DEPARTMENT OF NATURAL RESOURCES

GEOLOGY DIVISION

PRODUCTION AND PRORATION UNIT

SECONDARY RECOVERY REPORT NO. 2

Beaver Creek Field

ENHANCED OIL & GAS RECOVERY IN MICHIGAN

by

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PREFACE

This report on the Beaver Creek Field is the second in a series of reports on various secondary recovery projects within the State of Michigan. The first, Hamilton Field, Richfield Oil Pool, is already in print and available to the public. The remaining waterflood reports will be published as time permits and will be available on an individual basis as they are printed or in a combined volume at the completion of the series.

ABSTRACT

The Beaver Creek Field produces from an anticlinal structure being waterflooded in the Richfield interval. Orderly development and prudent operating procedures have allowed the field to surpass its original primary production estimates by over 3,000,000 barrels of oil.

INTRODUCTION

The Beaver Creek field is a textbook example of a successful waterflood project. The field is relatively uncomplicated in that its lateral limits are defined. It produces from one lensic rock unit whose permeability and porosity are relatively uniform throughout the field.

The field, located in parts of Beaver Creek Township, Crawford County and Garfield Township, Kalkaska County, produces from the Richfield zone at the base of the Lucas Formation - a part of the Detroit River Group. This producing horizon forms an anticlinal structure of Middle Devonian age. For purposes of illustration, the field is contoured on the top of the Dundee Formation because this is a less controversial subsurface correlation point and it amply reflects the Detroit River structure beneath.

Discovered in 1947, the field was soon found to contain five separate producing dolomitic lenses at a depth of about 4,400 feet. These lenses are labeled zones #1, #2, #3A and #4. The number 4 dolomitic zone is the principal pay zone and lies 100 feet below the top of the Richfield. The driving mechanism for the reservoir is a solution gas drive in the lowermost pay zones with a small gas cap in zone 4 in the southeast portion of the pool.

RICHFIELD RESERVOIR ROCKS

Richfield reservoir rocks are a part of the basal part of the Lucas Formation, Lower Detroit River Group. The Lucas Formation is a complex sequence of dolomites, limestones, anhydrites, and salts of Devonian age. The Richfield, often erroneously given formational status, is poorly defined in terms of widespread, easily recognizable 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 the recognition of certain unique salt and anhydrite beds near the base of the Lucas Formation. According to Hautau (1952, p. 1), ". . . the Richfield generally includes all sections 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 lowermost formation of the Detroit River Group. Richfield pay zones appear to span about 200 feet of section made up of dolomite beds of various thickness and separated by thin anhydrite beds and occasional limestone lenses. At least six of the porous beds within the Richfield interval have shown oil saturation and several others are considered potentially important reservoirs. 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 BEAVER CREEK FIELD HISTORY

The Beaver Creek Field was discovered with the drilling of Pure Oil Company's State-Beaver Creek A-1 in Section 17 of Beaver Creek Township on July 21, 1947. The well was drilled with a cable tool rig to a depth of 4,410 feet and initial production was 12 barrels of oil natural, and 115 barrels of oil after acid. The field was spaced on an order dated June 1, 1948, and development progressed on 40 acre spacing with wells being located in the center of the west half of a government surveyed quarter, quarter section. On October 1, 1949, Amendment 4, Proration Order No. 23, was adopted limiting production to 100 barrels of oil per day from each well. Amendment 41, Proration Order No. 23, added proration of gas, limiting it to 100 thousand cubic feet (Mcf) per day per well. This became effective September 1, 1961. The initial reservoir pressure was 2,138 pounds per square inch (psi), but with the development of the field and the addition of 98 new wells the pressure dropped to approximately 675 psi by 1963. At this time application was made to unitize the field for the purpose of waterflooding.

Unitization was made effective September 19, 1963, under Unitization Order 197-3 and amended December 1, 1974 with Order No. (A) 2-74. Waterflooding was commenced in 1964. Since 1964, 6 wells have been completed as water injection wells, 7 have been completed as producers, and 52 have been converted to water injection. At present, there are 58 water-injection wells and 53 producing-facility wells in the field.

The waterflood was set up under an 80 acre unit agreement with the basic 5-spot pattern. Total field production through 1975 was 10,832,151 barrels of oil and 18,670,641 Mcf of gas. Originally estimated recoverable stock tank oil was 7,750,000 barrels. This figure was reached in 1970 and since that time approximately 3,080,000 barrels of additional oil have been produced that are attributable to secondary recovery methods. The original gas-oil ratio for the field was 800-850 cubic feet per barrel (CFPB).

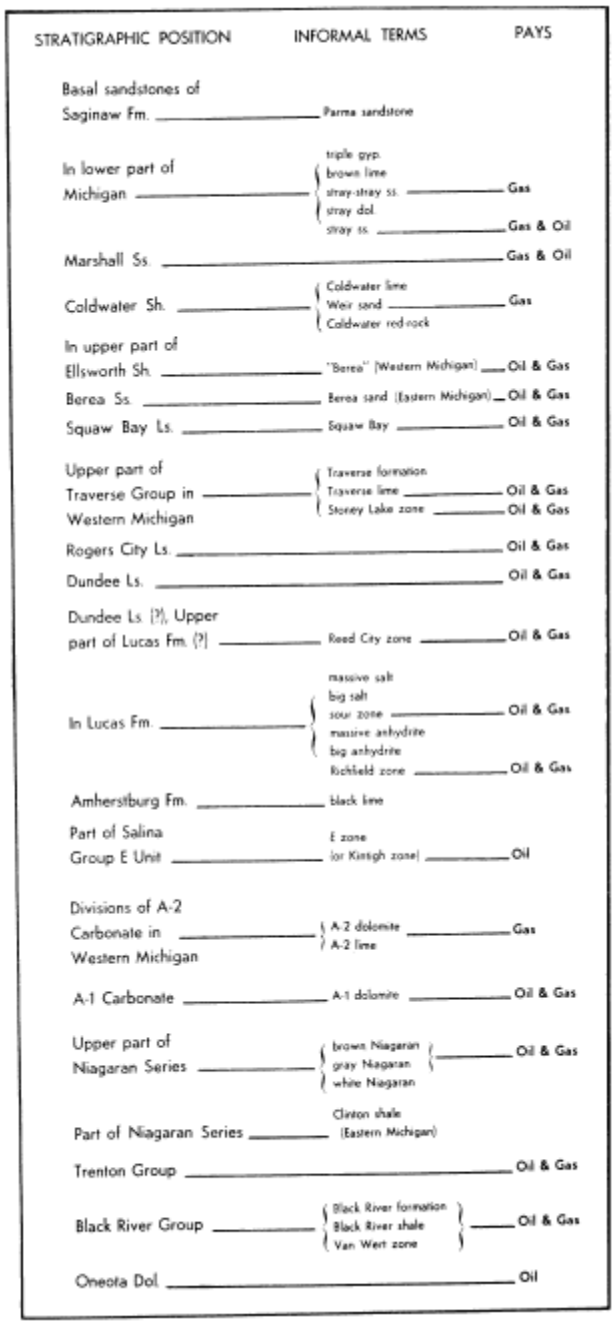

Figure 1. Principal oil and gas pays and informal terms used in petroleum exploration applied to parts of formations or groups of formations in the subsurface of the Michigan Basin.

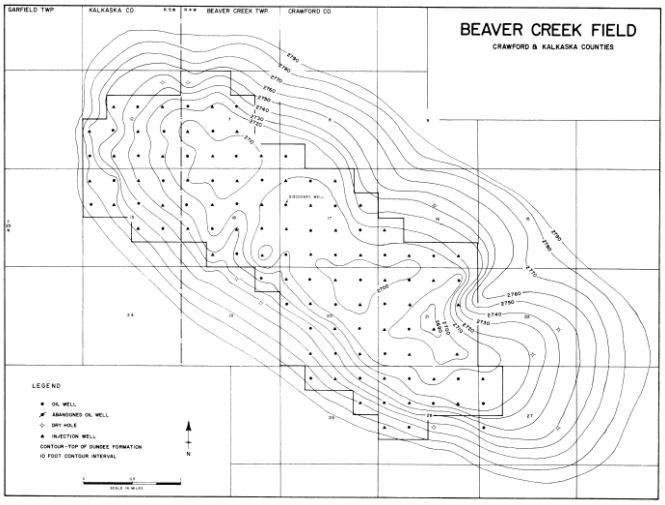

Figure 2. Structure of the Beaver Creek Field contoured on top of the Dundee Formation.

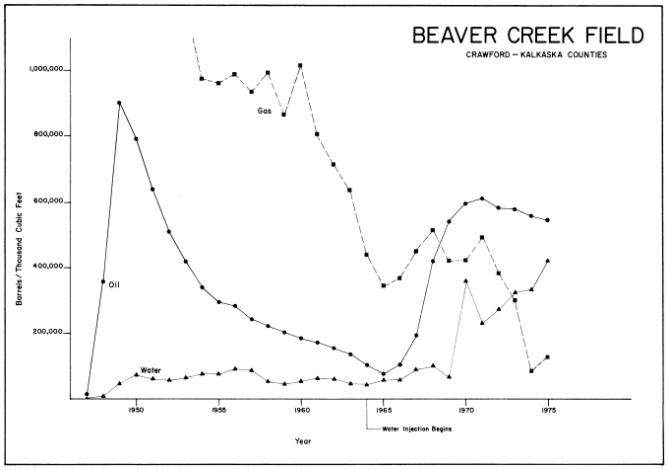

Figure 3. Oil, gas, and water production shown from the Beaver Creek Field. Oil and water production is shown in barrels. Gas production is shown in thousand cubic feet (MCF).

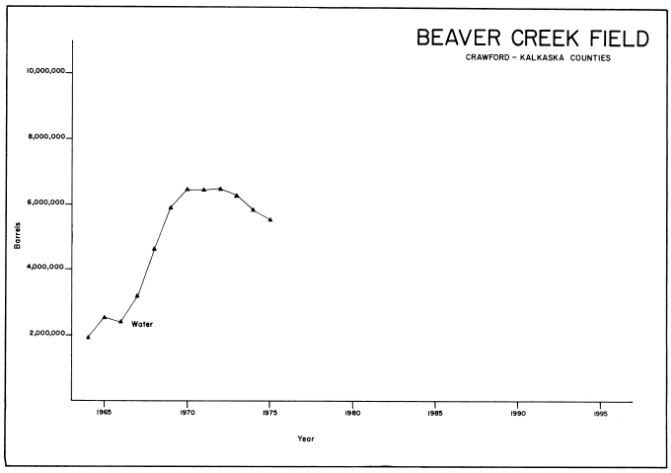

Figure 4. Water injected into the Beaver Creek Field to enhance oil and gas recovery. Injected water is shown in barrels.

Data Sheet No. 1

Beaver Creek Field

Richfield Waterflood Project

GENERAL POOL DATA	
Location	Crawford County, Beaver Creek Twp. (T25N, R4W) and Kalkaska County, Garfield Twp. (T25N, R5W)
Date of pool discovery	July 21, 1947
Discovery well	Pure Oil Company (Union Oil of California) State-Beaver Creek A-1, Permit Number 12988
Producing formation	Richfield Zone (Detroit River Group)
Pay zone lithology	Dolomite
Type of trap	Anticline
Drilled acres	4240
Unit acres	4680
Reservoir area, estimated	4600
ENGINEERING DATA	
Type of reservoir energy	Solution gas and gas cap expansion
Original reservoir pressure	2138 psi
Reservoir temperature	114°F
Viscosity of original reservoir oil	0.5 cp
Bubble point pressure	1886 psi zone 3, 1727 psi zone 4
Formation volume factor	1.4300
API oil gravity	40° to 45°
Original solution gas-oil ratio	800 to 850 cfpb
Average porosity	15% (0 to 25%)
Average permeability	0 to 19 md
Connate water (estimated)	34.2%
Net oil pay thickness	17.2 ft.
Acre feet of oil pay	79,120
RECOVERABLE HYDROCARBON DATA*	

Estimated original stock tank oil in place	39,700,000 bbls.
Estimated original recoverable stock tank oil	7,750,000 bbls. (recovered)
Calculated recoverable stock tank oil per acre foot	98.0 bbls. primary; 171.0 bbls. primary and secondary
Original gas in solution	36,000 million cubic feet (MMcf) est.
Estimated original recoverable gas	NA
Estimated additional recoverable oil due to secondary recovery methods	5,786,149 bbls.

*Estimations by Union Oil of California prior to initiation of waterflooding. Oil production through the end of 1975 exceeded estimate by 3,082,151 barrels.

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Beaver Creek Field, Crawford and Kalkaska Counties							
Year	Production Data						Remarks
	Gas		Oil		Water (estimated)		
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	
1947			14,744	14,744	1,312	1,312	
1948			369,732	384,476	9,855	11,167	
1949			904,342	1,288,818	49,640	60,807	
1950	1,256,492	1,256,492	794,123	2,082,941	74,460	135,267	
1951	1,531,619	2,788,111	640,556	2,723,497	61,320	196,587	
1952	1,381,141	4,169,252	510,192	3,233,689	59,130	255,717	
1953	1,223,017	5,392,269	420,509	3,654,198	66,430	322,147	
1954	977,129	6,369,398	342,183	3,996,381	78,840	400,987	
1955	963,017	7,332,415	298,310	4,294,691	78,110	479,097	
1956	990,818	8,323,233	285,357	4,580,048	93,075	572,172	
1957	937,971	9,261,204	242,850	4,822,898	88,695	660,867	
1958	997,537	10,258,741	222,876	5,045,724	52,560	713,427	
1959	869,596	11,128,337	203,716	5,249,490	48,910	762,337	
1960	1,019,782	12,148,119	186,240	5,435,730	52,147	814,484	
1961	806,702	12,954,821	173,478	5,609,208	62,300	876,784	
1962	713,971	13,668,792	156,576	5,765,784	60,955	937,739	
1963	636,936	14,305,728	137,585	5,903,369	48,180	985,919	
1964	439,738	14,745,466	102,233	6,005,602	46,720	1,032,639	Waterflood project begins
1965	344,517	15,089,983	79,211	6,084,813	59,130	1,091,769	
1966	369,834	15,459,817	105,284	6,190,097	59,860	1,151,629	
1967	450,656	15,910,473	195,842	6,385,939	90,402	1,242,031	
1968	514,225	16,424,698	420,511	6,806,450	100,375	1,342,406	
1969	422,080	16,846,778	542,674	7,349,124	69,350	1,411,756	

1970	425,068	17,271,846	597,839	7,946,963	361,350	1,773,106	Oil production surpasses original estimated
1971	495,118	17,766,964	612,402	8,559,365	231,410	2,004,516	
1972	383,207	18,150,171	585,821	9,145,186	276,305	2,280,821	
1973	300,614	18,450,785	580,626	9,725,812	326,822	2,607,643	
1974	88,960	18,539,745	560,144	10,285,956	334,888	2,942,531	
1975	130,896	18,670,641	546,195	10,832,151	422,342	3,364,873	

Table 1. Oil, gas, and water production from the Beaver Creek Field. Oil and water production figures are shown in barrels. Gas production figures are shown in thousand cubic feet (Mcf).

Beaver Creek Field, Crawford and Kalkaska Counties								
Year	Injection Data							
	Gas			Water			Pressure	
	No. Wells	Annual	Cumulative	No. Wells	Annual	Cumulative	Gas	Water
1963								
1964				41	1,941,254	1,941,254		2,250
1965				41	2,555,278	4,497,032		2,475
1966				41	2,413,283	6,910,315		2,470
1967				41	3,206,667	10,116,892		2,200
1968				55	4,648,305	14,765,287		2,172
1969				58	5,901,388	20,666,592		2,450
1970				58	6,457,883	27,124,457		2,200
1971				58	6,440,253	33,564,728		2,200
1972				58	6,489,694	40,054,422		2,200
1973				58	6,250,774	46,305,196		2,295
1974				58	5,836,198	52,141,394		2,150
1975				58	5,528,095	57,669,489		2,285

Table 2. Water injection data for the Beaver Creek Field. Water figures are in barrels.

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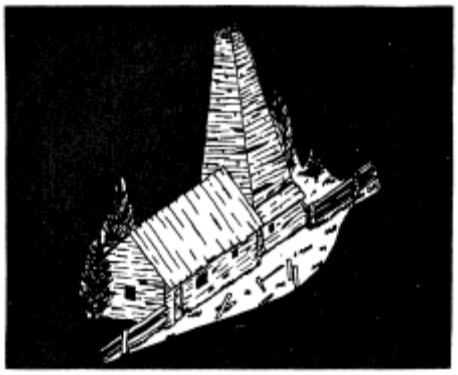
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