Introduction

Gas development started along the east flank of the Williston Basin (primarily Renville and Bottineau Counties) in 1908 when the North Dakota Gas Company began drilling wells near the town of Westhope (Harrison, 1978, oral communication). Oil production began in this area in 1952 when a random wildcat well (#1 Edwin Berentson, SWSE Sec. 21, T163N, R79W) drilled by the Zach Brooks Drilling Company discovered the Westhope Field. The discovery of the Westhope Field resulted in further exploration, development, and ultimately significant production along the eastern flank of the Williston Basin (fig. 1). Currently production is restricted to various intervals within the Madison Group (Mississippian) and overlying Spearfish Formation (Triassic).

This paper will examine the future oil and gas potential of the Birdbear Formation (Devonian) in north-central North Dakota and its relationship to recent exploration and production from the southwest portion of North Dakota along the Bicentennial, Beaver Creek, and Roosevelt trend.

Birdbear Formation

The Birdbear Formation lies on top of the Duperow Formation and beneath the Three Forks Formation in the central part of the Williston Basin or beneath the Lodgepole Formation along the margins of the basin where the Three Forks is not present (For additional details see the stratigraphic column on page 28). Oil and gas has been produced from the Birdbear Formation in Saskatchewan and Montana since the early 1960s (Ehrets and Kissling, 1985; Martiniuk et al., 1995) and in North Dakota since 1978.

The Birdbear Formation was deposited about 350 million years ago during the Devonian Period when North Dakota was situated just south of the equator on the slowly moving northward North American tectonic plate. The Williston Basin of North Dakota was part of an embayment that extended through Saskatchewan and Alberta to the open sea beyond. This embayment was repeatedly flooded by fluctuating sea levels, the maximum extent of which decreased throughout Birdbear time. This gradual decline in maximum sea levels resulted in the lower portion of the Birdbear Formation being dominated by deposits of shallow marine limestone and dolostones whereas the upper portion of the Birdbear is dominated by onshore deposits containing anhydrite. The presence of the evaporite mineral anhydrite and dolomitized limestone in the onshore deposits suggest that during this time North Dakota periodically experienced arid conditions similar to the modern sabkha environment of the Persian Gulf. This depositional history led to the development of porous and permeable dolostones encased in impermeable anhydrite and fine-grained carbonates. Tilting of these reservoirs by basement-related faults and multi-stage salt solution collapse structures allow for the formation of traps where the reservoir dolostones are draped over or pinchout along the flanks of structural highs. Oil in the Birdbear Formation is also trapped in extensively dolomitized stromatoporoid banks (stromatoporoids are an extinct carbonate secreting organism similar in some respects to modern sponges) and biostromes (“reefs”) that lie immediately below a layer of interbedded anhydrite and tidal flat carbonates (fig. 2).

Table 1. Summary tables of basic Birdbear Field information presented to the North Dakota Industrial Commission.

<table>
<thead>
<tr>
<th>Producing Interval</th>
<th>Producing Fields</th>
<th>Average TVD</th>
<th>Vertical Thickness (Ave., Ft)</th>
<th>Porosity (%)</th>
<th>K (md)</th>
<th>Water Saturation (%)</th>
<th>Oil Saturation (API)</th>
<th>BHT (°F)</th>
<th>Initial BHP (psia)</th>
<th>MIP Value Factor</th>
<th>GOR</th>
<th>GAS Gravity</th>
<th>Reservoir Drive</th>
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</thead>
<tbody>
<tr>
<td>“A” Zone Only</td>
<td>18</td>
<td>10475</td>
<td>4</td>
<td>13.9</td>
<td>4.730</td>
<td>27</td>
<td>38.4-44</td>
<td>228</td>
<td>4000</td>
<td>5255</td>
<td>1.4</td>
<td>877</td>
<td>0.856</td>
</tr>
<tr>
<td>“A” &amp; “B” Zones</td>
<td>8</td>
<td>10954</td>
<td>9.4</td>
<td>13.8</td>
<td>8.6</td>
<td>43</td>
<td>42.3-45</td>
<td>243</td>
<td>3151</td>
<td>5312</td>
<td>1.55</td>
<td>843</td>
<td>Solution Gas</td>
</tr>
<tr>
<td>“B” Zone Only</td>
<td>9</td>
<td>10805</td>
<td>12</td>
<td>12.8</td>
<td>4.8</td>
<td>44</td>
<td>39.4-43.6</td>
<td>244</td>
<td>4960</td>
<td>5240</td>
<td>1.51</td>
<td>709</td>
<td>Water Drive/Solution Gas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Producing Interval</th>
<th>Producing Fields</th>
<th>OIP (MBO)</th>
<th>Primary Recovery</th>
<th>EUR (MBO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“A” Zone Only</td>
<td>17</td>
<td>844</td>
<td>17.7</td>
<td>221</td>
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<tr>
<td>“A” &amp; “B” Zones</td>
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<td>879</td>
<td>22</td>
<td>286</td>
</tr>
<tr>
<td>“B” Zone Only</td>
<td>9</td>
<td>590</td>
<td>20</td>
<td>137</td>
</tr>
</tbody>
</table>

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Bicentennial-Beaver Creek-Roosevelt Trend
Production from the Birdbear Formation occurs along a trend that extends through Billings, McKenzie, and Golden Valley counties (fig. 1). Along this trend, Birdbear production from vertical wells is obtained from a dolostone reservoir known as the “B” horizon. The “B” horizon is from 8 to 20 feet in thickness and contains an average of 16% porosity with between 4 to 10 millidarcies permeability. Producible traps are formed where the “B” horizon overlies structural highs and is capped by impermeable anhydrites of the overlying “A” zone (Table 1) (Sperr and Burke, 2005; McClellan, 2006).

Additional production is sometimes possible where porous dolostones pinchout within the anhydrites of the overlying “A” zone. “A” zone dolostones are 2 to 4 feet thick with pay zone porosities that average 14% with permeabilities in the 4 to 30 millidarcy range (Table 1). A detailed analysis of this area is presented by Burke and Sperr (2005). Economic production from vertical tests of the Birdbear Formation is typically restricted to depths of less than 10,800 feet. However, economic quantities of oil can be produced from tests deeper than this when a 4,500 foot long horizontal leg is added to an existing vertical well. The potential of good production from the “A” zone, the stratigraphic nature of the trapping mechanism, and the possibility of multiple pay horizons suggests that significant Birdbear reserves may be found elsewhere in Williston Basin.

North-Central North Dakota
The rocks of the Birdbear Formation in the north-central portion of the Williston Basin are similar to those that produce along
the Bicentennial–Beaver Creek–Roosevelt trend. A cross section through these two areas demonstrates that the units are easily traceable across the basin (fig. 3). The north-central area was chosen for study on the basis of well control and the availability of cores. Thirteen cores provide insight into the distribution of the various depositional environments that formed the rocks (lithofacies) that represent the geologic history of this formation. The lowermost portion of the Birdbear Formation is a platform facies that immediately overlies the Duperow Formation. It consists of 30 to 43 feet of burrow mottiled to nodular lime mudstone to wackestone containing gastropods, brachiopods, and may be burrowed or nodular bedded. Reaching a maximum of 27 feet, these rocks have porosities ranging from 8 to 19.5 % with permeabilities as high as 3.3 millidarcies.

The basal portion of the biohermal or bank facies in north-central North Dakota is a light brown, to medium brown-grey dolomitic limestone containing fossil fragments (bioclastic) that are either surrounded by or are “floating” in mud-sized carbonate sediment (packstone to wackestone). Fossils including *Thamnopora*, *Amphipora*, laminar and hemispherical stromatoporoids, rugose corals, brachiopods and crinoids are abundant. The porosity is vuggy, solution enhanced or moldic where skeletal material is present (fig. 4).

The main bioherm consists of a lime wackestone and boundstone that is comprised predominantly of laminar, bulbous, and digitate stromatoporoids. Other fossils include rugose corals, *Thamnopora*, *Amphipora*, and colonial corals (*Syringopora*). Porosities range from 6 to 19% with permeabilities up to 237 millidarcies. Intergranular, moldic, intraparticle, pinpoint and vuggy are the common types of porosity and may or may not be solution enhanced. This is overlain by a lime wackestone to

Figure 2. Wireline log from a producing well in southwestern North Dakota with a representative section of the Birdbear Formation. The conventional producing horizon is informal unit “B” and where productive, consists of stromatoporoid and biohermal banks indicated in green. Informal unit “A” is the focus of this paper and consists of an interbedded sequence of anhydrites and dolostones and its producing horizon indicated in blue (modified from Burke and Sperr, 2006).

Figure 3. Cross-section from Roosevelt Field, Billings County, to Bottineau County. Potential productive zones (blue and green) that are present in the southwest portion of the state are correlate across the basin. The type section for the Birdbear Formation is represented by the Mobil Producing Co. – Pegasus Div Solomon Bird Bear #F-22-22-1 (Sandberg and Hammond, 1958). The cored section for that well is indicated by the hatchures to the left of the Gamma Ray log. The lower dashed line refers to the top of a platform facies that provides for the development of the potentially productive overlying biohermal or bank facies (Martiniuk et al., 1995).
grainstone. Localized mudstones are also present in the area. Fossils include Amphipora, Thamnopora, rugose and Syringopora corals, ostracods, and brachiopods. This portion shows similar types of porosity to the lower section but with lower porosity and permeabilities probably due to limited dolomitization. The interval is commonly heavily oil stained (Martiniuk et al., 1995).

The equivalent to the “A” zone in this area is characterized by an interbedded sequence of massive, chickenwire, or nodular mosaic anhydrite with thin shale partings. Interbedded within the anhydrite sequence are massive dolostones, very fine-grained (microsucrosic) dolostones, algal laminated dolostones, and mottled lime mudstones. The carbonate sequence is oil stained and commonly contains intergranular, intercrystalline and solution enhanced vuggy porosity.

**Exploration and Development Potential**

Significant potential exists for production from the Birdbear Formation on the east flank of the Williston Basin. This portion of the basin is well known for its salt tectonics. Newburg and South Westhope fields are located on the updip side of a prominent syncline resulting from the dissolution and collapse related to the Prairie salt (Anderson and Hunt, 1964; LeFever and LeFever, 1991). The activity in this area has produced the necessary structure to develop the correct facies relationships for production from the “B” zone. This may be tied further to the trapping mechanism related to two stage salt dissolution and collapse as seen in producing areas in northeastern Montana and southern Saskatchewan.

Cores also suggest that fluids have enhanced porosity and permeability. This may provide a diagenetic-stratigraphic trap where enhanced reservoir beds are trapped updip by tighter facies. Also, there is additional potential in horizontally drilling the thin dolostone beds of the “A” interval as exhibited by the well along the southwest portion of the basin.

**References Cited**

New Web Subscription Service Option

The Oil and Gas Division of the Department of Mineral Resources announces a new web subscription option that is designed to better meet the needs of mineral interest owners. The original subscription service is now listed as “Premium Services” and the new option is called “Basic Services”.

The basic services will give subscribers access to monthly production and sales volumes for all wells and units on a monthly basis, which will assist mineral owners in verifying the accuracy of their monthly royalty statements. A summary of basic well information can be found on the scout ticket page which will also contain a link to the complete scanned well file in Adobe PDF format. The well file contains the permit application form, completion reports, geological reports, details of work-overs, and copies of letters and other correspondence to and from the operators of each well.

The premium service is tailored more to the oil and gas industry professional. It contains everything included in the basic service plus digital and image well logs, production decline curves, core and thin-section photographs, state-wide well production for each month, a stripper well determination tool, and unitization statistics about all units that have been formed in North Dakota. Field orders can be accessed through the main index or by full text search. The associated scanned case files and hearing audio are also available for download. There is also a GIS mapping tool for researching gas analysis data through a cooperative effort between the PCOR Partnership and the ND Department of Mineral Resources and is hosted on the UND EERC web site.

The cost of the “Basic Service” is $50 per year and the cost of the “Premium Service” is $175 per year. For more information on subscribing to these services, go to https://www.dmr.nd.gov/oilgas/agreement.pdf and follow the instructions on the website user agreement.


