DEPARTMENT OF NATURAL RESOURCES

GEOLOGY DIVISION

PRODUCTION AND PRORATION UNIT

Secondary Recovery Report No. 4

Enterprise Field

ENHANCED OIL & GAS RECOVERY IN MICHIGAN

by

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PREFACE

This is the fourth in a series of reports on projects to enhance recovery of oil in Michigan. These projects are an effort by the Production and Proration Unit of the Geology Division to better serve the State of Michigan, the petroleum industry, and the public by making its information and expertise more readily available to all interested parties. Future reports are planned and will be published as they are finished. A compiled volume is planned when all of the reports have been completed.

The author wishes to acknowledge Mr. T. P. Burnette, Sun Production Company, Tulsa, Oklahoma, for his review of the manuscript and entry of certain missing information.

ABSTRACT

The Enterprise oil field of Missaukee and Roscommon counties is a successful Richfield interval water flood project indicated by the fact that oil production has exceeded expected primary production estimates by 42 percent as of 1975.

INTRODUCTION

Initial Traverse and Dundee tests by Sun Oil Company in the early 1940Ts in Section 11 of Enterprise Township, Missaukee County, proved to be non-commercial. However, the decision by Sun Oil Company to drill deeper in Section 11 led to the discovery of oil in the Richfield Formation in September, 1943. Additional field development through 1953 essentially delineated the extent of the Richfield reservoir, which is located in a closed anticlinal structure and situated primarily in Section 11 of Enterprise Township, Missaukee County.

The three mile by one mile elliptically shaped anticlinal trap is situated in an approximate northwest-southeast direction with most of the production from a minus 3270 feet subsea level datum. In the Enterprise field the oil production is obtained from nine dolomite stringers located immediately below the massive anhydrite and separated by either anhydrite or dense limestone.

RICHFIELD RESERVOIR ROCKS

Richfield reservoir rocks are assigned to the basal part of the Lucas Formation, Detroit River Group. The Lucas Formation is a dolomite, limestone, salt, and anhydrite sequence of Devonian age. The Richfield, often erroneously given formation status, is poorly defined in terms of widespread, easily recognized marker beds outside the main area of salt deposition. In the deeper central part of the basin, where most Richfield pools are found, Richfield pay zones are keyed to recognition of certain salt and anhydrite beds near the base of the Lucas Formation. According to Hautau (1952, p. 1), ". . . the Richfield generally includes all the section that

produces sweet crude below the massive anhydrites that underlie the lowest Detroit River salt beds, and above the highest fossiliferous black coralline limestones." The black coralline limestones are assigned to the Amherstburg Formation, the lower formation of the Detroit River Group. Richfield pay zones appear to span about 200 feet of section made up of dolomite beds of varying thickness and separated by thin anhydrite beds and some limestone lenses. Of the several thin dolomite beds within the Richfield interval, four are considered important reservoirs and at least six others have shown oil saturation. Between these reservoir rocks are relatively impervious evaporites. The vertical succession of these beds within the Richfield interval is an important element in the success of the waterflood project.

GENERAL ENTERPRISE FIELD HISTORY

The Enterprise oil field was discovered in September, 1943, with the completion of Sun Oil Company's Wilson #A-1 well. The well is located in section 11 of Enterprise Township, Missaukee County. In November, 1942, the State-Enterprise #A-1 was drilled into the Richfield zone, but completion problems caused Sun Oil Company to complete the well as a dry hole. In 1950 the State-Enterprise #A-1 was reworked and became a productive oil well. Familiarity with Richfield geology and core analysis evaluations led Sun Oil Company to complete the wells in the Enterprise field as open hole completions.

A drilling unit and well spacing order was issued by the Supervisor of Wells on November 16, 1950,to supersede the previous drilling unit and well spacing order dated September 18, 1945. The 1950 order expanded the definition of the Enterprise Richfield formation pool to encompass sections 1, 2, 3, 10, 11, 12, 13, 14, 15, Enterprise Township, Missaukee County, and sections 7 and 18 of Lake Township, Roscommon County. Both orders established 40-acre drilling units with the well to be located in the center of the south one-half of the governmental surveyed quarter quarter section of land. No oil and gas production allowables were established for the field.

Sun Oil Company engineering evaluations in 1952 indicated an economically successful gas pressure maintenance program could be implemented in the Enterprise field. In order to initiate the project, operating and unitization agreements were instituted. The unitization agreement specified the operations to include sections 10, 11, 12, 13, and 14 of Enterprise Township, Missaukee County, and section 18 of Lake Township, Roscommon County. See Figure 2 for the exact unit boundary of the project.

After operating and unitization agreements were established, gas pressure maintenance was commenced with the Ward #1 well in March, 1953. Through September, 1961, when this phase of the project was completed a total of 1,419,641 Mcf of gas was injected into the Ward #1 well. The gas injection phase of the Enterprise project was replaced by water injection in 1961 when the determination was made that the casinghead gas had been recycling through the reservoir. By the end of 1975 a total of 6,696,580 barrels of water had been injected into the field. At the present time, the field contains 19 producing wells, 15 water injection wells, and one brine disposal well.

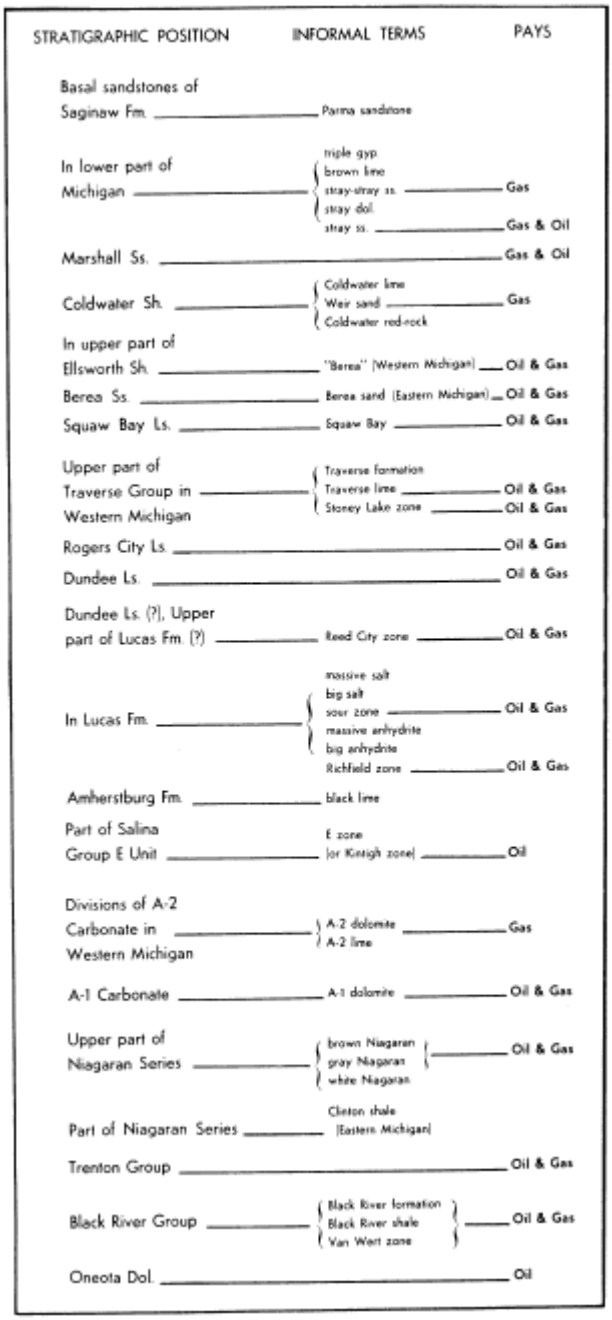

Figure 1. Principal oil and gas pays and informal terms used in petroleum exploration applied to parts of formations or groups of formations in the subsurface of the Michigan Basin.

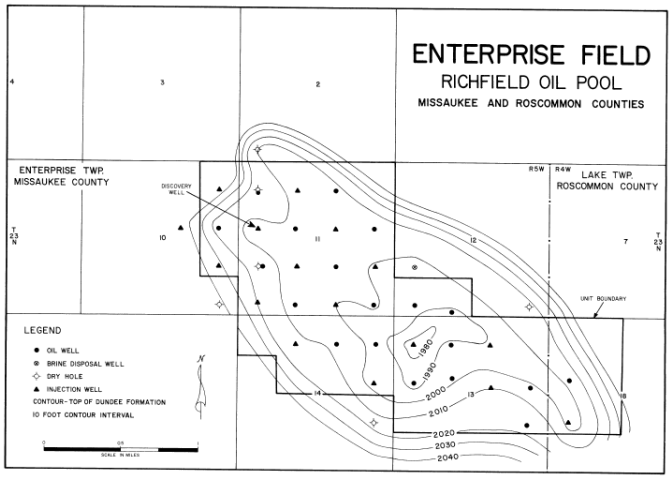

Figure 2: Structure of the Enterprise Field contoured on top of the Dundee Formation.

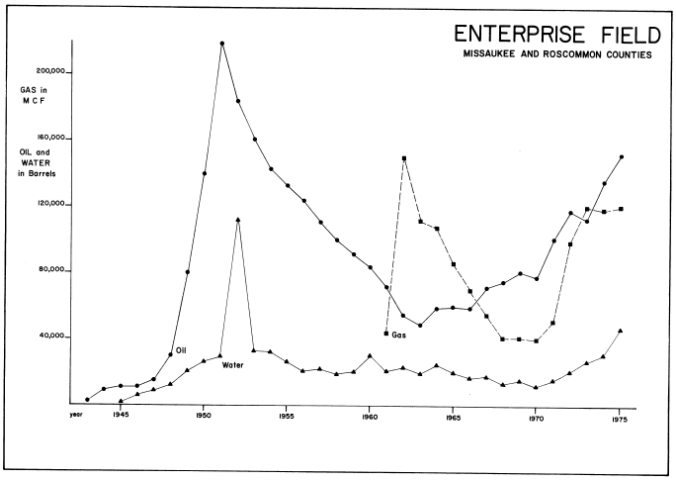

Figure 3: Oil, gas, and water production from the Richfield Pool, Enterprise Field. Oil and water production is shown in barrels. Gas production is shown in thousand cubic feet (MCF).

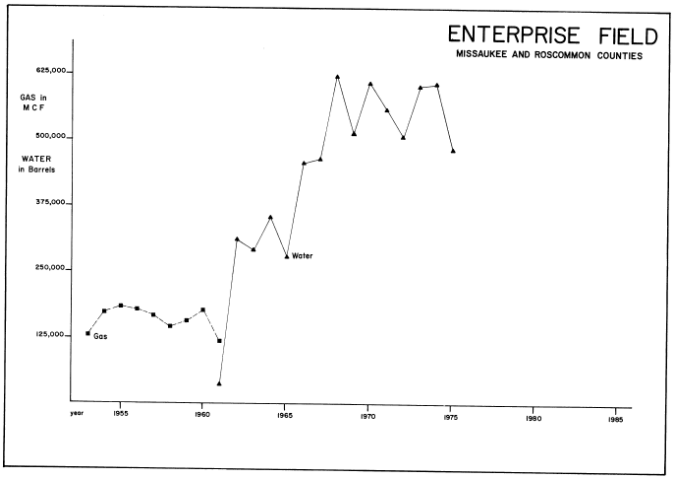

Figure 4: Gas and water injected into the Richfield Pool, Enterprise Field, to enhance oil and gas recovery. Injected water is shown in barrels. Injected gas is shown in thousand cubic feet (MCF).

The waterflood pattern can generally be described as a five spot pattern of injection with an irregular pattern for the southeastern portion of the field. Production through 1975 included 2,937,592 barrels of oil and 1,262,215 Mcf of gas. Oil production has exceeded by 42 percent primary production estimates of 2,070,000 barrels.

The Enterprise field possesses an average 16 feet of pay with 15.1 percent porosity and permeability of 3.5 millidarcies. Other field data are presented in Data Sheet No. 1. Historical oil and gas production data are listed in Table 1 with gas and water injection data listed in Table 2.

Data Sheet No. 1

Enterprise Field

Richfield Waterflood Project

GENERAL POOL DATA	
Location	Missaukee County, Enterprise Twp. (T23N, R5W) and Roscommon County, Lake Twp. (T23N, R4W)
Date of pool discovery	September 24, 1943
Discovery well	Sun Oil Company, Wilson #1 Permit number 10110
Producing formation	Richfield (Detroit River Group)
Pay zone lithology	Dolomite
Type of trap	Anticline
Drilled acres	1360
Unit acres	1840
Reservoir area, estimated acres	1320

ENGINEERING DATA	
Type of reservoir energy	Solution gas
Original reservoir pressure	2300 psig
Reservoir temperature	116°F
Viscosity of original reservoir oil	0.5 cp
Bubble point pressure	2300 psig estimated
Formation volume factor	1.44
API oil gravity	43°
Original solution gas-oil	850 cfpb

ratio	
Average porosity	15.1%
Average permeability	3.5 md
Connate water (estimated)	25%
Net oil pay thickness	15.8 ft
Acre feet of oil pay	20,224

RECOVERABLE HYDROCARBON DATA*

Estimated original stock tank oil in place	12,700,000 bbls.
Estimated original recoverable stock tank oil	2,036,000 bbls.
Calculated recoverable stock tank oil per acre foot	101 bbls. primary; 158 bbls. primary and secondary
Original gas in solution	10,800 MMcf
Estimated original recoverable gas	7,280 MMcf
Estimated additional recoverable oil due to secondary recovery methods	1,155,000 bbls.

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Other publications available in this series:

#1 - HAMILTON FIELD, RICHFIELD OIL POOL, 1976 Wilson, S. E., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and R. J. Pollom

#2 - BEAVER CREEK FIELD, 1976 Pollom, R. J., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and S. E. Wilson

#3 - CRANBERRY LAKE FIELD, RICHFIELD OIL POOL, 1976 Wilson, S. E., F. L. Layton, J. S. Lorenz, A. D. Matzkanin, and R. J. Pollom

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Its activities are guided by public service available to all who are interested in the use or development of our resources, the protection of our environment, and sound land use management.

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Enterprise Field, Richfield Waterflood, Missaukee and Roscommon Counties							
Year	Production Data						Remarks
	Gas		Oil		Water (estimated)		
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	
1943 - 1952				704,402		217,675	
1953			161,136	865,538	33,215	250,890	Gas injection begins
1954			143,136	1,008,674	32,850	283,740	
1955			133,893	1,142,567	26,645	310,385	
1956			124,099	1,266,666	21,170	331,555	
1957			111,172	1,377,838	22,265	353,820	
1958			100,932	1,478,770	19,345	373,165	
1959			91,691	1,570,461	20,800	393,965	
1960			84,274	1,654,735	30,168	424,133	
1961	44,028	44,028	72,640	1,727,375	21,169	445,302	Gas injection discontinued, Waterflood begins 1961
1962	150,110	194,138	55,328	1,782,703	23,360	468,662	
1963	111,818	305,956	48,925	1,831,628	19,710	488,372	
1964	107,773	413,729	59,212	1,890,840	24,820	513,192	
1965	86,445	500,174	60,505	1,951,345	20,440	533,632	
1966	70,105	570,279	59,177	2,010,522	16,790	550,422	
1967	55,387	625,666	71,894	2,082,416	17,387	567,809	
1968	40,776	666,442	74,647	2,157,063	13,870	581,679	
1969	40,975	707,417	81,701	2,238,184	15,695	645,189	
1970	40,076	747,493	77,888	2,316,652	12,045	657,234	
1971	55,725	803,218	101,965	2,418,617	16,060	673,294	
1972	99,443	902,661	118,391	2,537,008	21,535	694,829	
1973	120,595	1,023,256	113,070	2,650,078	27,010	721,839	
1974	118,921	1,142,177	135,897	2,785,975	31,755	753,594	
1975	120,038	1,262,215	151,617	2,937,592	46,172	799,766	

Table 1. Oil, gas, and water production from the Richfield Pool, Enterprise Field. Oil and Water production is shown in barrels. Gas production is shown in thousand cubic feet (Mcf).

Enterprise Field, Richfield Waterflood, Missaukee and Roscommon Counties								
Year	Injection Data						Injection Pressure	
	Gas	Gas		Oil	Water		Gas	Water
	Inj. Wells	Annual	Cumulative	Inj. Wells	Annual	Cumulative		
1953	1	130,515	130,515				2,275	
1954	1	170,546	301,061				2,400	
1955	1	180,571	481,632				2,285	
1956	1	177,817	659,449				2,123	
1957	1	163,119	822,568				2,109	
1958	1	145,562	968,130				2,075	
1959	1	158,495	1,126,625				2,004	
1960	1	174,265	1,300,890				1,930	
1961	1	118,751	1,419,641	5	36,320	36,320	1,920	1,790
1962				5	310,615	346,935		2,540
1963				5	297,533	644,468		2,140
1964				5	351,604	996,072		2,390
1965				5	278,780	1,274,852		2,000
1966				11	457,581	1,732,433		1,993
1967				11	467,492	2,199,925		2,330
1968				13	623,424	2,823,349		2,350
1969				13	513,762	3,337,111		2,300
1970				13	609,592	3,946,703		2,300
1971				13	558,076	4,504,779		2,350
1972				15	507,807	5,012,586		2,500
1973				15	597,180	5,609,766		2,500
1974				15	607,200	6,216,966		2,500
1975				15	479,614	6,696,580		2,500

Table 2. Gas and Water injection data for the Richfield Pool, Enterprise Field. Gas figure are in thousand cubic feet (Mcf). Water figures are in barrels.

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