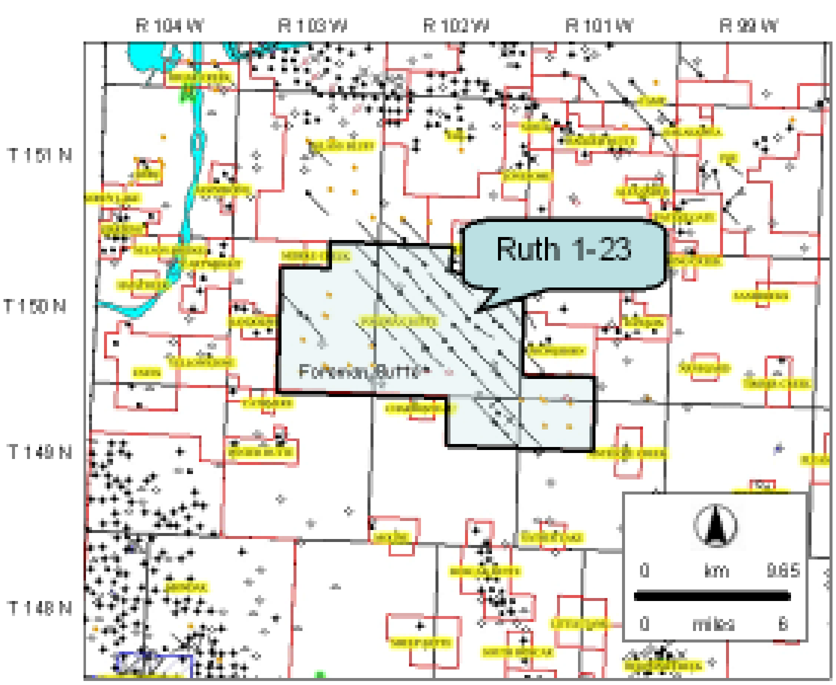
Some notes on the recent production from the Ratcliffe interval of the Madison Group in McKenzie County, North Dakota

By Stephan H. Nordeng

The recent development of the Foreman Butte field in western North Dakota demonstrates that there is considerable potential for horizontal drilling methods to extract new production from low porosity and low permeability carbonate reservoirs within the Madison group. Between its discovery in late 2004 and the end of March 2007, the Foreman Butte field in McKenzie County (T150N-R102W and R103W) has produced more than 2 million bbls (barrels) of oil and 1,400 MMCF (million cubic feet) gas from some 38 wells drilled to a vertical depth of approximately 9300 feet. Production is obtained from horizontal laterals that tap an oolitic/pisolitic shoal island complex within the Alexander and Flat Lake subintervals of the Ratcliffe. This reservoir typically has porosities in the range of five to ten percent with total reservoir thicknesses that are less than 20 feet. In spite of low porosity, initial production from these wells has been as high as 680 bbls oil per day.

Foreman Butte was discovered when the Ruth 1-23 (NW NW, Sec. 23, T150N-R102W) (fig. 1) was drilled and completed by Zinke and Trumbo, Inc. in late 2003. This well was, according to documents on file with the North Dakota Oil and Gas Division, designed to test a seismically defined structural high that lay up dip some 2½ miles to the east of established Madison Group production in the Pronghorn field. The vertical pilot well penetrated three anticipated reservoirs within the Charles and upper Mission Canyon Formations. Wireline logs and wellsite observations indicated that only the Ratcliffe interval contained enough promise to warrant further tests. A drill stem test (DST) was conducted over a 12-foot-thick portion of the Ratcliffe, that on logs, contained between five to seven percent porosity. Cuttings samples through this same interval confirmed the presence of small quantities of interparticle and intercrystalline porosity that contained visible traces of oil. The DST recovered more than 1200 feet of gas and almost 500 feet of gas cut mud. The DST sample chamber, however, was filled almost to capacity with drilling mud with only a trace of oil and a very small amount of gas. On the positive side, the Ratcliffe porosity zones in the Ruth 1-23 are 10 to 15 feet above the same zones in the Pronghorn field that produce oil.

Zinke and Trumbo, Inc. drilled a horizontal lateral close to a mile into the Ratcliffe. The well was put into production after a simple "open hole" completion for 400 bbls of oil/day, 225 MCF of gas/day and 372 bbls of water/day. Cumulative production from this well, as of February 2007, stands at 89,707 bbls oil, 55 MMCF gas and 190,464 bbls of water. During the last four years over 40 wells have been drilled in this field. Total field production through February of 2007 has reached 1.96 million bbls of oil and 1,300 MMCF gas. Virtually none of this production would have occurred without the application of horizontal drilling.



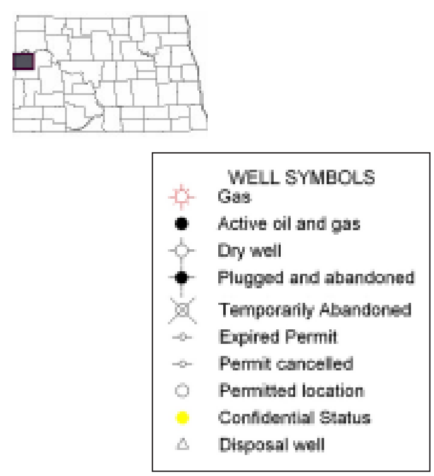


Figure 1. Map showing the distribution and location of the oil and gas wells in the vicinity of the Foreman Butte Field. Note that the horizontal laterals that produce from the Ratcliffe interval are plotted as northwest-southeast trending lines.

The productive zones in Foreman Butte consist of the Alexander and Flat Lake subintervals of the Ratcliffe (fig. 2). Both of these subintervals appear to be the product of nearshore sedimentation that resulted in deposition of limestones in an environment that may be similar to the modern Trucial Coast on the Arabian Peninsula. Reservoir rocks in Foreman Butte contain oolites, pisolites and other sedimentary structures that suggest deposition as shoals or bars in a near shore environment dominated by wave and tidal currents. Subsequent cementation of these rocks drastically reduced the original porosity to the point that most vertical wells that penetrate these rocks are incapable of producing oil at economic rates. However, wells that penetrate the same reservoir horizontally expose a much larger amount of the reservoir to the well bore that drains the rock and in doing so transforms a vertical "dry hole" into a productive oil and gas well.

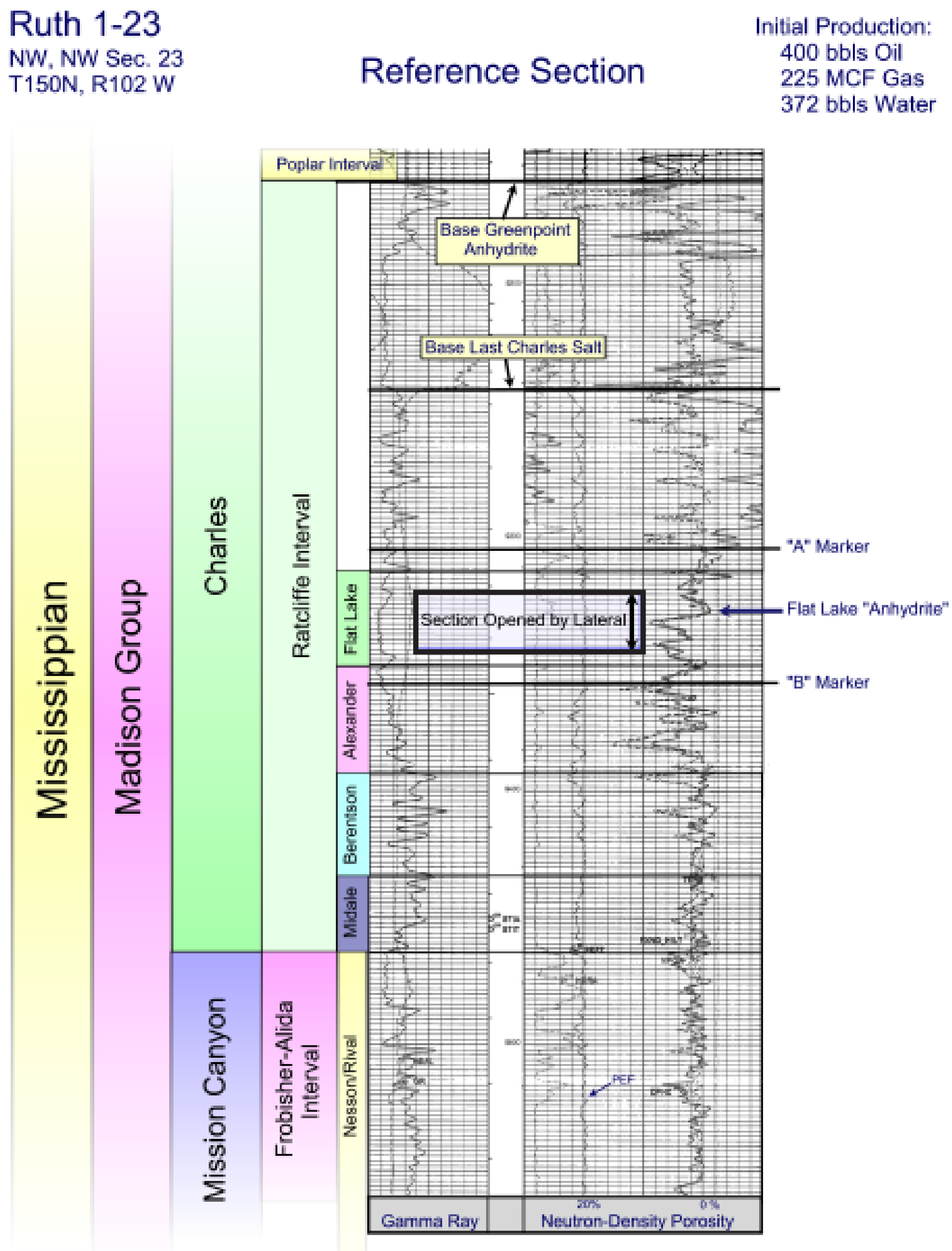


Figure 2. A reference section for the Foreman Butte Field using the neutron-density log obtained from the Ruth 1-23 well. The approximate stratigraphic position that was drilled by the horizontal leg of this well is detailed by the box placed within the Flat Lake subinterval. The accompanying structure contour maps are made with the mean sea level elevation of the "A" marker which is placed at the base of a widespread anhydrite that is found beneath the "Last Charles Salt".

The "Flat Lake Anhydrite", as defined here, includes those rocks that have negative density porosities and those that lie between the base of the anhydrite that marks the top of the Flat Lake subinterval and the top of the "dolomite" that is used as the "B" marker.

Even though the porosities are low and the productive interval is thin, the distribution of lateral porosity is extensive within the shoal facies. Cross-sections (fig. 3) illustrate that the porous zones within the shoal complexes grade rapidly into anhydritic carbonates and anhydrites. In several instances, anhydrite signatures on porosity logs mark the edge of production or a significant decrease in production. Apparently, this happens when porous peritidal shoal facies change into nonproductive sabkha facies dominated by impermeable anhydrites, anhydritic limestone or dolostone.

The regional distribution of "anhydrite" within the Flat Lake subinterval (figs. 4 & 5) may be interpreted to represent a set of facies developed along a north-south trending shoreline that were deposited during a brief sea-level high stand. This shoreline formed as sea-levels reached a point of maximum depth before dropping. The result was the formation of a set of islands, shoals or bars that mark the highest level that the seas reached. Subsequent drops in sea-level filled topographic lows formed by tidal or intershoal channels with anhydrite as the sabkha facies prograded seaward to the west.

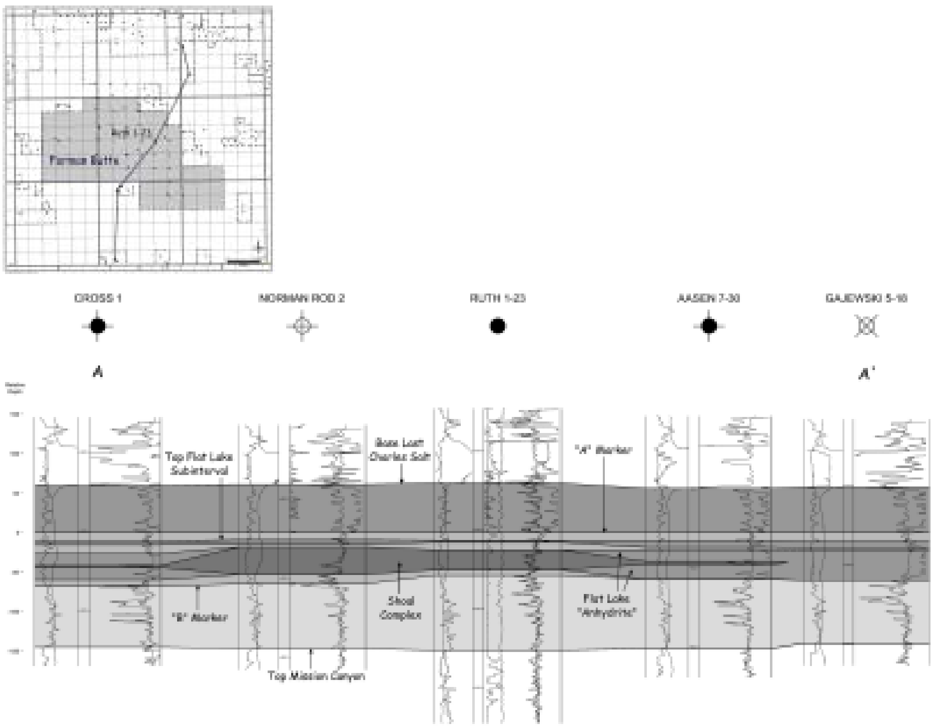


Figure 3. A stratigraphic cross-section through the Foreman Butte Field from south (A) to north (A') that passes through the Ruth 1-23 discovery well. This section is "flattened" on the "A" marker and illustrates the facies transition from near shore limestone shoals and bars to onshore or restricted lagoonal deposits of anhydrite. The presence of anhydrite within the Flat Lake interval reduces the pore space that may otherwise contain oil or gas. Therefore, maps of the amount of anhydrite within the Flat Lake subinterval should be useful differentiating between potentially productive and nonproductive properties.

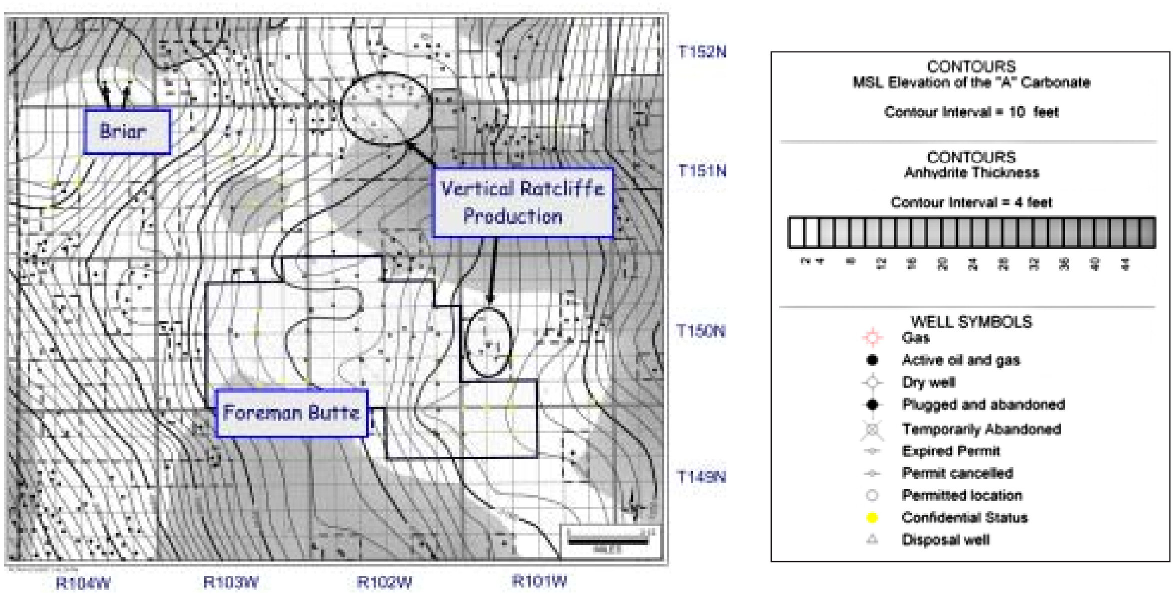
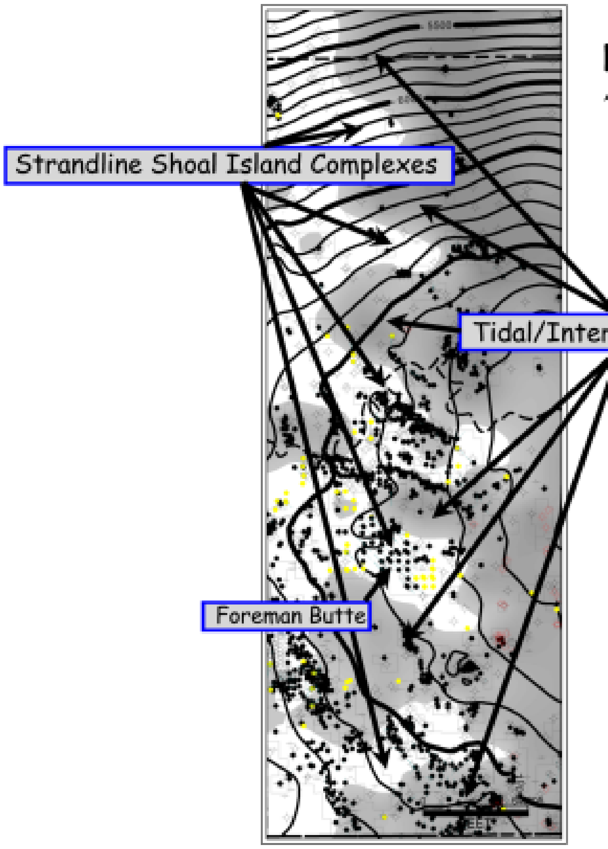


Figure 4. The structure on the "A" marker is portrayed on this map as solid contour lines and is overlain by a set of shaded areas that illustrate the thickness of "anhydrite" between the base of the anhydrite that marks the top of the Flat Lake subinterval and the "B" marker. Most, if not all, of the production from the Ratcliffe interval in the region mapped is located in areas with little or no anhydrite. It is also interesting to note that production from the Ratcliffe is not limited to any particular structure. It is possible that virtually all of the anhydrite free land updip to the west of the Foreman Butte field is potentially productive.



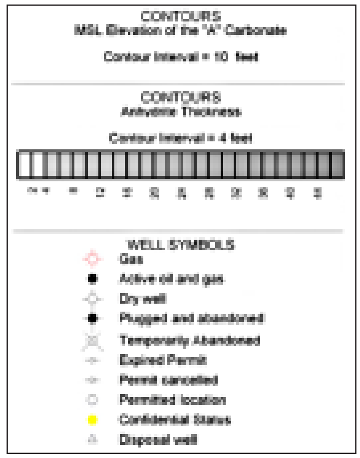


Figure 5. The regional distribution of “anhydrite” within the Flat Lake subinterval may be interpreted to represent a set of facies developed along a north-south trending shore line that were deposited during a brief sea-level high stand. This shoreline formed as sea-levels reached a point of maximum depth before dropping. This resulted in the formation of a set of islands, shoals or bars that mark the highest level that the seas reached. Subsequent drops in sea-level allowed for previously formed tidal or intershoal channels to fill with anhydrite as the sabkha facies prograded seaward to the west.

The geographic distribution of anhydrite within the Alexander/Flat Lake subintervals suggest that coalesced shoal island complexes form an anhydrite “free” limestone corridor. This corridor is locally more than 6 miles across and extends north-south along depositional strike for more than 60 miles. The carbonates of the Alexander/Flat Lake subintervals pinch out into thick massive anhydrite to the east and presumably landward of the shoal complex. West of the shoal complex, thinner anhydrites are locally present possibly reflecting inter-island playa deposits formed during minor drops in sea-level. These “playa” anhydrites lie updip of the shoal complexes and may therefore play important roles in the formation of individual traps.

What is a horizontal well?

Horizontal drilling is a developing technology that allows for the production of oil and gas from reservoirs that have been otherwise uneconomic. This technology has opened a new frontier for the North Dakota oil and gas industry.

The reason for this is based on how much of an oil bearing rock is opened up by a well bore. When reservoirs are thin or contain rock through which fluids flow very slowly, the amount of rock that is exposed to the well bore determines whether or not economic quantities of oil can be recovered. Horizontally drilled wells are capable of increasing the amount of the reservoir exposed to the well bore by factors that range into the thousands. This greatly enhances the productive capacity of many oil-bearing rocks.

The process of drilling a horizontal well involves a complex set of integrated technologies. Basically, a horizontal well is made by drilling a hole that slowly changes angle from near vertical at the surface to near horizontal within the oil- and gas-bearing target formation. This is done by slowly increasing or “building” the angle of the well bore with respect to the vertical use of a down-hole assembly that includes a bit that can be “steered” as well as instrumentation that measures the direction and dip of the hole that is being drilled. Steering the well bore into the horizontal requires flexing the steel drill pipe over the course of a thousand feet or more so that it slowly bends into the orientation that is needed to “land” the well bore within the target rock layer. Once the well is “landed” a horizontal well or “leg” is guided through the reservoir using samples of drilled rock and geophysical measurements as reference.