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NITROGEN IN CLEAR CREEK AND CHARLSON FIELDS, NORTH DAKOTA

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ABSTRACT

Large accumulations of high purity nitrogen gas have been found in some Williston Basin oil fields. This gas has been considered for use in oil production operations.

Estimates of nitrogen gas contained in the Minnelusa formation in Clear Creek and Charlson fields in North Dakota are presented. The estimates are based on quantitative analysis of logs from 154 wells. The log calculations were performed by Pure Oil Co., utilizing their COMLOG system.

INTRODUCTION

Large accumulations of free nitrogen gas occur in many underground formations throughout the southwestern portion of the Williston basin. They have been found extensively on the Cedar Creek anticline, Montana,[1] Nesson anticline, North Dakota,[4] and in Billings County, N. Dak.

Economically valuable nitrogen accumulations must be of sufficient size to guarantee the amount needed and must be near the place of use. Two such sources were found in the Minnelusa formation in the Clear Creek and Charlson fields, Fig. 1, located on the Nesson anticline.

Some of the potential uses for these accumulations of nitrogen are: Reservoir pressure maintenance, nitrogen slug injection in water floods, nitrogen slug injection in miscible displacement, nitrogen gas blanketing in storage tanks, gas-lift production of oil and displacing fluid with nitrogen in well completions.

References and illustrations at end of paper.

The estimation of the volume of nitrogen in the Minnelusa formation in these fields was made possible by completing the large number of logging calculations with a digital computer.

GEOLOGY

Structure

The Clear Creek field is south of the Missouri River and on the west flank of the Nesson anticline [Fig. 1]. The structure of the Minnelusa formation is a large, broad, south-plunging nose, that overlies the oil productive Madison-Mississippian reservoir. The field is 3-1/4 miles long and 3 miles wide, and contains about 5,700 acres.

The structural contours on top of the Minnelusa formation are shown in Fig. 2. Structural relief is greater than 180 ft. As shown in Fig. 3, the gross potential producing zone ranges in thickness from 230 to 360 ft.

The Charlson field extends from the Missouri River southward and lies on top of the Nesson anticline [Fig. 1]. The structure of the Minnelusa formation is an anticlinal closure, containing approximately 14,300 acres, and overlies the oil producing Madison-Mississippian

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reservoir. The field is 7 miles long and 5 miles wide.

The structural contours on top of the Minnelusa formation are shown in Fig. 4. Closure is greater than 100 ft. As shown in Fig. 5, the gross potential producing zone ranges in thickness, from 150 to 260 ft.

Stratigraphy

The Minnelusa formation, of Pennsylvanian age, in the Williston basin is defined as that strata overlying the Mississippian unconformity and underlying the Opeche formation of Middle Permian.[3]

The Minnelusa is from 0 to 300 ft thick in western North Dakota. Deposition was erratic east of the Black Hills in South Dakota, and the formation has been found in wells to range from 0 to 350 ft thick. In west central North Dakota the formation has a fairly uniform thickness of 250 ft.

The Minnelusa formation consists of six separate identifiable zones just south of the Clear Creek field. The direction of sedimentation was to the northwest but the formation was eroded progressively northward and overlapped the Opeche-Minnekahta interval of the Permian. The deposition of the Minnelusa extends through the Charlson field and the lowermost zone subcrops in the Beaver Lodge field six miles to the north.

The Minnelusa sandstone in this area is white, pale red and pinkish gray in color with sand grains that are angular to sub-rounded. It is of fine-grained texture and fair to good porosity. The sands are normally cemented by dolomite and may contain white chert fragments and thin anhydrite layers.

METHOD OF ANALYSIS

The reservoir rock properties of the Minnelusa formation in Clear Creek and Charlson fields were determined by well log analysis. The method was used because only two core analyses of portions of the Minnelusa formation in the two areas, are available.

Logs from 154 wells were analyzed, by visual inspection, to obtain formation tops, gross thickness and resistivity and radioactivity measurements. Quantitative calculations were performed by Pure Oil Co., utilizing their COMLOG[2] system. This system is an application of computer methods to conventional well log interpretative calculations. The use of COMLOG permitted several sets of complete calculations to be made using various values for parameters such as cementation factor, diameter of invasion, and neutron log porosity limits.

Gamma ray logs were used to pick formation tops and gross thicknesses. These data were used to draw the structure contour maps [Figs. 2 and 4] and the isopach maps [Figs. 3 and 5]. For most wells, microlaterlog interpretations gave porosities. For two wells sonic logs were used, and for 22 wells, neutron logs were used to determine porosities. Laterolog interpretations gave water saturations.

Typical examples of gamma ray, laterologs and microlaterologs for the two fields are shown in Figs. 6 and 7. The interval analyzed in the Clear Creek well is from 7,190 ft to 7,510 ft and in the Charlson well it is from 6,932 ft to 7,100 ft. The intervals which produced nitrogen on drill stem tests are also indicated on the logs.

To compute volumes of nitrogen gas, a cutoff porosity of 5 per cent and a critical water saturation of 56 per cent were used. Reservoir pressures used were determined by averaging final shut-in pressures from two drill stem tests in Clear Creek field and five drill tests in Charlson field. These pressures are probably lower than the true static reservoir pressures. Reservoir temperatures were calculated from bottom-hole temperatures recorded on the resistivity logs.

The volume of nitrogen gas per acre was calculated for each well by the following equation:

$$N_2 = [43,560\ \phi h\ (1-S_w)]\ \frac{P_1\ T_2\ Z_2}{P_2\ T_1\ Z_1}$$

where:

N_2 = nitrogen gas in place, standard cu ft/acre
43,560 = cu ft/acre ft
ϕ = porosity, fraction
h = net thickness, ft
S_w = average water saturation, fraction
P_1 = reservoir pressure, psia
P_2 = 14.7 psia
T_1 = reservoir temperature, °R
T_2 = standard temperature, 520°R
Z_1, Z_2 = compressibility factors, dimensionless

LOG INTERPRETATION PARAMETERS

To make the quantitative interpretations of the various resistivity and radioactivity logs, values for several basic parameters were required. These values are shown in Table 1. The Minnelusa formation water resistivity [R_w], 0.05 ohm-meter at 68F, was obtained from a commercial laboratory. At 160F, R_w is 0.023 ohm-meter and the ratio R_w/R_{mf}, for a salt saturated mud, is close to one.

The diameter of invasion [DI] of 20 in. was assumed because the salt saturated mud, used in most of the wells in the two areas investigated, characteristically produces a small DI, but some

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invasion must have occurred during the relatively long periods that the formation was exposed to the mud. The DI has little effect on the porosity value because the ratio R_w/R_{mf} is close to one. The DI of 20 in. has little effect on the water saturation value because most of the rock volume investigated by the laterolog is far beyond 10 in. from the wellbore.

The commonly accepted value of 2 was used for the saturation exponent [n]. Values of 2.0 and 2.3 were used for the cementation factor [m].

Minimum and maximum porosities for neutron log calculations were determined by analysis of sonic and microlaterolog porosities.

WELL LOG ANALYSIS RESULTS

The depth, gross and net thicknesses, average porosity, and average water saturation were calculated for each well. These values, for all the wells in each area, were averaged to give the values shown in Table 2.

The zones within the gross thickness that are relatively shale free, as indicated by the gamma ray log, were analyzed quantitatively. The aggregate thicknesses of these zones in the Clear Creek and Charlson areas are 238 ft and 192 ft, respectively. The net thicknesses represent the aggregate of the analyzed zones, ranging in thickness from 2 to 44 ft, whose porosities are equal to or greater than 5 per cent, and whose water saturations are less than 56 per cent.

The average gross thickness of the Minnelusa in the Clear Creek area is 38 per cent greater than the gross thickness in the Charlson area. However, the average net thicknesses, porosities and water saturations are nearly equal in the two areas.

Comparisons of the log porosities with the two available core analyses, both from Charlson field, show that the average porosities are nearly equal, but comparison on a foot-by-foot basis is not favorable. A similar comparison of water saturation is more favorable on a foot-by-foot basis, but the log saturations are slightly higher than the core values. Porosities calculated from the two sonic logs agree with microlaterolog porosities for offset wells.

NITROGEN GAS VOLUMES

This study indicates that the Minnelusa formation, within the limits of the Clear Creek oil field [outlined in Figs. 2 and 3], contains 165 billion scf nitrogen. The volume of nitrogen within the Charlson field [outlined in Figs. 4 and 5], was calculated to be 370 billion cu ft.

The volumes of nitrogen per acre and per acre-foot were calculated for each well. The averages of these volumes for each field are shown in Table 3. The total volume in each field was determined by multiplying the average volume per acre by the number of acres in the field.

Assuming an abandonment pressure of 1,000 psi for Clear Creek field, the recoverable reserves are about 68 per cent of the gas in place, or 112 billion scf. In Charlson field, 71 per cent of the gas in place, or 262 billion scf, are recoverable reserves.

Drill stem tests in the two fields have indicated the potential nitrogen deliverability. The L. Wisness No. 1 well [Fig. 6] in SENW sec. 23, T 152 N, R 96 W, Clear Creek field [Figs. 2 and 3] flowed 27.5 million cu ft of 95.7 per cent nitrogen per day from 7,184 to 7,250 ft [4,796 to 4,862 ft below sea level] at a flowing pressure of 2,795 to 3,050 psi. In Charlson field, the G. L. Thompson No. 2-A well [Fig. 7] in SESESE sec. 7, T 153 N, R 95 W [Figs. 4 and 5] flowed 18.8 million cu ft of 97.4 per cent nitrogen per day from 6,930 to 7,005 ft [4,569 to 4,644 ft below sea level] at a flowing pressure of 2,420 to 2,840 psi.

DISCUSSION OF RESULTS

The calculations of nitrogen volumes in Charlson and Clear Creek fields represent the first published data on this gas in the Williston basin. The results of the well log analyses are believed to be based on sound basic theory and assumptions. However, these estimates of gas volumes per acre are conservative because the estimates are based on the assumed cut-off porosity and critical water saturation values, and because the reservoir pressures used to calculate volumes of nitrogen are probably lower than the true static reservoir pressures.

Several wells outside the limits of the two oil fields were used in the study for mapping control. The analysis of the logs from most of the wells indicate that the nitrogen intervals are not restricted to the limits of the oil fields. In the Clear Creek area, the nitrogen interval extends eastward into the Blue Buttes field. In the Charlson area, the potentially productive interval extends southeastward toward the Antelope field.

CONCLUSIONS

Sufficient volumes of nitrogen gas are available in the Minnelusa formation in Charlson and Clear Creek oil fields to warrant consideration for production operations. This study of these areas did not locate the areal limits of the nitrogen bearing intervals.

A thorough analysis of well logs should give the data necessary for estimating nitrogen reserves in the Williston basin.

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TABLE 1 -- LOG INTERPRETATION PARAMETERS

Parameter	Value	How Obtained
Formation Water Resistivity (R_W)	0.05 ohm-meters	From commercial laboratory
Cementation Factor (m)		
Sand	2.0	Assumed
Dolomite	2.3	Assumed
Saturation Exponent (n)	2.0	Assumed
Diameter of Invasion (DI)	20 inches	Assumed
Neutron Log Porosity Limits		
Minimum (Ø min)	1 and 5	From sonic and microlaterolog porosities
Maximum (Ø max)	25 and 30	

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TABLE 2 -- AVERAGE MINNELUSA RESERVOIR CHARACTERISTICS

	Clear Creek field	Charlson field
Average Depth, feet	7,205	6,767
Average Gross Thickness, feet	272	197
[1]Average Net Thickness, feet	39.8	38.3
[1]Average Porosity, percent	13.9	13.3
[1]Average Water Saturation, percent	38.6	36.4
[2]Average Reservoir Pressure, psia	3,350	3,195
Average Reservoir Temperature, °F	168	148
[3]Number of Wells Averaged	37	117

[1]Includes only those zones with porosities of 5 percent or greater and water saturations of less than 56 percent.

[2]Averages of final shut-in pressures from 2 drill stem tests in Clear Creek field and 5 drill stem tests in Charlson field.

[3]Includes 9 wells outside Clear Creek oil field and 12 wells outside Charlson oil field.

TABLE 3 -- NITROGEN GAS IN CLEAR CREEK AND CHARLSON FIELDS

	Clear Creek field	Charlson field
Nitrogen gas per acre foot (average), Mscf	631.8	626.8
Nitrogen gas per acre (average), MMscf	28.7	25.8
Nitrogen gas per field, MMscf	165,000	270,000
[1]Area of field, acres	5,760	14,320

[1]Field areas delineated by North Dakota Industrial Commission

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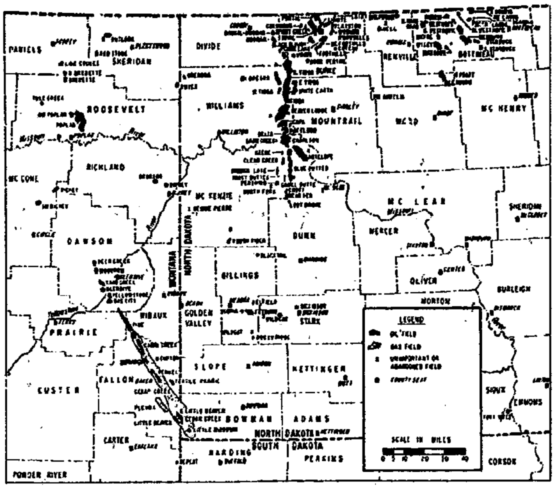

FIGURE 1 - OIL AND GAS FIELDS OF THE WILLISTON BASIN IN MONTANA, NORTH DAKOTA, AND SOUTH DAKOTA

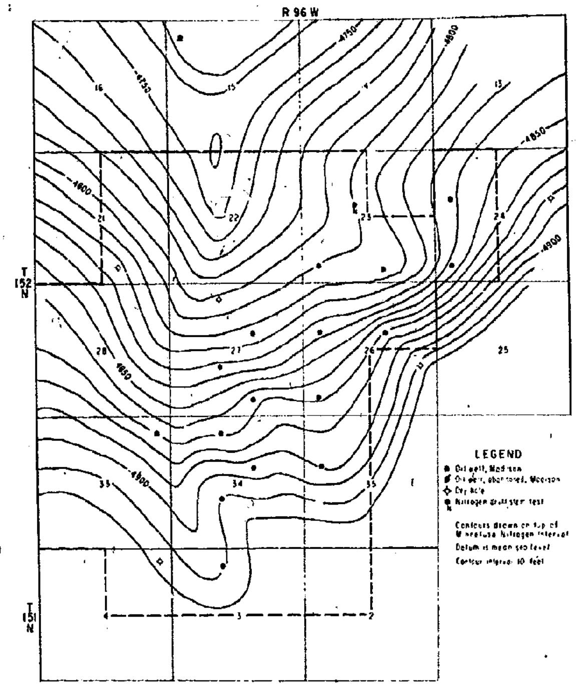

FIGURE 2 - Structure-Contour Map of Clear Creek Field

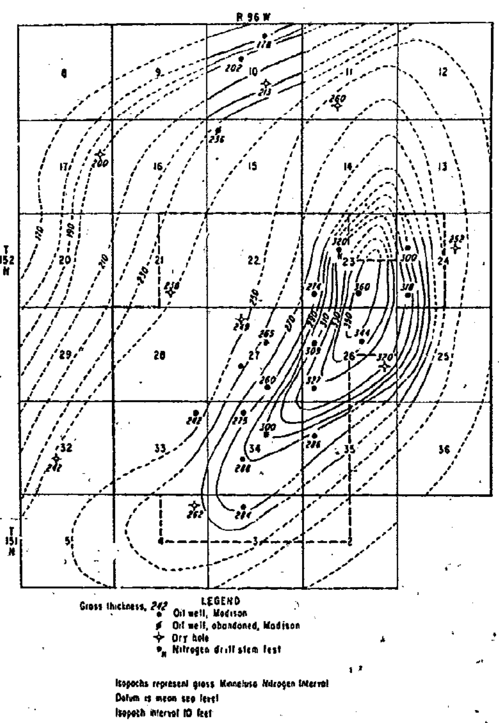

FIGURE 3.-Isopach Map of Clear Creek Field.

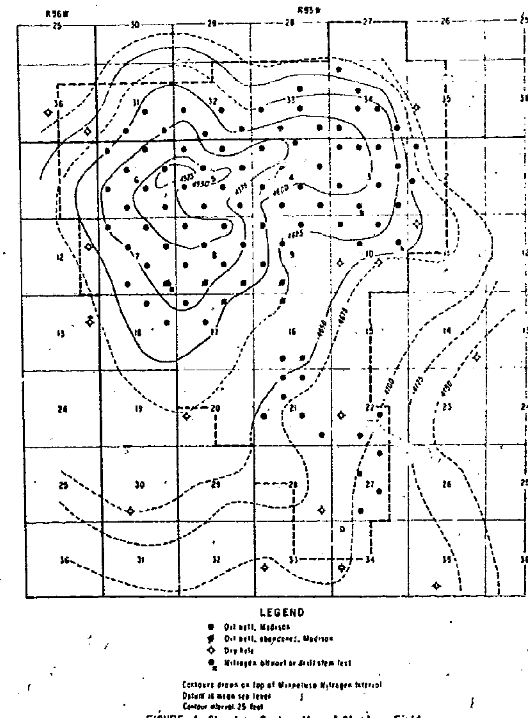

FIGURE 4.-Structure-Contour Map of Charlson Field.

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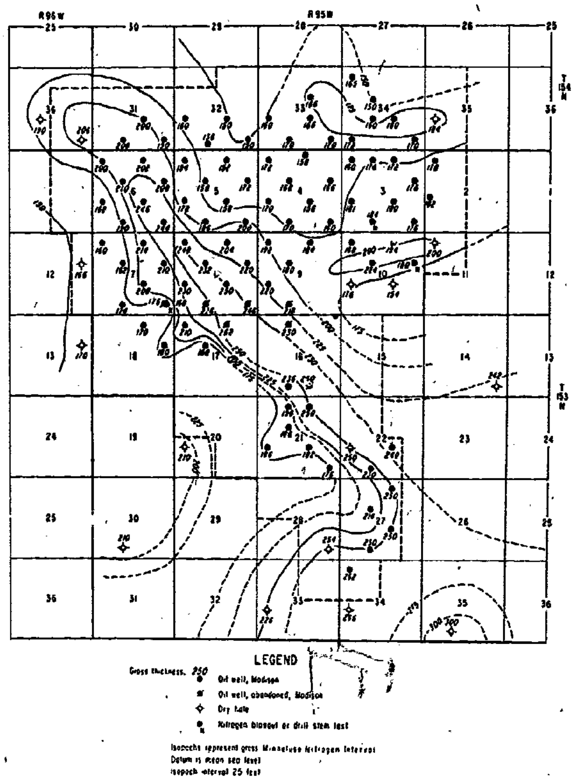

FIGURE 5- Isopoch Map of Charlson Field.

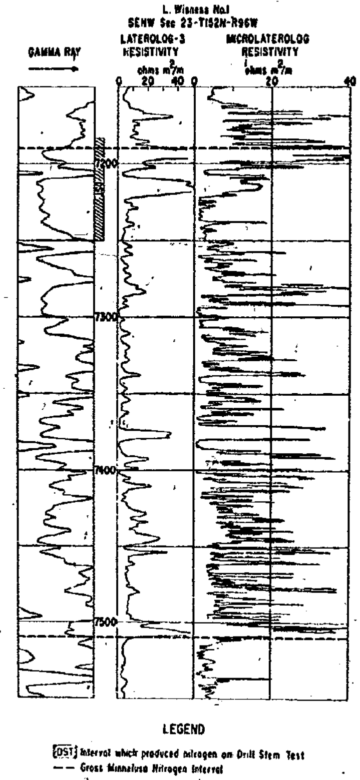

FIGURE 6 - Typical well logs, Clear Creek Field

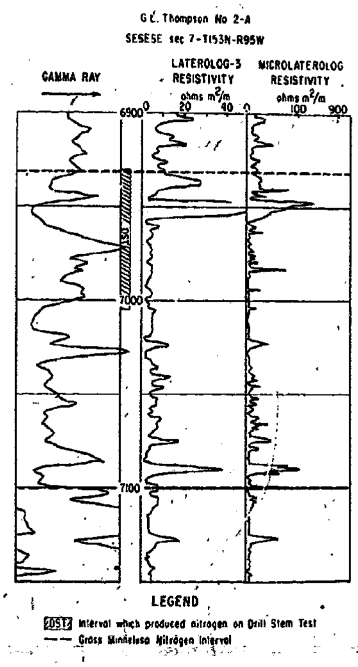

FIGURE 7.-Typical well logs, Charlson Field

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