USING RECENT ADVANCES IN 2D SEISMIC TECHNOLOGY AND SURFACE GEOCHEMISTRY TO ECONOMICALLY REDEVELOP A SHALLOW SHELF CARBONATE RESERVOIR: VERNON FIELD, ISABELLA COUNTY, MI.

TYPE OF REPORT: QUARTERLY

REPORTING PERIOD START DATE: JULY 1, 2004

REPORTING PERIOD END DATE: SEPTEMBER 30, 2004

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DATE REPORT WAS ISSUED: OCTOBER, 2004

DOE AWARD NUMBER: DE-FC26-00BC15122

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ABSTRACT

One of the principal objectives of this demonstration project is to test surface geochemical techniques for detecting trace amounts of light hydrocarbons in pore gases as a means of reducing risk in hydrocarbon exploration and production. During this reporting period, microbial samples were collected from the Trusty Steed prospect area in Grand Traverse County, Michigan. The samples were analyzed using the MOST technique and revealed only a local (1-point) anomaly. A decision to resample over that point is pending, but drilling has been postponed for the time being.

The main news this reporting period is that in the Bear Lake area, northwest Michigan, Federated Oil & Gas Properties' Charlich-Fauble 2-9HD horizontal lateral, has cumulative production of more than 72,000 barrels of oil and is still producing 50 to 75 bopd from a Silurian Niagaran reef reservoir eighteen months after the well was completed. Surface geochemical surveys conducted in the demonstration area were consistent with production results although the ultimate decision to drill was based on interpretation of conventional subsurface and 2D seismic data. The surface geochemical techniques employed were Solid Phase MicroExtraction (SPME) and Microbial Oil Surveying Technique (MOST). The geochemical results have been submitted to World Oil for publication.

New geochemical surveys are planned for November in the Springdale quadrangle in Manistee County, Michigan. These surveys will concentrate on sampling over the trace of the proposed horizontal wells rather than a broad grid survey.

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Figure 2. Generalized Stratigraphic Column for the Michigan Basin.

Figure 3. A detailed map showing the Bear Lake survey area, geochemical sample locations, and well control where total depth is greater than 4000 ft. Squares and triangles denote SPME and Microbial geochemical sample locations, respectively. Black outlines are probable reef locations based on interpretation of subsurface and seismic data. Purple line in Section 9 is the Charlich-Fauble 2-9HD horizontal lateral. Red lines are roads. Gray lines and numbers denote one square mile sections (landgrid). Dashed rectangle outline represents the area of the SPME survey.

Figure 4. Contour plot of Bear Lake SPME propane data; blue areas denote lows, red areas are highs, the likely pinnacle reefs are outlined in gray.

Figure 5. Contour plot of Bear Lake SPME pentane data; blue areas denote lows, yellow areas are highs, the likely pinnacle reefs are outlined in gray.

Figure 6. Contour plot of Bear Lake MOST microbial data; blue areas denote lows, red areas are high. White outlines are likely reef locations based on subsurface and seismic data.

Figure 7. Microbial contour map of the Trusty Steed prospect area in Grand Traverse County, Michigan. Triangles represent geochemical sample locations. Lows are indicated by yellow-filled contours and red-filled contours indicate highs.

1.0 EXECUTIVE SUMMARY

New Findings

The project has located hydrocarbons in the Bear Lake demonstration area (Figure 1). Surface geochemical surveys conducted in the demonstration area were consistent with production results although the ultimate decision to drill was based on interpretation of conventional subsurface and 2D seismic data. The surface geochemical techniques employed were Solid Phase MicroExtraction (SPME) and Microbial Oil Surveying Technique (MOST).

Lessons Learned

Several lessons were learned from the Bear Lake demonstration. For Niagaran reef work, the SPME and MOST geochemical sampling grid should be smaller, on the order of 100 ft by 100 ft, rather than the 200-meter (600 ft) grid used in the original Bear Lake prospect area. However this tends to be expensive and a better strategy, which we intend to employ in future studies, is to conduct surveys along the path of the proposed lateral. This strategy will greatly reduce sampling costs and should provide the information needed by the operator.

Sampling at the same interval spacing as seismic shot points also seems to make sense to allow improved, albeit qualitative comparisons between the two data types. It appears that geochemical surveys over developed fields have to be interpreted with caution due to the disturbances caused by production (e.g. pressure drawdown) which seem to produce negative or apical anomalies in the vicinity of the well bore extending out at least 1/2 mile. Perseverance and patience are also virtues in this type of exploration, as well as adopting a consistent set of sample procedures.

Should Something Else Have Been Done?

In retrospect, the SPME geochemical survey should have been extended to the south and west at least one-half mile. However it is difficult to know how far to extend surveys in general and the tendency is to center the survey over a prospect delineated by other means. In addition, the MOST survey should have had a tighter sample spacing in the Southern portion of the Bear Lake prospect area.

Previously we believed, for comparative purposes, that a standardized and systematic sampling grid for the geochemical program would also provide improved interpretation of results (e.g., gridding and contouring constraints) between the different geochemical sampling techniques. However we now believe this strategy should be amended to concentrate on tight sampling along the proposed lateral and sparse sampling in the near vicinity because most new Niagaran wells have a horizontal-leg. If the intention is to reduce drilling risk in known reservoirs rather than locate new reservoirs, this variable sampling strategy may provide better resolution where it is needed while reducing geochemical survey costs.

Goals and Results

One main goal of this project was to locate and produce hydrocarbons using surface geochemistry as a screening tool. Overall, the SPME and MOST surface geochemical techniques at Bear Lake indicated hydrocarbon presence in the southwest quarter of Section 9 and possibly in the vicinity of the likely reef in section 4. The presence of hydrocarbons was confirmed by Federated's successful horizontal lateral.

Applications

As mentioned in previous reports, the results of the Bear Lake, Vernon, Springdale, and North Dakota geochemical surveys, can be applied to other carbonate and sandstone reservoirs worldwide. In particular, the application of appropriate surface geochemistry surveys seems warranted based on the work done here, as well as the advice to record the surveys at the same grid density as complimentary seismic data. We now believe dense geochemical sampling should be conducted along the proposed path of a horizontal well and sparse sampling in the near vicinity. This variable sampling strategy may provide better resolution where it is needed while at the same time, reducing geochemical survey costs for small operators.

Did Data Support Project or Not?

In regard to the Bear Lake project, the SPME pentane and propane geochemical surveys indicated the possibility of hydrocarbons in the vicinity of Federated's successful horizontal lateral.

Future Work

More geochemical work will be done in conjunction with further field demonstrations as part of this project in the Springdale area as well as in other areas in Michigan to test the Silurian reef play. Tight geochemical sampling will be employed along the path of proposed horizontal laterals.

2.0 EXPERIMENTAL

2.1 Geochemical Sampling Program – Michigan

The geochemical program this quarter focused on the Trusty Steed prospect in Grand Traverse County, Michigan (Figure 1).

2.2 Data Analysis

Eighteen microbial samples were taken in the Trusty Steed prospect area in Grand Traverse County, Michigan following the instructions of Geo-Microbial Technologies (Ochelata, Oklahoma). These soil samples were taken from an average depth of 8 inches and placed into paper bags with roll-down tops provided by GMT. The samples consist of approximately 4 ounces of soil. Immediately after collection, the samples were shipped overnight to GMT for analysis of butane-consuming microbes.

3.0 RESULTS AND DISCUSSION

Bottom Line

In the Bear Lake area, northwest Michigan, U. S., Federated Oil & Gas Properties, Inc. (Federated) completed a successful re-entry horizontal lateral, the Charlich-Fauble 2-9HD, producing at rates of 200 bopd when the well was brought on line in early 2003. Eighteen months later, the well is still producing 50 to 75 bopd from a Silurian Niagaran reef reservoir and the well has cumulative production of more than 72,000 barrels of oil. Surface geochemical surveys conducted in the field demonstration area were consistent with production results although the ultimate decision to drill was based on interpretation of conventional subsurface and 2D seismic data. The surface geochemical techniques employed were Solid Phase MicroExtraction (SPME) and Microbial Oil Surveying Technique (MOST).

Introduction

As part of a DOE-supported field demonstration project being performed by Michigan Technological University with involvement of Jordan Exploration Company, LLC (Jordan), a surface geochemistry program was undertaken in the Bear Lake area of Manistee County, Michigan to discover if geochemical anomalies were associated with Niagaran reef production. The focus of the project is to learn how to combine techniques (conventional subsurface/seismic and surface geochemistry) as an exploration/exploitation tool to locate by-passed oil in mature fields.

Surface geochemical techniques are based upon the concept that hydrocarbon seepages occur above or in the near vicinity of hydrocarbon accumulations (Soli, 1957; Horvitz, 1972; Klusman and Saeed, 1996). Although once debated fiercely, the concept is now generally accepted (Davidson, 1994, 2004). There are several different types of anomalies that can be observed. Usual shapes include focal or apical anomalies, halo or doughnut-shaped anomalies, and linear anomalies. Direct hydrocarbon indicator techniques can yield any shape of anomaly. Microbial techniques yield focal anomalies over virgin accumulations, including pinnacle reefs, but tend to produce halo anomalies over produced fields such as Vernon Field in Montcalm County, MI (Wood et al., 2003, 2004). This Bear Lake case study examines results using SPME (Solid Phase MicroExtraction) and MOST (Microbial Oil Surveying Technique) techniques, but other techniques are also being used and evaluated in other fields as part of the demonstration project.

Conventional Subsurface/Seismic Interpretation

Subsurface structural mapping using well data from existing Niagaran penetrations and several 2-D seismic lines was conducted over the Bear Lake prospect area. In analyzing seismic data, to integrate with the well control two key criteria were used to identify the location of probable Niagaran reefs (1) disruption in the Gray Niagaran reflector and (2) a travel-time increase between the Gray Niagaran and the A-2 Carbonate (Figure 2). Utilizing these criteria in combination with well control, Jordan developed an isotime/interval isopach map (Quinlan, 2002) that was used to locate probable Niagaran reefs in the Bear Lake area prior to the geochemical surveys. Four of these likely reefs are shown on Figure 3 by the black outlines labeled "Reef?". Concurrently, Federated was also pursuing exploration concepts in the same area and ultimately re-entered and side-

tracked the Charlich-Fauble 2-9 well. The geochemical surveys were designed to cover the Jordan acreage, but coincidentally overlapped with the Federated property. However we were able to integrate our geochemical survey with the results from the Federated well.

Solid-Phase MicroExtraction (SPME)

The SPME technique uses solid fibers to determine the concentration of low-molecular weight hydrocarbons in the headspace gas of near-surface soil (Zhang and Pawliszyn, 1993; Boleneus, 1994). SPME sample cores were taken at approximately one meter depth. Sample cores were quickly placed into 125 ml glass sample jars with a septum in the lid and sealed. Samples were kept on ice during transportation to reduce microbial activity. In the laboratory, samples were brought to room temperature and the sample shaken. The SPME fiber that absorbs hydrocarbons was then exposed 10 minutes to the headspace gas in the sample container before being withdrawn for subsequent analysis by gas chromatograph.

Microbial Oil Surveying Technique (MOST)

The MOST technique, developed over 30 years ago by Phillips Petroleum, is available to industry through Geo-Microbial Technologies (GMT). Microbial samples were taken with a shovel at an average depth of eight inches and approximately four ounces of soil was placed into paper bags with roll-down tops that were sent overnight to GMT. GMT incubates soil samples for one week in agar gel, and then counts the butane-oxidizing microbes, reporting the average of three measurements per sample.

Decisions Leading to Charlich-Fauble 2-9HD

Figure 3 illustrates the well control, surface geochemical sampling locations, and probable reef locations interpreted from subsurface and seismic data. SPME and MOST geochemical results (discussed later) showed positive anomalies in the area suggesting hydrocarbons in portions of Section 9. Federated held leases within section 9 and independent of our studies drilled a horizontal lateral from an existing wellbore based upon subsurface interpretations from well control, and to a lesser extent, seismic data (Seaman, 2002). Federated re-entered the Charlich-Fauble 2-9, set a plug at 4550 ft, drilled through the casing, turned a 90 degree angle, and drilled about 550 ft south southwest (see depiction in Figure 3) through the A-1 Carbonate and Brown Niagaran with the last 100 feet or so being in the reef, where returns and circulation were lost under overbalanced conditions. After swabbing, the well flowed. Stabilized production as of March, 2003 was approximately 200 bopd, no water, and 110 mcf gas (Michigan DEQ, 2004). Initial bottom hole pressure was 1749 psia. After producing 9,000 bbls of oil, pressure had dropped to 1636 psia (Federated, 2003).

SPME and MOST Interpretations

Figures 4 and 5 illustrate SPME contour plots for propane and pentane, respectively; hexane and butane data were also measured but are not shown here. In sections 4 and 9 SPME geochemical anomalies appear to be associated with the likely locations of reefs interpreted from subsurface and seismic data. The reefs in Sections 4 and 9 exhibit propane geochemical anomalies (Figure 4)

that are interpreted as halo anomalies (low value directly over the reef, high values surrounding the reef). In contrast, propane values are low in the vicinity of the likely reefs in Sections 3 and 8 and these likely reefs do not exhibit anomalies. The pentane data (Figure 5) is interpreted to show a strong halo anomaly near the likely reef in section 9 while the reef in Section 4 appears beneath a positive anomaly. The pentane plot is interpreted to show a halo or positive anomaly associated with the likely reef in section 8 but no pentane anomaly is seen over the likely reef in Section 3. [Gridding and color filled contours were allowed to extend to the edges of the SPME data area for interpretation purposes.]

Figure 6 shows the result of the MOST geochemical survey that covered a larger area than the SPME survey and varied in its sample spacing due to collecting conditions and constraints. Anomalies (reds and greens) appear, in part, to be consistent with the SPME propane plot-positive halo-type anomalies in Sections 4 and 9 and no anomalies in Sections 3 and 8 in the vicinity of the likely reefs. In addition, the MOST survey shows a positive anomaly in the east central portion of section 9 that may be an undrilled reef.

4.0 CONCLUSIONS

Summary

Overall, the SPME and MOST surface geochemical techniques at Bear Lake indicated hydrocarbon presence in the southwest quarter of Section 9 and possibly in the vicinity of the likely reef in section 4. The presence of hydrocarbons was confirmed by Federated's successful horizontal lateral. Re-analysis of the subsurface and seismic data available to the authors indicated that the interpreted outline of the likely reef in section 9 could have been extended to the southwest where the horizontal lateral was drilled (Figure 6). Considering this possibility, the high (red) propane and the high (yellow) pentane halo anomalies shown along the Charlich-Fauble horizontal well path (Figures 4, 5) could have been interpreted as the edge of a positive anomaly over the reef that was not fully imaged by the SPME survey because the survey did not extend far enough to the south. The MOST survey results are inconclusive in the area of the well path due to the broad spacing of the survey.

Additional Results, Dundee Limestone, Michigan Basin

Several techniques-surface iodine, enzyme leach on samples from "B" soil horizons, headspace gas from samples collected at 36-inch depth, and microbial-were employed in the Vernon field in Michigan looking for by-passed oil in the middle Devonian Dundee Limestone. At Vernon field the microbial survey produced the best results, thus it was decided to employ MOST techniques in all subsequent work. In the Vernon field, surface geochemical results indicated marginal potential which was confirmed when two wells were drilled that were uneconomic. Geochemical sampling for Dundee and Traverse potential is continuing in the Michigan Basin.

Additional geochemical work in Michigan's Dundee fields has also been consistent with drilling results-poor wells were experienced in locations where surface geochemical results indicated little possibility of finding commercial hydrocarbons. In particular, surface geochemistry over produced fields seems to reliably delineate depletion halos (i.e., areas of suppressed geochemical signal consistent with pressure depletion). Field demonstrations confirm that surface geochemical techniques complement and enhance, but do not replace, conventional subsurface/seismic approaches.

Trusty Steed Prospect

Due to the results of the microbial data (one high point over the survey area) for the Trust Steed prospect area in Manistee County, Michigan, geochemical resampling would be beneficial. However, since drilling has been postponed in the prospect area, further geochemical sampling will also be postponed.

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6.0 FIGURES

Figure 1. Index map showing all geochemistry sampling locations in Michigan.

Figure 2. Generalized Stratigraphic Column for the Michigan Basin.

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Figure 5. Contour plot of Bear Lake SPME pentane data; blue areas denote lows, yellow areas are highs, the likely pinnacle reefs are outlined in gray.

Bear Lake Region, Manistee County, Michigan Contour Map of Microbial Data			
Location: [T23N-R15W]	▲ Microbial Locations		
Reef Locations: ○	* Gas Wells	◇ Dry Holes	MTU
Contour Int: 5 Microbial Counts	◆ Oil Wells	* Brine Disposal Wells	6/15/2004

Figure 6. Contour plot of Bear Lake MOST microbial data; blue areas denote lows, red areas are high. White outlines are likely reef locations based on subsurface and seismic data.

Trusty Steed Prospect, Grand Traverse County, Michigan Microbial Contour Map			
Location: [T25N-R12W]	▲ Microbial Locations	○ Location Wells	C. Asiala
Gridding Algorithm: Kriging	☼ Gas Wells	⊖ Dry Holes	MTU
Contour Interval: 5	◆ Oil Wells	✱ Brine Disposal Wells	10/05/2004

Figure 7. Microbial contour map of the Trusty Steed prospect area in Grand Traverse County, Michigan. Triangles represent geochemical sample locations. Lows are indicated by yellow-filled contours and red-filled contours indicate highs.