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THE RICHFIELD CHALLENGE

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FOREWORD

This review of the development of the Richfield pay zone in Michigan oil fields is not intended as a complete dissertation on any of the various facets and problems of this producing section.

The complex character of the Richfield makes broad generalization difficult and somewhat questionable. The review is written primarily to acquaint those unfamiliar with the so-called Richfield formation with its broader aspects, the major oil developments in it, and with present production practices and potential possibilities of the formation; also, to propose that "Richfield" be recognized and formally adopted as the name of a subsurface member of the Detroit River group not represented in the outcrop area.

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THE RICHFIELD CHALLENGE

A Review of the Richfield Developments in Michigan

The Richfield is a subsurface oil field name originally applied to that section of the Detroit River Group of dolomites, anhydrites, and thin irregular dolomitic limestones that lies below massive anhydrites and above a highly fossiliferous black coralline limestone. The name first was used in Richfield (now AuSable) Township of Roscommon County by Sun Oil Company geologists when referring to the producing section in their Bauman No. 1 discovery well of the St. Helen Oil Field. Later in other areas several pays producing sweet crude were developed in similar dolomites above the base of the big anhydrite, and these also were included in the Richfield. In oil field terminology the Richfield generally now includes all the section that produces sweet crude below the massive anhydrites that underlie the lowest Detroit River salt beds, and above the highly fossiliferous black coralline limestone.

General Stratigraphy and Lithology of the Richfield

The Detroit River Group of the Devonian rock series has until recent years been used as a catch-all name for formations below the Dundee Limestone and above the Sylvania. The group generally is described as an evaporite series characterized by alternating beds of anhydrite, limestone, dolomite and salt. The individual beds vary from thick massive salts and anhydrites to thin beds of limestone, dolomite, salt and anhydrite. Many beds are lenticular. The thickening and thinning or lensing out of the beds make regional correlations based on the anhydrites and dolomites not only very difficult and time consuming, but of extremely doubtful value.

The Richfield is the basal member of the evaporite series, being the transitional zone between the true evaporites above and the highly fossiliferous marine black coralline limestones below. If confusion in terminology is to be avoided, the Richfield then becomes the basal member of the Detroit River Group of evaporites.

The Richfield includes approximately a 200-foot section above the black coralline limestone and produces sweet crudes from fine-grained, brown to buff, granular to crystalline dolomites which range from a few inches to ten feet in thickness. The dolomites are separated by anhydrites and some thin lenticular limestones.

Below the lowest massive Detroit River salt bed and above the massive anhydrite, a section ranging in thickness from 150 feet to 200 feet contains sour oil and gas. This section is limestone predominantly but the pays are dolomitic and in many places are separated by thin anhydrite or salt beds. This zone of the basin has been correlated with the Tuscola pay in the Akron Field, Tuscola County. In the basin the massive anhydrite separates the sour Tuscola zone from the Richfield. A detailed description of well borings is necessary in order to pick the top and the bottom of the Richfield. The base of the thickest Richfield anhydrite, ranging from 15 feet to 25 feet, frequently is used for correlation between wells in the individual fields.

The Richfield is the section producing sweet oil, and nearly everywhere is 1200 feet to 1300 feet below the top of the Dundee Formation in the area of major development in Roscommon, Ogemaw, Crawford, Missaukee, and adjacent areas. No definite marker beds have been recognized between the top of the Dundee and the Richfield. The massive fossiliferous, black coralline limestone below the Richfield, now frequently reported on the drilling logs, apparently is an excellent marker for stratigraphic correlations throughout the producing area, but, in determining the base of the Richfield, caution must be exercised to pick the correct - the coralline - black lime.

The Richfield section contains ten or more dolomite beds that range from a few inches to ten feet in thickness, separated by anhydrites and some lenticular limestones. The interval between beds varies from two to thirty feet. At least six of the dolomite beds have shown oil saturation, and four or more are considered important reservoirs. The dolomites are not saturated completely with oil. In most places, the oil is concentrated in streaks or lenses of relatively low porosity and permeability which range from several inches to a few feet in thickness.

On producing structures the pays are limited in areal extent by the limits of porosity and permeability. In the more porous and thicker zones, the pays are limited by edge water or high percentage connate water saturation. The porosity variations are somewhat local and range from 7 to 30 per cent. The average for total pay sections in individual fields is between 14 and 17 per cent. Core studies and well performance data show that the porosity range throughout the Richfield producing area is relatively uniform. The dolomites are considered to be productive when permeabilities are as low as 0.5 millidarcy but only where such low permeability is associated with more permeable streaks that can act as pipelines or carriers for the tighter portions of the pay. The permeability variations are local, and nearly everywhere are associated with porosity variations. Permeabilities range from 0.5 to 60 millidarcies with an average of 4.0 to 6.5 millidarcies for overall pay section in the individual fields.

History

The first commerical Richfield producing well was completed in December of 1941 by the Sun Oil Company in AuSable, formerly Richfield, Township of Roscommon County, in the area now known as the St. Helen Oil Field. This well, after acidizing, produced 150 barrels of sweet crude oil daily in initial flow tests. The development of commercial production in the zone encouraged deeper drilling and testing in other producing areas of the State where earlier drilling to shallower producing formations indicated major anticlinal structures. Many wells in wildcat areas were set up with the Richfield or lower zones as objectives and scattered producing wells were completed in various parts of the basin.

A zone producing sour crude was encountered overlying the Richfield and several wells soon were producing oil commercially from this (Tuscola type) sour pay. The operators unfamiliar with the Richfield and observing low initial producing rates, deemed "discretion the better part of valor", and were slow to offset wells then considered marginal producers. Time passed and the wells continued to flow and gradually wells paid off while production still remained above marginal limits. The industry began to study the records in the various areas and realized that a new and entirely different major producing zone had been found. Additional drilling of the Richfield slowly increased the area of production. New equipment, acidizing, and production techniques were developed to meet the requirements of this new pay. Wells which formerly would have been abandoned now are made into commercial producers and higher initial producing rates are more common. Older wells were deepened, reworked, or reacidized where new information indicated all pays had not been penetrated. Wells showed improved performance when reacidized by new methods. Engineering studies showed the fields were gas drive reservoirs. A pilot pressure maintenance plant was put into operation in the East Norwich Field in Missaukee County in July of 1947.

In 1952, ten years after discovery, five Richfield pools were numbered among the top 15 fields of the State in daily average production. The prospects for the future look bright with development continuing at an increasing tempo in all Richfield producing areas.

The pilot injection project in East Norwich is showing very encouraging results and plans are underway to enlarge the program. Operators in other areas are following closely the developments in East Norwich and are considering establishment of similar projects in other Richfield reservoirs. The industry now is studying and working on the application of unitization plans in several of the larger fields to avoid the inefficiencies and inequalities of haphazard fluid injection programs.

Extensions and wildcat wells now in the process of completion have reported excellent natural shows in the Richfield in several basin areas, pointing the way to new potentially major producing areas. All signs point to a continued orderly development and the application of the latest technological developments to the problems of Michigan's newest major producing zone, the Richfield.

Rate of Development

The development of the Richfield has been slow due to many factors, including: Relatively low initial production rates, low daily average producing rates and associated long pay out periods, high completion costs, above average depth of wells, and lack of adequate information on well and field recoveries based on actual performance data. War time shortages and emergency conditions have tended to hold down development of the Richfield.

Completion Practices

The Richfield cannot be discussed without considering well completion practices which account frequently for 25 per cent of the overall costs of the wells. Many of the rotary wells now are coring the entire producing section of the Richfield with diamond coring bits which average close to 100 per cent core recovery. Rather detailed descriptions of these cores are made. Sections of the cores from pay zones are sent to laboratories for analyses to obtain data on porosity, permeability, and oil and water saturations. Acidizing programs usually are based on core studies, if available. Spinner or electric pilot surveys are run to locate and evaluate the number of permeable zones in order to plan acidizing programs on wells spudded into the producing section. Packers of various types are used in most wells to separate pays in an effort to acidize individual pays. Under ideal conditions, each pay should be acidized separately in order to insure adequate acidization of individual pays. Packers have been successful in many wells, but frequent failures of packers, cement, or vertical breakdown between perforations have been reported. When pipe is run through pay zones and cemented, the casing must be perforated in sections showing permeability and oil saturation.

Initial Production Rates

Before acid, many wells have showings that range from a smell of oil to several hundred feet of oil in hole. Many wells of this kind flow from 20 to 70 or more barrels per day after acid treatment. Some wells flow when drilled in, but such wells are always improved by acid treatment. Records show that 10- to 70-barrel flowing wells become 40- to 300-barrel wells when acidized.

Production Practices

Oil is produced from Richfield pays essentially by the stop-cock method of production with short flow periods and relatively long shut-in periods. The wells are shut-in when accumulated oil in casing is produced and gas begins to break through from casing into the tubing, thus conserving the gas energy in the casing. Recently, application to the flowing wells of flow intermitters, either pressure or time controlled, in order to better control and prevent excess loss of gas during break through period, has become a widespread practice. Tests have shown a substantial decrease in gas-oil ratios and a steadier production with less down time when oil is flowed by intermitters. At all times, wells in the Richfield produce very near to full capacity, and will not produce appreciably more oil if casing pressures are lowered by bleeding off casing gas.

Water Conditions

Brine production has not yet proved to be a major problem. The wells produce small quantities of brine -- from one-half to seven barrels daily. Richfield connate waters are highly saline approaching saturation with chlorides. The majority of the wells are treated at regular intervals with fresh water or a mixture of fresh and salt water to prevent salting off of tubing and to remove salt from the face of the formation. The water is pumped or lubricated into the wells through the casing and allowed to remain on the bottom during intervals between flows, and is produced during the subsequent flow period. It also is necessary to hook the wells at frequent intervals to remove paraffin accumulation from the tubing.

Field Production Data (March 31, 1952)

FIELD	NUMBER OF WELLS PROD.	PUMP	FLOW	BARRELS OIL/DAY PER WELL	CUMULATIVE OIL PRODUCTION	DAILY OIL	DAILY WATER
Beaver Creek	90	32	58	17.2	2,868,061	1550	125
East Norwich	75	16	59	16.8	2,924,878	1260	165
St. Helen	73	9	64	16.8	1,448,219	1230	81
Rose City	61	25	36	19.7	609,954	1200	40
Enterprise	26	6	20	20.3	569,581	527	82

Gas-Oil Ratios

Gas-oil ratios in the Richfield range from nearly natural dissolved gas-oil ratio of reservoir fluid, or approximately 800-900 cubic feet per barrel, to ratios in excess of 100,000 cubic feet of gas per barrel.

Gas-Oil Ratios (The five major Richfield reservoirs, April, 1952

FIELD	GOR (cfpb) LOW	HIGH	GAS WELLS	DAILY GAS CU. FEET*	GOR CFPB
Rose City	500	3,207	4 shut-in	1,249,500	1050
St. Helen	244	4,950	3 shut-in 2 high	2,013,196	2041
Beaver Creek	485	4,554	2 gas 1 high	5,100,000	3319
Norwich	130	10,920	Gas converted to injection	3,100,000	2480
Enterprise	253	6,160	1 high	805,000	1530

*Based on gas production from wells that have been tested in the fields prior to April 1, 1952.

The Richfield crudes are saturated crudes at original reservoir pressures with from 775 - 850 cubic feet of dissolved gas per barrel. Rose City, St. Helen, Beaver Creek, and Norwich Oil Fields have gas caps in one or more of the pays in the structurally higher parts of the field. Some evidence that local gas caps occur outside the structurally higher areas has been found.

Reservoir Pressures

Reservoir pressure data are most useful to the petroleum engineer in analyzing well and reservoir performance. The exceptionally low permeability of the Richfield pay sections is evident immediately when wells are shut-in and allowed to build up to full static reservoir pressure. A very long shut-in period is required to attain static pressure even on relatively new wells showing higher initial pressure in the more permeable sections of the fields. Individual wells have reached near static pressure in 200 - 250 hours or from nine to ten days. One well was shut-in for five months and continued to build up pressure at the rate of approximately 100 pounds per month. Loss of revenue resulting from long shut-in periods has limited obtaining data on shut-in pressures to key wells and to shorter build-up periods of 100 - 110 hours. A program of 20-hour shut-in pressure surveys at six month intervals recently was adopted in several fields. It is hoped that these surveys will show reservoir performance as well as indicate actual day to day operating bottom hole pressures. The history of the 20-hour pressure surveys will become more valuable with each additional survey. These surveys permit the operator to follow normal flow schedules and do not entail the loss of revenue associated with longer pressure build-up periods.

Basic Reservoir Data (The five major Richfield reservoirs, April, 1952)

	NORWICH	ENTERPRISE	ST. HELEN	BEAVER CREEK	ROSE CITY
Original BHP (psi)	2310	2300	2270	2138	2000 ≠ (?)
Original BHT (°F)	114	116	108	114	107
Gas in solution	850	850	840	820	800 ≠ (?)
Net pay	14'	17'	11'	15'	10-11'
Viscosity (Centipoise)	.55	.5 Est.	.55 Est.	.5	.55 Est.
Porosity %					
Range	9-21	7-24	9-26	9-30	7-30
Average	17	15	17	14	15
Permeability (Md)					
Range	.5-50	.5-50	.5-60	.5-60	.5-60
Average	6	3.7	4	6.2	4
Connate Water	25% Est.	25% Est.	25% Est.	25% Est.	25% Est.
Gravity Oil °API	41-44	41-44	41-44	41-44	41-44
Shrinkage Factor	.70 Est.	.70 Est.	.714	.71	.70 Est.
Formation Vol. Factor	1.44	1.44	1.40	1.42	1.44
Recovery per ac/ft*					
Barrels	135-140	130-150	130-140	140-150	130-135
Recovery per acre*					
Barrels	1890-2000	2200-2500	1450-1550	1960-2100	1430-1500
Recoverable Oil STO*					
Barrels	5,650,000	2,652,000	3,840,000	7,550,000	3,360,000
Oil in place, STO*					
Barrels	28,300,000	13,260,000	19,200,000	37,800,000	16,800,000

*Estimated recoveries and oil in place based on approximate pay thickness and performance of wells completed and on production in early April, 1952.

At the present time we have approximately 115,400,000 ≠ barrels of Richfield oil in place of which, by primary producing methods, we can expect to produce an estimated 20% or close to 23,000,000 barrels of oil.

Type of Drive

All of the Richfield reservoirs are gas-drive reservoirs. Gas-drive fields basically are those fields where gas is the primary energy source for the producing mechanism. Three sources of gas energy are available in reservoirs having gas caps such as Beaver Creek, East Norwich, St. Helen, and Rose City -- the Richfield reservoirs:

1. Free gas in the gas cap or locally in structurally high areas, exerts an outward force capable of driving oil to wells down structure. Gas cap fields are most efficiently produced when the gas cap is allowed

to expand by limiting free gas withdrawal and by returning the produced gas to the reservoir. An expanding gas cap aids in maintaining a lower rate of pressure decline through conservation of available gas energy. A lower rate of pressure decline means higher producing rates and longer producing life for wells.

2. Free gas in suspension or bubbles and lentils of free gas throughout the reservoir occur in many pays that have saturated reservoir fluids similar to the Richfield. This gas expands as pressure declines, creating a force capable of moving oil toward low pressure areas around the producing wells. Free gas will displace oil from structurally higher undrained areas or undrained pore spaces, and materially increase ultimate recoveries. When excess free gas enters producing channels, the result is high gas-oil ratios and a decline in recovery efficiency.

3. Dissolved gas is that gas held in solution or dissolved in the oil. This gas reduces the viscosity of the oil and is available for work by conversion to free gas as pressure is reduced. The dissolved gas supplies a large part of the energy required to lift the oil to the surface under flowing conditions and increases the numbers of gas globules held in suspension as reservoir pressures decline.

No Effective Water Drive

Brine production has been very small in the Richfield reservoirs and field performance data show the absence of an effective water drive.

Gas-Oil Ratios as an Index to Recovery Efficiency

All available reservoir and field performance data indicate a low order of recovery efficiency in the Richfield reservoirs. Since gas is the only source of energy for the producing mechanism, economic production of oil will cease when the supply of gas is exhausted or when pressure energy of gas is no longer capable of forcing fluids into the well bores. Wells in the Richfield are drilled primarily for the production of oil. Any gas encountered in the oil-bearing strata is associated with oil and should be conserved and utilized for the efficient production of oil. No well should produce gas in excess of that minimum necessary to obtain its normal daily oil production. The efficiency with which a gas-drive is operated lies in the amount of stock tank oil produced per unit of net gas produced. The producing gas-oil ratio can thus be utilized to compare efficiency of various operating methods. The average field gas-oil ratio becomes a basic working tool for the engineer in analyzing reservoir performance. The majority of the wells in the Richfield are unable to produce appreciably more fluids than shown in test work, as they are limited by the physical characteristics of the pays. Gas cap wells can produce gas with little or no oil on a 24-hour basis. These wells withdraw large quantities of fluid or gas energy from the reservoir at the expense of more efficient wells. The result of large free gas withdrawals is a major decrease in recovery efficiency.

Gas Conservation and Pressure Maintenance will increase Recoveries

The conservation of gas in gas-drive reservoirs has been a major problem in the industry for many years. The rapidly increasing cost of finding and developing new reserves throughout the nation is forcing attention on improved recovery methods. Need for some form of pressure maintenance in the Richfield reservoirs if recovery efficiency is to attain higher levels, is demonstrated. The large areal extent of the fields, the pay thickness, the present low recovery efficiency, the high cost of developing new reserves, the wide spacing pattern, and the increasing success and interest in pressure maintenance all are factors favoring the eventual adoption of fluid injection programs for the Richfield reservoirs. In other states, the return of produced gas to the reservoirs has proved more workable under unitization plans. Field unitization has enabled engineers to produce the reservoirs under optimum conditions. Millions of barrels of additional oil now are being recovered under such plans. Feasibility and success of gas injection in the Richfield has been established by the pilot gas injection project in the East Norwich Field operated by the Sun Oil Company. Water injection has not yet been attempted, but is a future possibility.

The East Norwich Pressure Maintenance Project

Discussion of the East Norwich gas injection project requires a basic understanding of the physical characteristics of the pay and a knowledge of actual well and field performance trends. It is hoped that the preceding discussion has given this basic background.

Five wells have been used for gas injection in the East Norwich Oil Field. Three wells now are in use and daily injection rates are close to 500,000 cubic feet per well at 2100-2150 pounds per square inch well head pressure. Producing wells surrounding the injection area have reflected the influence of pressure maintenance by a deviation from normal established field production-decline curves. Wells directly offsetting the injection wells begin to show a lower rate of production-decline in from eight to ten months. Wells two locations from injection area indicated a retardation of normal decline in from eighteen to twenty months, and wells in the third row in approximately thirty months. The producing wells nearest the gas injection area have shown increased production and a reversal of the average established production-decline curves for wells in this field. Production from wells within the influence of gas injection has been sustained at rates above production rates from wells outside the area. After almost five years of gas injection, no channeling has been observed in this field. The uniformly low permeability of the dolomite pays and the local nature of the streaks of somewhat higher permeability are believed to be responsible for the absence of gas channeling and the concentric advance of the gas front. All pays are open in newer injection wells, as it is evident that each pay takes gas in proportion to its percentage of permeable pay section. Producing rates on wells with high gas-oil ratios have remained well above normal, indicating a flushing or sweeping action associated with some recycling as the gas front advances. Gas-oil ratios have shown gradual increases, but no well has shown an excessive rise in gas production associated with a sharp decline in oil production. Plugging back and selective acidization of one injection well was attempted in an effort to produce oil from an upper pay. The well produced approximately 65,000 M.C.F. of gas with no oil in several months of testing. An offset well that produced seventy barrels of oil daily at the start of the test declined to less than thirty barrels daily before the project was abandoned. This experiment proved the value of gas injection in the area, and at the same time showed gas was being injected into several pays.

Reservoir pressure studies in the injection area show higher producing bottom hole pressures. The pressure contours give evidence of a uniform area of influence around the injection wells.

Evidences of the success of the East Norwich gas injection project are: Higher current producing rates, retardation and reversal of production-decline curves, higher reservoir pressures, widening area of influence, uniform advance of gas front, no apparent channeling or by-passing of gas, and the comparative performance of wells inside and outside the injection area.

The potentialities of gas injection or pressure maintenance in the Richfield of Michigan may be demonstrated by using the East Norwich injection area as a yardstick. Conservative estimates based on performance in the East Norwich injection project already show an anticipated increase in recovery of over fifty per cent. The reserves in the Richfield are large, and recent discoveries, new extensions and development of proved areas will add rapidly to these reserves. An increasing percentage of Michigan's future petroleum production may be expected to come from the Richfield and deeper formations. Every new producing section presents new problems which are a challenge to the industry. The problems of the Richfield have presented one of the greatest challenges faced by the industry in Michigan to date. The problems are being solved, and with the example of East Norwich before it, the industry now is moving forward confidently to meet "the Richfield Challenge" and then on to deeper formations.