon that has been converted (measured by RockEval). Price used a more complete database and re-calculated the data based on what he considered more realistic input parameters. The reasons for these adjustments are beyond the scope of this review; however his methods appear to be supported by the data and adequately explained. He estimated that the Bakken was capable of generating between 271 and 503 BBbls of oil with an average of 413 BBbls. Price also re-calculated the data previously presented by Schmoker and Hester (1983) and Webster (1984); the re-calculated values also fall within the range stated above. These values combined with the idea that the oil has not migrated from the Bakken is what is under dispute. Price also states that 50% of this oil is recoverable (on average, 200 billion barrels of oil).

The model as presented by Price in this paper appears solid. Considerable input was given to this paper by North Dakota Geological Survey geologists concerning the geology of the overall geology of the Williston Basin and specifically the Bakken

Formation. In addition to samples collected for analysis from the ND Geological Survey Core and Sample Library, Price used the well files from the Oil and Gas Division extensively. This data and the considerable input from staff geologists adds to the credibility of the geological portion of the model.

New estimates of the amount of hydrocarbons generated by the Bakken were presented by Meissner and Banks (2000) and by Flannery and Kraus (2006). The first of these papers tested a newly developed computer model with existing Bakken data. Data used was not as extensive as some of the other studies mentioned in this discussion therefore estimates of generated oil presented were 32 BBbls. The second paper by Flannery and Kraus used a more sophisticated computer program with extensive data input supplied by the ND Geological Survey and Oil and Gas Division. Early numbers generated from this information placed the value at 200 BBbls (pers. comm. Jack Flannery, 2005). Estimates had been revised to 300 BBbls when the paper was presented in 2006. Even if the lower value of 32 BBbls is correct, the amount that may be potentially recovered from the Bakken is significant.

How much of the oil that has been generated is technically recoverable is still to be determined. Price places the value as high as 50% recoverable reserves. A primary recovery factor of 18% was recently presented by Headington Oil Company for their Richland County, Montana wells. Values presented in ND Industrial Commission Oil and Gas Hearings have ranged from 3 to 10%. The Bakken play in the North Dakota side of the basin is still in the learning curve. North Dakota wells are still undergoing adjustments and modifications to the drilling and completion practices used for this formation. It is apparent that technology and the price of oil will dictate what is potentially recoverable from this formation.

The paper under discussion is an unpublished manuscript by Dr. Leigh Price entitled "Origins and characteristics of the basin-centered continuous-reservoir unconventional oil-resource base of the Bakken Source System, Williston Basin." The manuscript had been sent out for peer review prior to his death as U.S.G.S. protocol states. It was my understanding that many of the reviews had been returned with comments and a "publish" statement. It is unknown whether or not those corrections or comments were addressed by Dr. Price. There has been an outside request for the U.S.G.S. to publish this manuscript. They have responded that it has not completed the peer review process and therefore should not be published. The information is valuable and should be published with a disclaimer or perhaps a discussion. The data is valuable and of great benefit to the state. It should also be left to the geological community to determine whether or not they would accept interpretations presented within the report.

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