PUERTO CHIQUITO MANCOS, WEST

(Oil)

T. 25-27 N., R. 1 E., R. 1 W., NMPM
Rio Arriba County, New Mexico

By: Albert R. Greer
Benson-Montin-Greer Drilling Corporation

GEOLOGY

Regional Setting: Eastern flank, San Juan Basin

Surface Formations: Cretaceous, Lewis Shale and Tertiary, Ojo Alamo Sandstone

Exploration Method Leading to Discovery: Surface and subsurface geology

Type of Trap: Stratigraphic, fractured shale

Producing Formation: Cretaceous, Niobrara interval of Mancos Shale

Gross Thickness and Lithology of Reservoir Rocks: Approximately 150 feet total of three separate zones within an overall section of approximately 250 feet of fractured shale

Geometry of Reservoir Rock: Apparently (from interference tests) a jigsaw pattern of tight, low permeability, blocks interconnected by a high capacity fracture system. Tight blocks are measured in terms of tens of acres of reservoir volume

Other Significant Shows: Cretaceous, Dakota Sandstone gas and distillate (low volume)

Oldest Stratigraphic Horizon Penetrated: Jurassic, Morrison Formation

DISCOVERY WELL

Name: Bolack-Greer No. 2 Bolack (present operator: Benson-Montin-Greer Drilling Corp.)

Location: NE SW (1785' FSL and 2120' FWL) sec. 13, T. 25 N., R. 1 W., NMPM

Elevation (KB): 7,090 feet

Date of Completion: July 23, 1963

Total Depth: 6,022 feet

Production Casing: 5½" at 5,976 feet with 150 sacks of cement

Perforations: None (open hole)

Stimulation: 100 gallons acid and sand-oil fractured with 85,620 gallons oil and 111,000 lbs sand

Initial Potential: 95 BOD (pump)

Bottom Hole Pressure: 1,620 psig at datum of + 1,195 feet

DRILLING AND COMPLETION PRACTICES

Surface Casing: 400 feet of 10¾" cemented to surface

Intermediate Casing: 7 5/8" set within 500 feet of pay zones with enough cement to cover Mesaverde Group

Production Casing (Liner): 5½" cemented back up into intermediate casing, hole below intermediate drilled with gas if available, or air, or air and nitrogen

Stimulation: Sand-oil fracture with 200,000 to 500,000 lbs of sand, 200,000 to 500,000 gallons of lease crude, injection rates of 50 to 100 barrels per minute

NOTE: Above approximates conditions for majority of wells drilled in sixties and early seventies

RESERVOIR DATA

Productive Area:
Proved (as determined geologically): Approximately 50,000 acres within participating area of unit
Unproved: Several thousand acres within pool boundaries outside of unit
Approved Spacing: 320 acres
No. of Producing Wells: 11 (4 injection, 7 observation or temporarily suspended)
No. of Abandoned Wells: None
No. of Dry Holes: None following discovery well, 2 prior to discovery well

Average Net Pay: Indefinite, probably less than 50 feet

Porosity: Indefinite, fracture porosity probably on order of 1 percent

Permeability: Unknown (transmissibility, from interference tests, ranges up to 6 darcy-feet)

Water Saturation: Unknown, probably quite low

Initial Field Pressure: 1,620 psig at + 1,195 feet datum

Type of Drive: First 15 years, primarily gravity drainage, with some liquid expansion initially; pressure maintained essentially constant by gas injection from fifth to fifteenth year (1968 to 1978); final stages of depletion will include solution gas drive and gas "cycling" by gas injection

Gas Characteristics and Analysis: Sweet, primarily solution gas with some gas cap gas; CO_2 and N_2 0.3 percent; methane through hexanes 26 percent; heptanes + 46 percent

Oil Characteristics and Analysis: Sweet, 39° to 40° API gravity, yellow-green

Associated Water Characteristics and Analysis: No produced water

Original Gas, Oil, and Water Contact Datums: Gas-oil, approximately + 1,600, no bottom water

Estimated Primary Recovery: See "Field Commentary"

Type of Secondary Recovery: See "Field Commentary"

Estimated Ultimate Recovery: See "Field Commentary"

Present Daily Average Production: 750 BOD (December, 1977)

Market Outlets: Oil: pipeline to Shell's system for most part, some trucked to Bloomfield; gas: all but small volume is gathered and injected in reservoir. None sold.

FIELD COMMENTARY

The Puerto Chiquito Mancos, West field is located about fifteen miles north of Regina, New Mexico. It underlies lands of the Santa Fe National Forest, the Jicarilla Indian Tribe,

CHARACTERISTICS OF THE RESERVOIR ROCK OF THE BOULDER AND PUERTO CHIQUITO POOLS AND THE GAVILAN EXTENSION OF WEST PUERTO CHIQUITO

Although the majority of the industry's oil reservoirs that are fractured are those that comprise a rock with matrix porosity laced with fractures, the operators in the Boulder and Puerto Chiquito pools have recognized the producing reservoirs to be of fracture porosity only. (See excerpts from 1978 Four Corners Geological Society publication: yellow and pink sheets next following).

BOULDER MANCOS

(Oil)

T. 28 N., R. 1 W., NMPM

Rio Arriba County, New Mexico

By: C. N. Needham
Mobil Oil Corporation

GEOLOGY

Regional Setting: East flank, San Juan Basin

Surface Formations: Cretaceous, Lewis Shale; Tertiary- Cretaceous, Animas Formation; and Tertiary, San Jose Formation

Exploration Method Leading to Discovery: Probably subsurface

Type of Trap: Fractured shale on a monocline

Producing Formation: Cretaceous, Mancos Shale

Gross Thickness and Lithology of Reservoir Rocks: See field commentary

Geometry of Reservoir Rock: See field commentary

Other Significant Shows: None

Oldest Stratigraphic Horizon Penetrated: Cretaceous, Mancos Shale

DISCOVERY WELL

Name: P-M Drilling Co. No. 1 Bayless

Location: NE NE (330′ FNL and 330′ FEL), sec. 15, T. 28 N., R. 1 W.

Elevation (KB): 7,427 feet

Date of Completion: May 15, 1961; plugging approved in 1965

Total Depth: 4,429 feet

Production Casing: 4½″ at 4,150 feet cemented with 50 sacks of cement

Perforations: Open hole 4,150 feet to 4,429 feet

Stimulation: Sand-oil fracture with 42,000 gallons of oil and 20,000 lbs. of 20/40 sand; treating pressure 2,500 lbs. Injection rate 33 barrels per minute

Initial Potential: Pump 85 BOD

Bottom Hole Pressure: Unknown

DRILLING AND COMPLETION PRACTICES

Set 8 5/8″ to 10¾″ casing at approximately 130 feet with 100 sacks of cement; drill with gel-type mud to about 600 feet above pay, set 5½″ to 7½″ intermediate casing with 150 sacks of cement; drill to total depth with gas or air; set 4½″ liner to total depth; perforate and oil-fracture with about 60,000 gallons of oil. Variations are to set slotted liner or complete open-hole. Some natural completions have been made.

RESERVOIR DATA

Productive Area:

Proved: 1,700 acres

Unproved: North and south limits of field not defined by dry holes

Approved Spacing: 80 acres

No. of Producing Wells: 7

No. of Abandoned Wells: 18

No. of Dry Holes: 4

Average Net Pay: Fractured reservoir; gross productive interval ranges from 51 feet to 643 feet and averages 278 feet

Porosity: Fracture porosity

Permeability: Fracture permeability

Water Saturation: Unknown

Initial Field Pressure: Unknown

Type of Drive: Gravity, solution gas

Gas Characteristics and Analysis: Unknown

Oil Characteristics and Analysis: 37° API gravity, 0.1 percent sulfur

Original Gas, Oil, and Water Contact Datums: Variable

Estimated Primary Recovery: Has produced 1,000 barrels per acre to July 1977

Type of Secondary Recovery: None

Estimated Ultimate Recovery: 1,700,000 BO, 1,500,000 MCFG

Present Daily Average Production: 60 BOD, 15 MCFGD, 14 BWD

Market Outlets: Oil, Shell Pipeline Corporation; gas, used for lease operation or vented

FIELD COMMENTARY

The Boulder field is in northwest New Mexico, about sixteen miles northeast of the town of Gavilan on State Highway 96 on the Jicarilla Indian Reservation. It is located on the east flank of the San Juan Basin.

The field is on a monocline imposed on regional west dip. No closure or nose is mapped in the area of the field. Production is from fractures in the Mancos Shale. The cause of the fractures in the San Juan Basin have been discussed by several authors who present different interpretations. The reader is referred to London (1972), and Gorham, and others (1977), for recent reports on fractured Mancos Shale production.

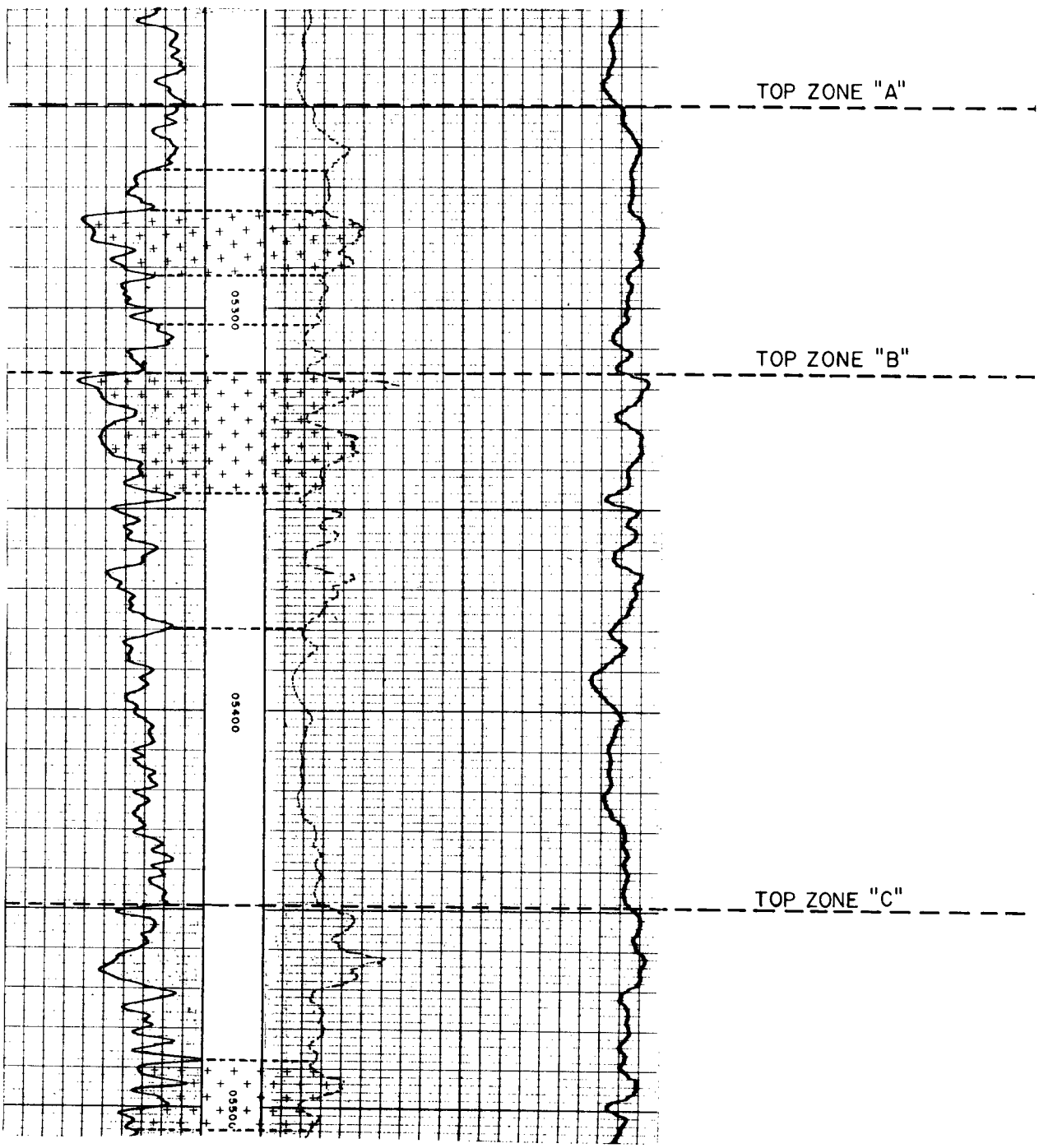
An analysis of a fractured reservoir such as Boulder is a singularly vexatious task because few parameters can be defined adequately. However certain observations can be made:

1. The field has produced 1,700,000 BO, 1,400,000 MCFG, and 700 BW since discovery. Production has ranged from a high of 465,798 BO in 1963 to a low of 16,197 BO in 1975. In July 1977, the field produced 60 BOD. The conclusion is that the field is nearly depleted using present production methods.
2. Water recovery has been reported on completion of some wells: S.O.T. No. 6, SE¼SW¼, sec. 26, T. 28 N., R. 1 W.; S.O.T. No. 7, NW¼NE¼, sec. 35, T. 28 N., R. 1 W.; Gulf No. 1-298, SE¼SE¼, sec. 10, T. 28 N., R. 1 W.; Mobil No. 14-23, SW¼SW¼, sec. 12, T. 28 N., R. 1 W.; and during the completion attempt S.O.T.

IDENTIFICATION OF MAIN PRODUCING ZONES
NORTHEAST PUERTO CHIQUITO
AND
SOUTHWEST PUERTO CHIQUITO

BENSON-MONTIN-GREER DRLG. CORP.

CAÑADA OJITOS UNIT NO. B-18



Some of the specific features of these reservoirs confirming that each one comprises fracture porosity only (no matrix porosity) are summarized briefly below; and described in a little more detail on the next following pages.

1. Lithology.

2. Cores of the reservoir rock showing fractures.

3. High percentage for sum of water and oil saturations found in cores.

4. Formation fracture treatments required to establish production.

5. Interference tests.

6. Production testing of the Canada Ojitos Unit C-34.

7. Testing during completion and drill stem tests.

8. Note: Porosity logs so far available are practically useless, since they do not show effective hydrocarbon porosity.

CHARACTERISTICS OF THE RESERVOIR ROCK OF THE BOULDER AND PUERTO CHIQUITO POOLS AND THE GAVILAN EXTENSION OF WEST PUERTO CHIQUITO

Reference: Item 1, Page 4.

"Lithology"

Although the subject reservoirs are referred to as "fractured shale reservoirs" and occur in the Niobrara member of the Mancos shale formation, the lithology of the reservoir rock varies from shale to siltstone to sandy layers; and sometimes containing a high percentage of calcium or dolomite. (Reference is made to AAPG paper by W.W. London, 1972, "Dolomite in Flexure-Fractured Petroleum Reservoirs in New Mexico and Colorado": American Association Petroleum Geologist Bulletin, v. 56, p. 815-821.)

Reference: Item 2, Page 4.

"Cores of the reservoir rock showing fractures"

Cores taken in the West Puerto Chiquito pool in the Canada Ojitos Unit L-11 and C-2 wells contained hairline horizontal fractures interesected by coarser vertical fractures.

CHARACTERISTICS OF THE RESERVOIR ROCK
OF THE BOULDER AND PUERTO CHIQUITO POOLS
AND THE GAVILAN EXTENSION OF WEST PUERTO CHIQUITO
PAGE 7

Reference: Item 3, Page 4.

"High percentage for sum of water and oil saturations found in cores"

9

CA-20

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

Page No.

CORE ANALYSIS RESULTS

Company BOLACK & GREER, INC. Formation GALLUP File RP-3-1916
Well CANADA-OJITOS UNIT 12-11 Core Type DIA. CONV. Date Report 8-30-64
Field WILDCAT Drilling Fluid 100% OIL Analysts HUFF
County RIO ARRIBA State NEW MEX. Elev. 7220 GR Location NW SW Sec 11 T25N R1W

Lithological Abbreviations

SAND-SD DOLOMITE-DOL ANHYDRITE-ANHY SANDY-SDY FINE-FN CRYSTALLINE-XLN BROWN-BRN FRACTURED-FRAC SLIGHTLY-SL
SHALE-SH CHERT-CH CONGLOMERATE-CONG SHALY-SHY MEDIUM-MED GRAIN-GRN GRAY-GY LAMINATION-LAM VERY-V
LIME-LM GYPSUM-GYP FOSSILIFEROUS-FOSS LIMY-LMY COARSE-CSE GRANULAR-GRNL VUGGY-VGY STYLOLITIC-STY WITH-W/

SAMPLE NUMBER	DEPTH FEET	PERMEABILITY MILLIDARCYS	POROSITY PERCENT	RESIDUAL SATURATION PER CENT PORE OIL	RESIDUAL SATURATION PER CENT PORE TOTAL WATER	SAMPLE DESCRIPTION AND REMARKS
1	6673-74	0.02	3.3	39.4	57.6	Sandstone, silty, carb
2	6674-75	0.22	4.4	22.8	68.2	Sandstone, silty, carb
3	6675-76	0.12	4.1	24.4	63.4	Sandstone, silty, carb
4	6676-77	0.03	4.0	25.0	52.6	Sandstone, silty, carb

Although the subject cores were allowed to weather under New Mexico's August sun on the drilling rig's catwalk (and the wellsite geologist was correct when he said that the cored rock was not productive and not worth analyzing), when the analysis was made the cores still contained too high a percentage of liquids to be representative of producible reservoir material.

Reference: Item 5, Page 4.

"Interference Tests"

Interference tests of West Puerto Chiquito show transmissibility on the order of 5 to 10 darcy feet with a volume of hydrocarbon pore space of about 2500 barrels per acre.

This 2500 barrels per acre could be contained in:

3 feet of producing reservoir with 10% porosity, or
2 feet of producing reservoir with 15% porosity.

Typical sand reservoirs with matrix porosity show permeabilities for these porosities on the average of about 1 millidarcy and 10 millidarcies respectively. The resulting transmissibility at 3 millidarcy feet and 20 millidarcy feet falls far short of that actually measured.

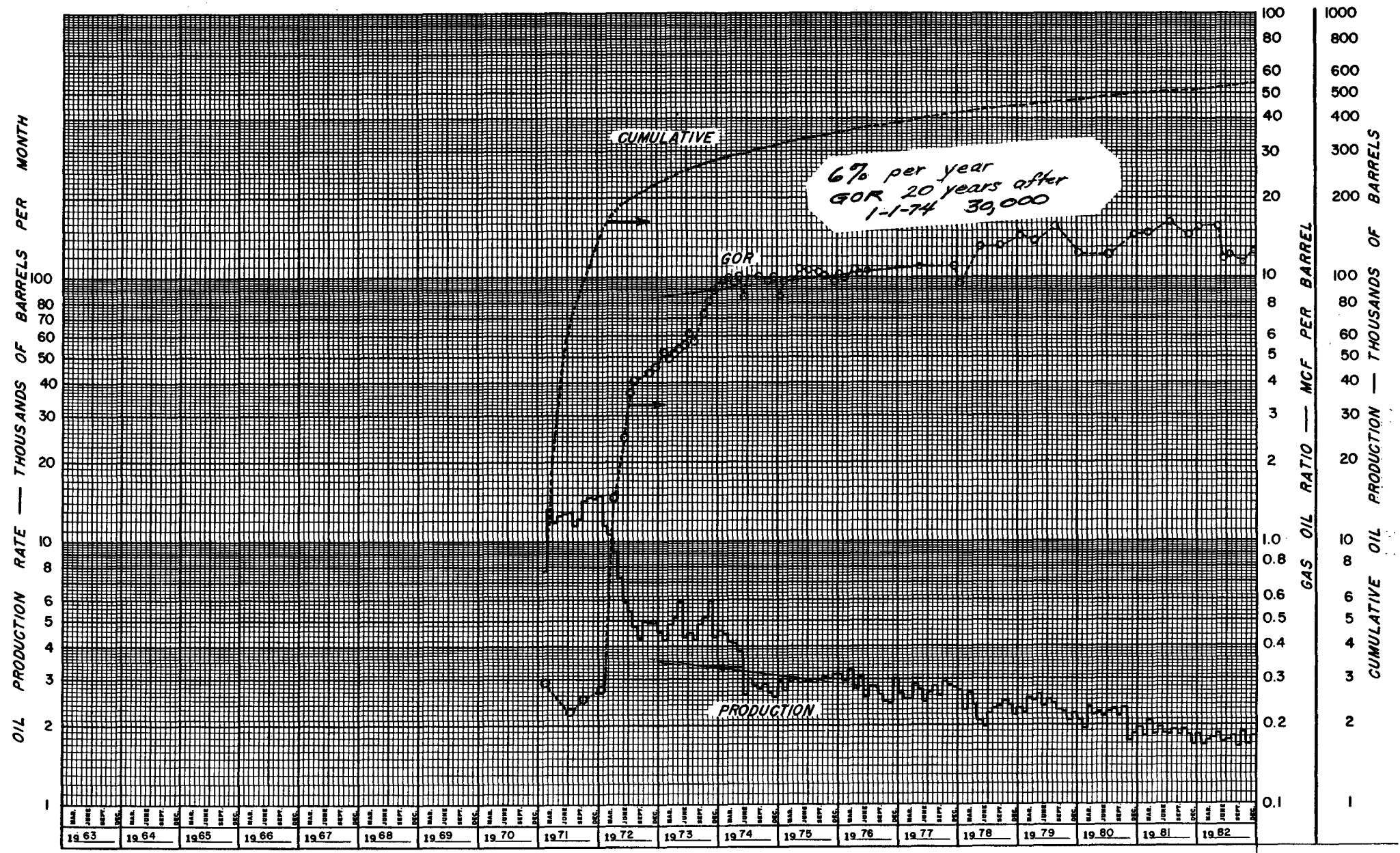
The measured transmissibility is 2000 to 3000 times that shown for a 10% porosity sand and 300 to 400 times that shown for a 15% porosity sand.

Reference: Item 6, Page 4.

"Production testing of the Canada Ojitos Unit C-34"

Testing of the C-34 well confirms the fact that a high capacity fracture system exists in which initial production resulted from gravity displacement of the high capacity system; followed by gravity displacement of the intervening "tight" blocks.

See graph next following.



PRODUCTION HISTORY
CANADA OJITOS UNIT WELL C-34

C.O.U. C-34
PRODUCTION
HISTORY

S. 34 - 25N - 1W

Reference: Item 7, Page 4.

"Testing during completion and drill stem tests"

For sands with matrix porosity, completion testing (and drill stem tests) ordinarily shows only a small volume of mud and mud filtrate before indigenous reservoir fluids are produced into the wellbore.

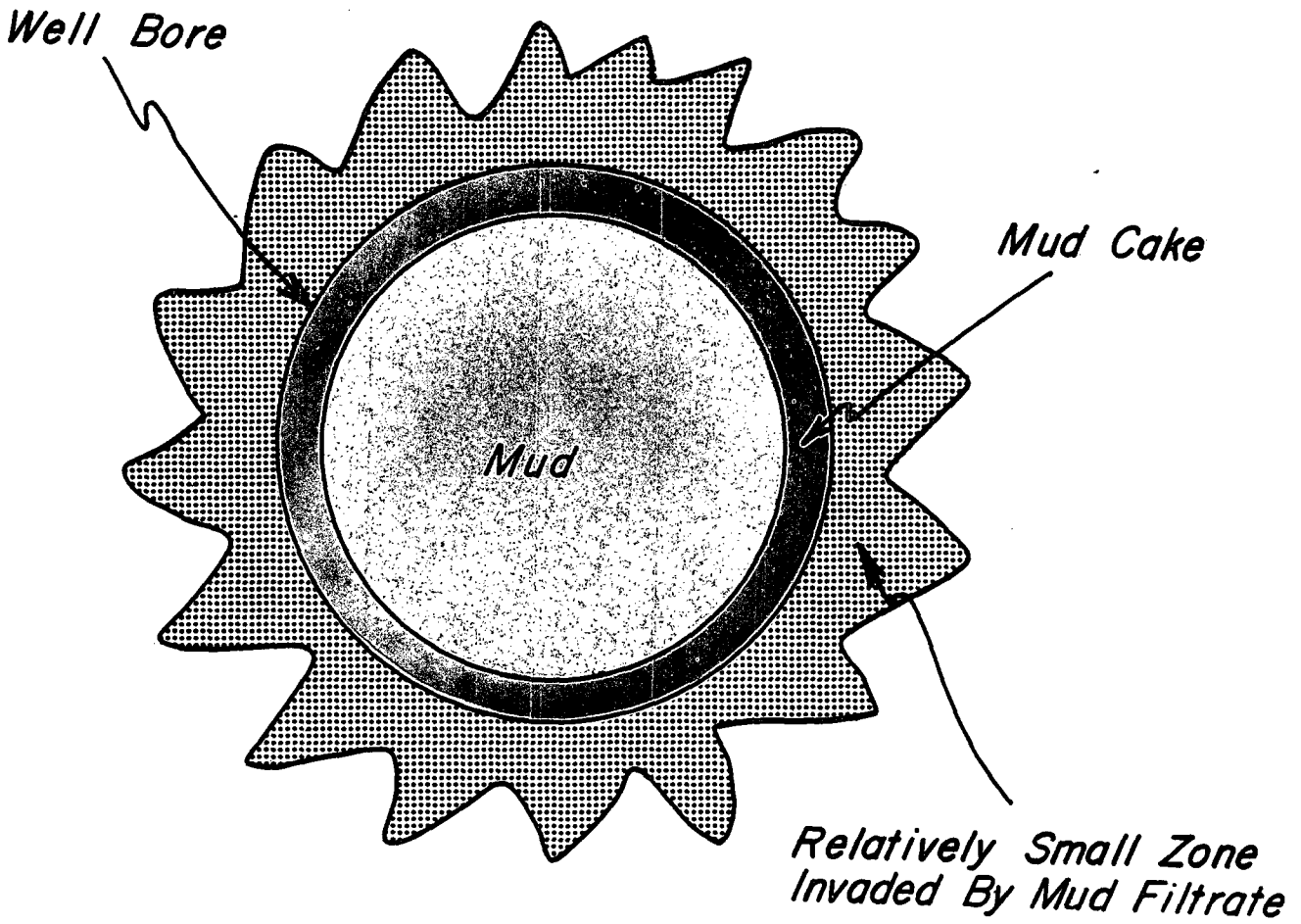
Conversely, for the fracture porosity of the Niobrara, these tests frequently show large volumes of mud or water which were induced thorugh lost circulation in the drilling or completion process.

This results when the wellbore has intersected fractures and the necessarily large volumes of mud (and usually lost circulation material) are used to finally plug off the fractures and regain circulation.

See sketches next two pages.

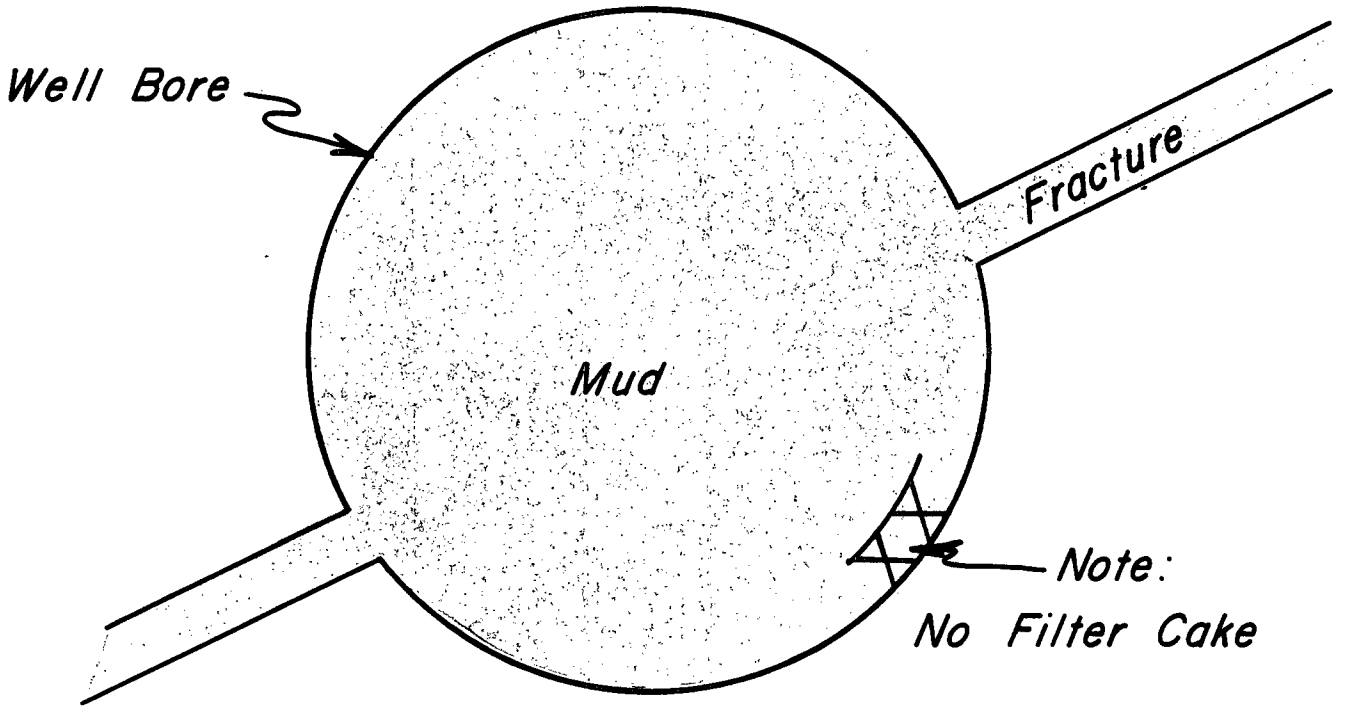
DRILLING FLUID DISTRIBUTION IN A TYPICAL SAND

NO APPRECIABLE LOSS OF CIRCULATION ON DRILLING



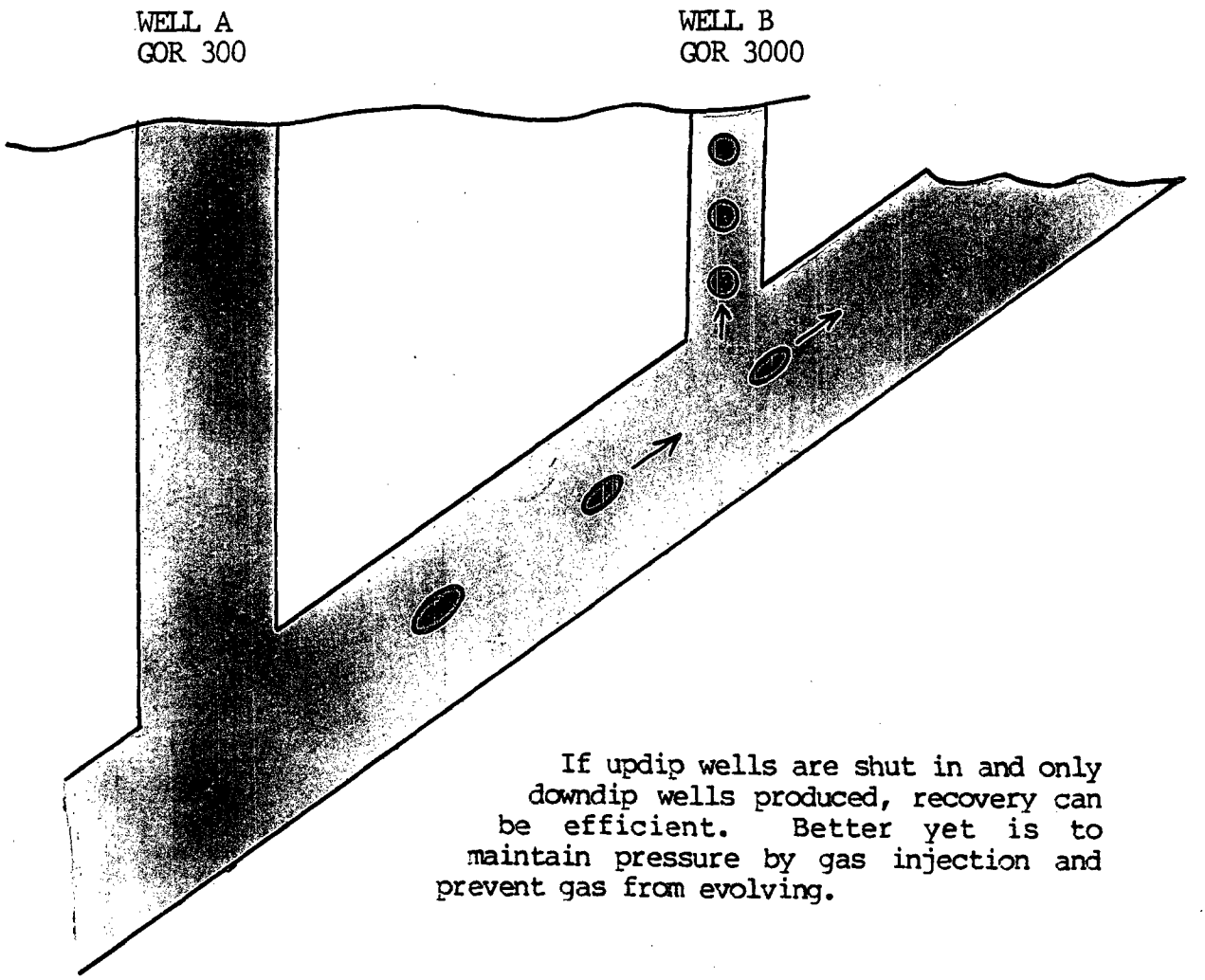
DRILLING FLUID DISTRIBUTION IN A FRACTURED RESERVOIR WITH MATRIX POROSITY

SIGNIFICANT LOSS OF CIRCULATION ON DRILLING IF FRACTURE INTERSECTED BY WELL BORE



GRAVITY DRAINAGE IN FRACTURE POROSITY

The same high relative permeability characteristics that makes the solution gas drive mechanism in fracture porosity so inefficient makes the highly efficient gravity drainage depletion process attainable given proper structural dip, transmissibility and controlled production of the reservoir.



If updip wells are shut in and only downdip wells produced, recovery can be efficient. Better yet is to maintain pressure by gas injection and prevent gas from evolving.

OIL RECOVERIES UNDER GRAVITY DRAINAGE DEPLETION AND PRESSURE MAINTENANCE AS DEPENDENT ON PHYSICAL RESERVOIR CHARACTERISTICS AND AS AFFECTED BY WELL SPACING

FRACTURED SHALE RESERVOIRS