4s 39w 22 Sw

Amoco Production Company

See report in Neitzel well file

Tulsa, Oklahoma
February 13, 1978

File: Technical Service 5107SJ

Dan Hartmann
Denver Division

Subject: Petrologic Analysis of Niobrara Chalk, Neitzel 1-28, Walz B1-33, and Carter 1-22, Cheyenne County, Kansas.

X-ray analysis and SEM photographs of these samples have been completed and the results are enclosed with this memo. Thin sections are being prepared and will be sent when ready.

The x-ray data (Table 1) show that most of the samples are fairly pure chalks, consisting mainly of calcite. The most common impurities are quartz, clay (illite, kaolinite) and pyrite. Sample 1 from the Carter well is a black shale and consequently high in clay.

Figures 1-5 are representative of the samples chosen for SEM photography. For the most part, the samples are clean, coccolith-rich chalks with little evidence of solution or tight cementation. More impure samples (Figures 3 and 5) contain fewer coccoliths and exhibit very fine flakes of clay.

The porosities, permeabilities, grain densities, and mercury injection curves measured by Routine Testing and Analysis are enclosed. Inasmuch as the grain densities are anomalously low for carbonates, the porosities should probably be considered as minimum figures, and may actually be somewhat higher.

Laurel Babcock

Laurel Babcock

LB:km
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cc: H. D. Winland
D. L. Boyne/J. L. Severson

BEECHER ISLAND FIELD YUMA COUNTY, COLORADO

by

John P. Lockridge [1]

ABSTRACT

The Beecher Island field is located on a low relief anticlinal closure on the eastern flank of the Denver basin in Yuma County, Colorado. The field was discovered in 1919 but commercial development did not commence until 1972. Biogenic gas is produced from chalk with high porosity but low permeability at the top of the Smoky Hill Member of the Cretaceous Niobrara Formation at a depth of 1500 to 1800 feet. There are 21 gas wells, each on a 640 acre unit. Nineteen of these wells have been stimulated with a foam fracturing treatment and will deliver from 100 to 300 MCFGD. Cumulative production as of December 31, 1976 was 598,000 MCF.

INTRODUCTION

The Beecher Island is located on a low relief anticlinal closure on the eastern flank of the Denver basin in Yuma County, Colorado (Fig. 1). Gas is produced from a chalk at the top of the Smoky Hill Member of the Cretaceous Niobrara Formation at a depth of 1500 and 1800 feet. There are 21 gas wells, each on a 640 acre pooled area. Cumulative production as of December 31, 1976 was 598 million cubic feet.

EXPLORATORY AND DEVELOPMENT HISTORY

Discovery is attributed to the Midfields No. 1, SE SW NW Section 14-T2S-R43W (Fig. 2), completed in 1919 for a reported flow of 2,000 MCFGD from the Niobrara (Barb, 1946). Recent developments have not yet verified production in Section 14. Midfields drilled three additional gas wells in T2S-R43W in the early 1920's which were reported to have flowed 2,000 MCFGD. The Midfields No. 4 in the NW SE SE Section 20 has produced gas for many years for use on the W. D. Strangways ranch.

The Major Petroleum No. 1 Winegar (or No. 1 Blackwell), SW SE NW Section 7-T2S-R43W, was drilled in 1928 and 1929 and tested 200 MCFGD from the Niobrara. The I.T.I.O. No. 1 Strangways, NW NW Section 21, was drilled and abandoned in 1936 at a depth of 5592 feet in Precambrian. This well was reportedly drilled on an anticlinal structure mapped by a reflection seismograph survey. Continental Oil drilled a dry hole in the NW NW Section 28-T2S-R43W to a depth of 2885 feet in the Morrison. Non-commercial gas was reported at 1475 feet, presumably from the Niobrara. A Precambrian test, the Livermore No. 1 Green, SW NE Section 8-T2S-R43W, was drilled and abandoned in 1952 with essentially no evaluation of the

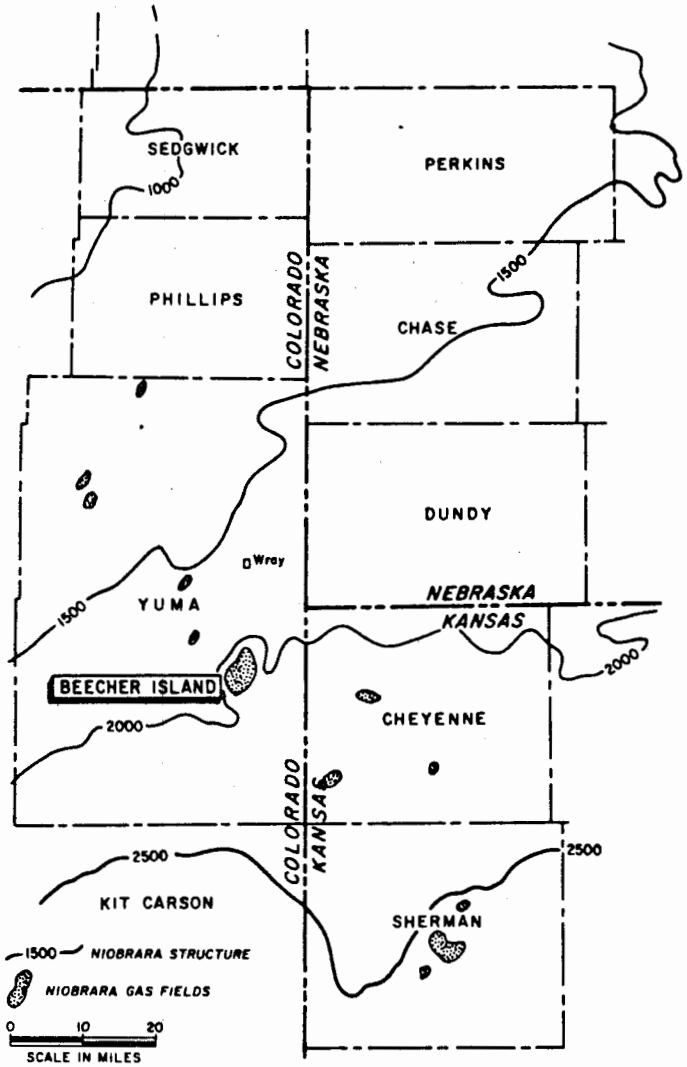

Fig. 1 — Index map showing location of Beecher Field.

[1] Mountain Petroleum, Denver, Colorado

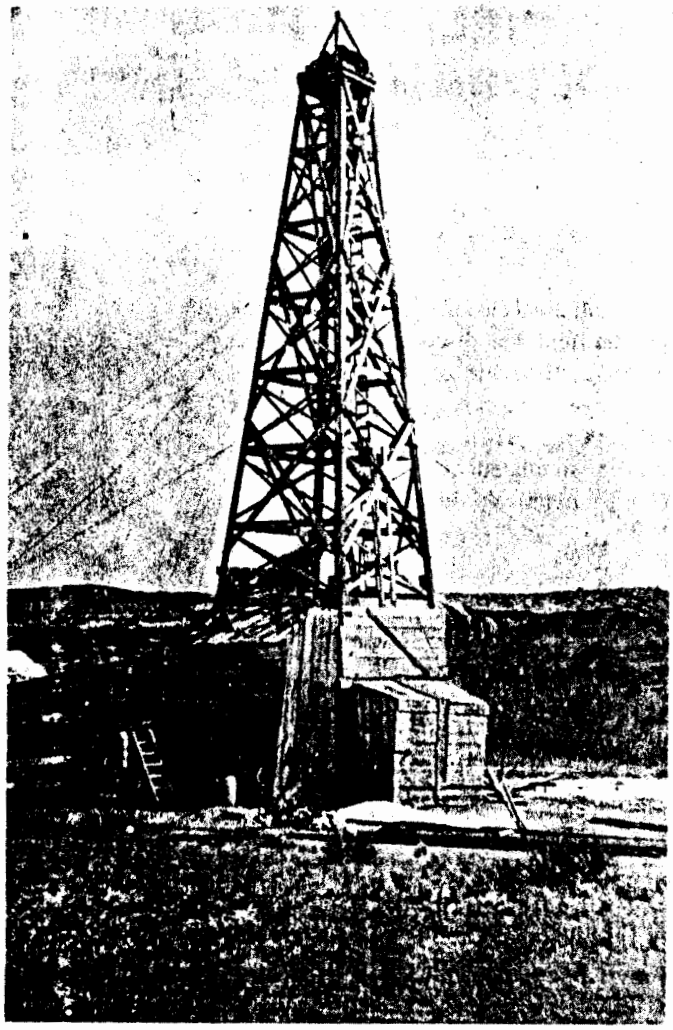

Fig. 2 — Discovery well, Beecher Island Field. Midfields Oil Co. No. 1, Section 14-T2S-R43W, Yuma Co., Colorado. Drilled in 1917-1918.

Niobrara. The highest well yet drilled in the field area was by Sure at the No. 1 Whomble in the SW SW Section 32-T2S-R43W. This wildcat was drilled in 1955 to the Cretaceous "J" sandstone. The Niobrara was probably not considered to be an objective in the I.T.I.O., Continental, Livermore and Sure wells. However, the electric log for the Sure No. 1 Whomble has resistivity characteristics in the upper Niobrara similar to logs in wells subsequently completed as gas wells.

The structural closure which could be inferred from the pre-1972 well data is presented on Figure 3. Only minor modification has resulted from subsequent well data (Fig. 4).

Mountain Petroleum Ltd. embarked on an investigation of the Beecher Island area in 1971. Old well records were reviewed and the production of gas from the Midfields No. 4 was confirmed. Oil and gas leases were obtained in 1971 and six wells were drilled in 1972 by Mountain Petroleum Ltd., five of which were completed as low volume gas producers from the upper Niobrara. With the incentive of higher prices and new completion techniques, additional development was undertaken in 1974 and there are now 21 gas wells in the Beecher Island field, each on a 640 acre spaced unit (Order No. 300-1, Colorado Oil and Gas Conservation Commission). The limits of the field have not been firmly established, and it is anticipated the density of wells will be increased to provide adequate drainage.

Gas from Beecher Island is purchased by Kansas-Nebraska Natural Gas Company, Inc. for the interstate market. Prices are under the jurisdiction of the Federal Power Commission and range from $.35 per MCF to $1.44 per MCF.

STRUCTURE

The Beecher Island field is located on a low relief anticlinal closure on the eastern flank of the Denver basin. Regional northwest dip is approximately 25 feet per mile, or about ¼°. The highest area of the structure is in the southwest portion of T2S-R43W where the Niobrara is at a datum above +2100 (Fig. 4). The structural feature extends in a north-northeasterly direction into the southern portion of T1S-R43W, and is presumed to extend to the south-soutwest for a few miles in T3S-R43W and R44W. An east component of dip of approximately 150 feet has been established by wells drilled near the south line of T2S-R43W. A syncline has been interpreted along the east-southeast side of the field at a datum near +1950 resulting in interpreted structural closure of 150 to 200 feet.

East-west normal faults with a vertical displacement of 50 to 100 feet have been interpreted. These faults have not been observed in logs of wells at Beecher Island, but have been observed in logs of wells in the Vernon field area, T1N-R44W, Colorado, an unnamed field in T3S-R42W, Colorado and elsewhere. The faults are believed to be listric in character and probably do not extend to the underlying Dakota Group. The gas-water contact appears to be at a different datum in adjacent blocks separated by faults.

STRATIGRAPHY

The natural gas at Beecher Island is produced from a chalk at the top of the Smoky Hill Member of the Cretaceous Niobrara Formation. Nomenclature for the Niobrara and adjacent formations is shown on the electrical log of the Sure No. 1 Whomble (Fig. 5). "Beecher Island zone" is used informally herein to refer to the 25 to 30 foot upper Smoky Hill chalk bed with distinctive physical properties from which gas is produced at Beecher Island.

The Upper Cretaceous Niobrara Formation was deposited over an extensive portion of the central and western United States during a major transgressive stage of marine deposition.

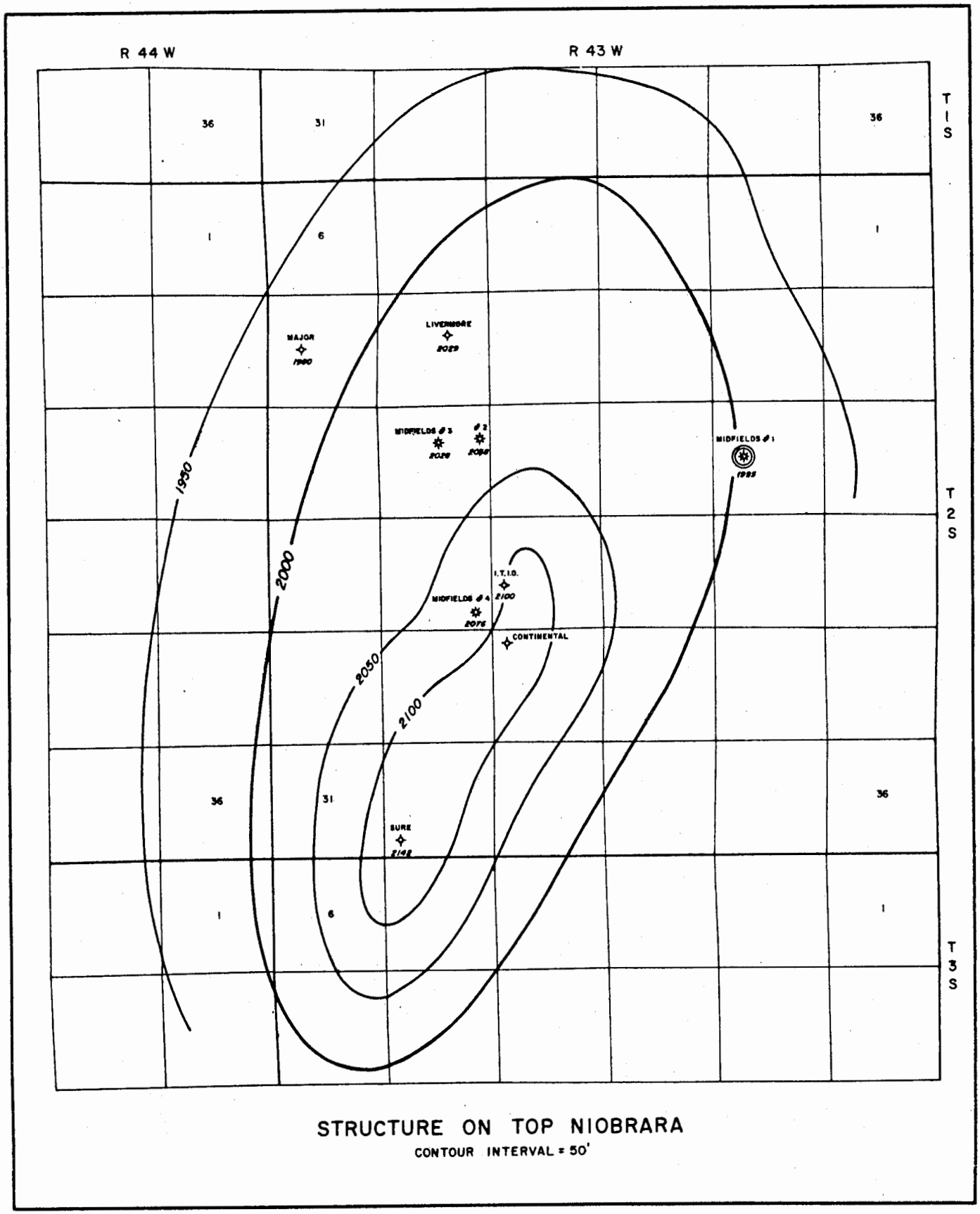

Fig. 3 — Pre-1972 map of Beecher Island field, Yuma, Co., Colorado

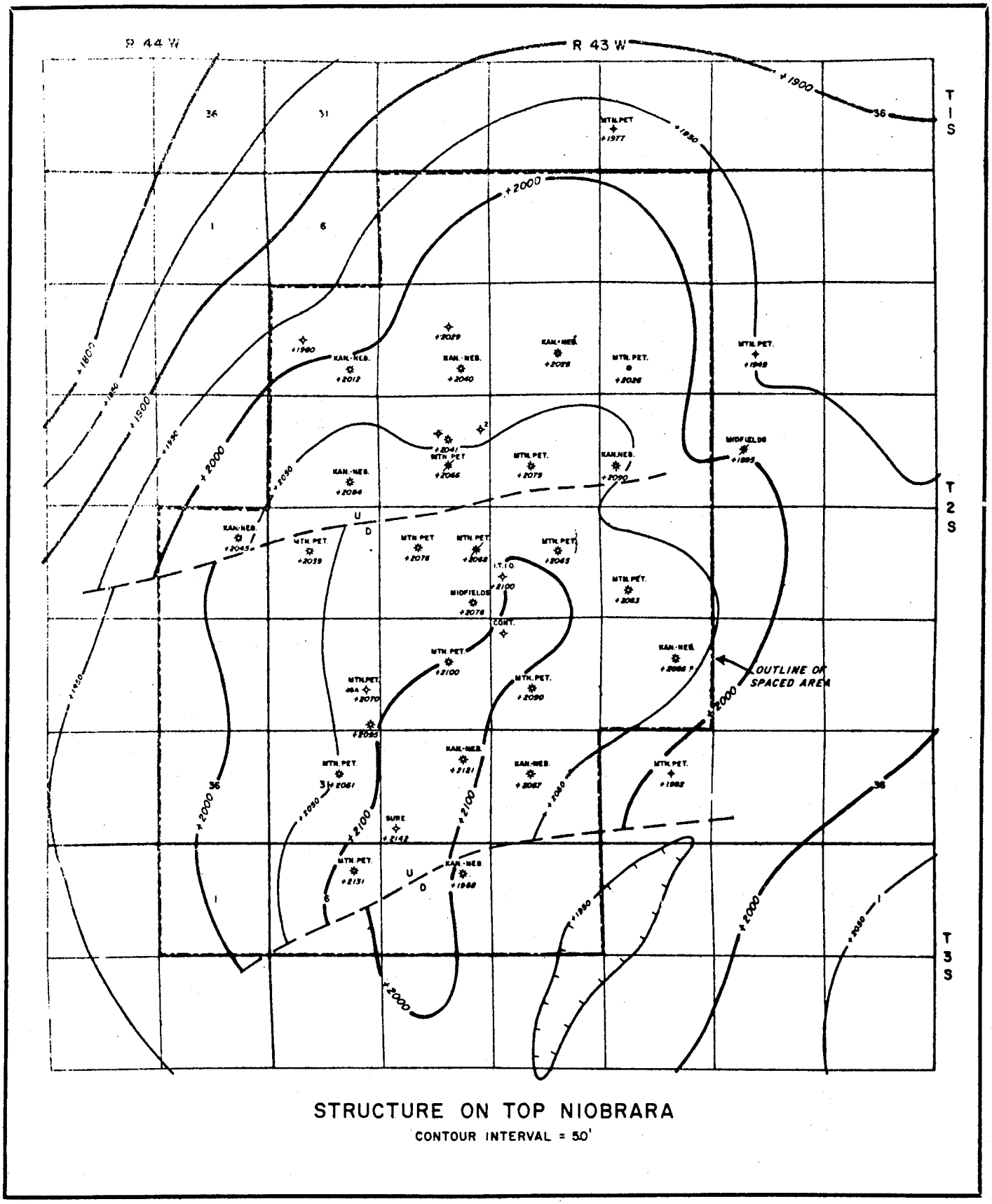

Fig. 4 — Structure map on top of Niobrara, Beecher Island field, Yuma Co., Colorado.

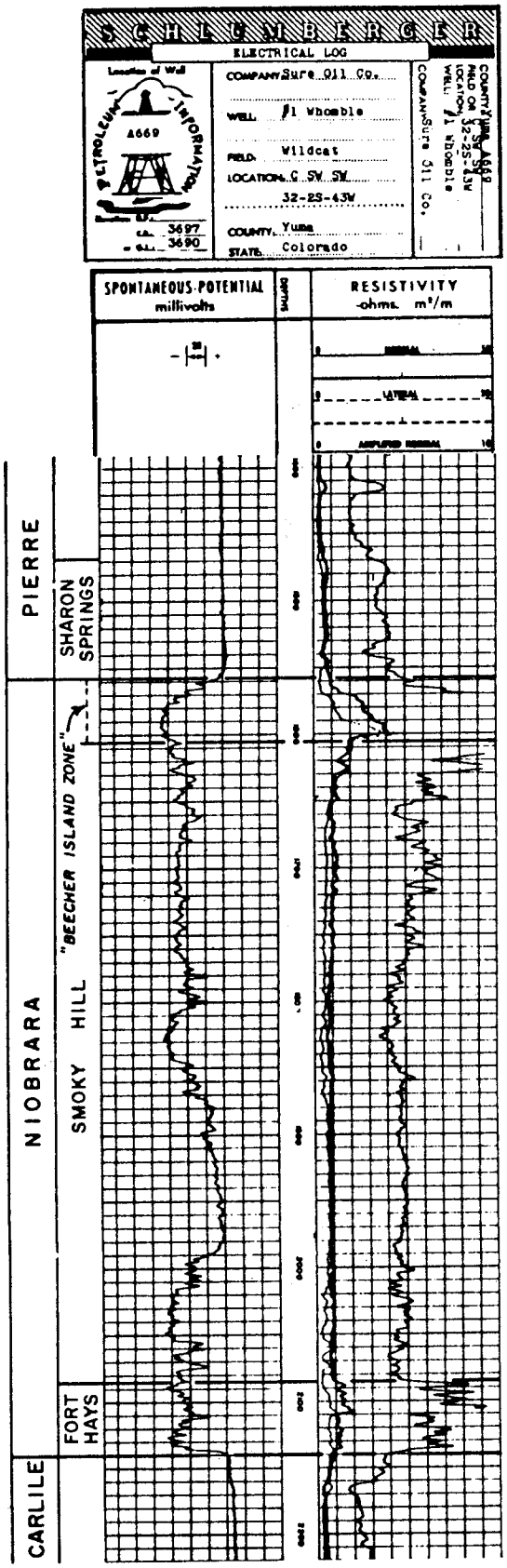

Fig. 5 — Electric Log from Beecher Island field. Sure No. 1 Whomble SW SW Section 32-T2S-R43W Yuma Co., Colorado.

Relatively quiet and deep water conditions contributed to the deposition of laterally persistent beds over extensive areas and the Beecher Island zone can be recognized and correlated over an area of more than 50,000 square miles in Colorado, Kansas and Nebraska.

The top of the Niobrara is readily recognized in drill cuttings as "the first white specks" and in thousands of wells in the Denver basin has been routinely described as light to medium gray, speckled, very calcareous shale. The Beecher Island zone, however, is distinctive in well cuttings utilizing a hand lens or 20x binocular microscope because of its lighter color, and can be recognized as light gray chalk (rather than shale) with a speckled to mottled appearance. However, with normal drilling rates of 2 feet per minute and lax 30 foot samples, the wellsite geologist often does not have any of the cleaner chalk zone in his samples.

Magnification in the range of 1000x to 5000x utilizing a scanning electron microscope reveals the Beecher Island zone to be a relatively clean chalk comprised predominately of coccolith and rabdolith plates (Fig. 6). These nannofossils are primary constituents of most Cretaceous chalks (Scholle, 1977). Coccolith and rabdolith spheres are nannoplankton comprised of numerous calcareous plates which typically range in size from 1 to 10 microns. As the plankton die, the calcareous plates fall to the sea floor where they accumulate as a chalk ooze. As the soft sediment is buried, lithification progresses resulting in stages ranging from soft porous limestone to very hard dense limestone. The photomicrographs in Figure 6 provide an interesting view of the fairly high "inter-plate" primary porosity present in the chalk pay zone at Beecher Island and indicate only moderate lithification.

X-ray diffraction analysis of core samples from the Beecher Island zone from the Kansas-Nebraska No. 1-32 Ekberg, NE/4 Section 32-T2S-R43W, provided the following information on chemical composition. *

Calcite	85%
Quartz	5%
Clay Minerals	10%
Illite, Montmorillonite and Mixed Layer	5%
Kaolinite	5%
	100%

Analyses have shown a range of 8 to 15 per cent insoluble residue.

RESERVOIR CHARACTERISTICS AND RESERVES

The high porosity and low permeability of the Beecher

* Dr. Arthur J. Ehlmann, Core Analysis for The Western Company, December 20, 1976.

Fig. 6a — 1 micron ⊢—⊣. Mountain Petroleum, Ltd. No. 1-16 State, Section 29-T2S-R43W. Depth 1680-1690′. Rabdolith with spine intact and coccolith plates.

Fig. 6b — 1 micron ⊢—⊣. Mountain Petroleum, Ltd. No. 1-16 State, Section 29-T2S-R43W. Depth 1720-1730′. Coccolith and rabdolith plates.

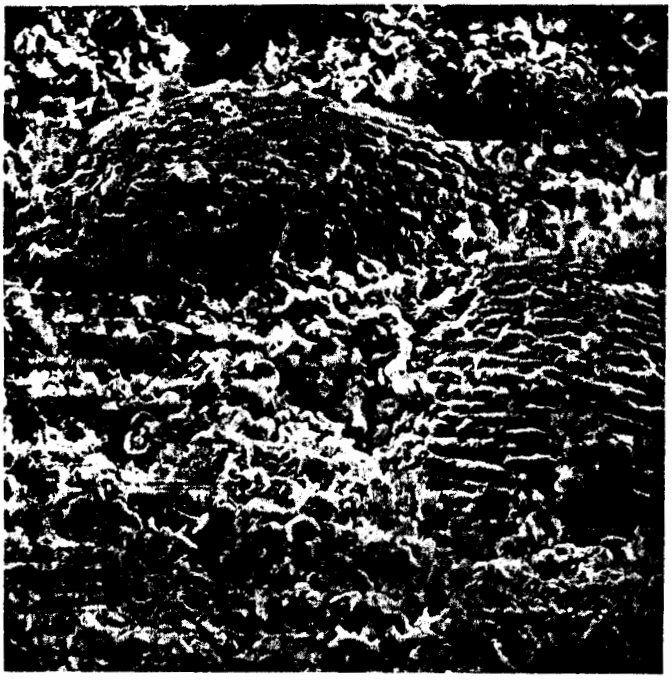

Fig. 6c — 10 microns ⊢——⊣. Kansas-Nebraska No. 1-32 Whomble, Section 32-T2S-R43W. Depth 1518′. Coccolith and rabdolith plates and foraminifera.

Fig. 6d — 1 micron ⊢⊣. Kansas-Nebraska No. 1-32 Whomble, Section 32-T2S-R43W. Depth 1518′. Coccolith and rabdolith plates.

Fig. 6 — Photomicrographs (Scanning Electron Microscope) of "Beecher Island Zone," Smoky Hill Member, Niobrara Formation.

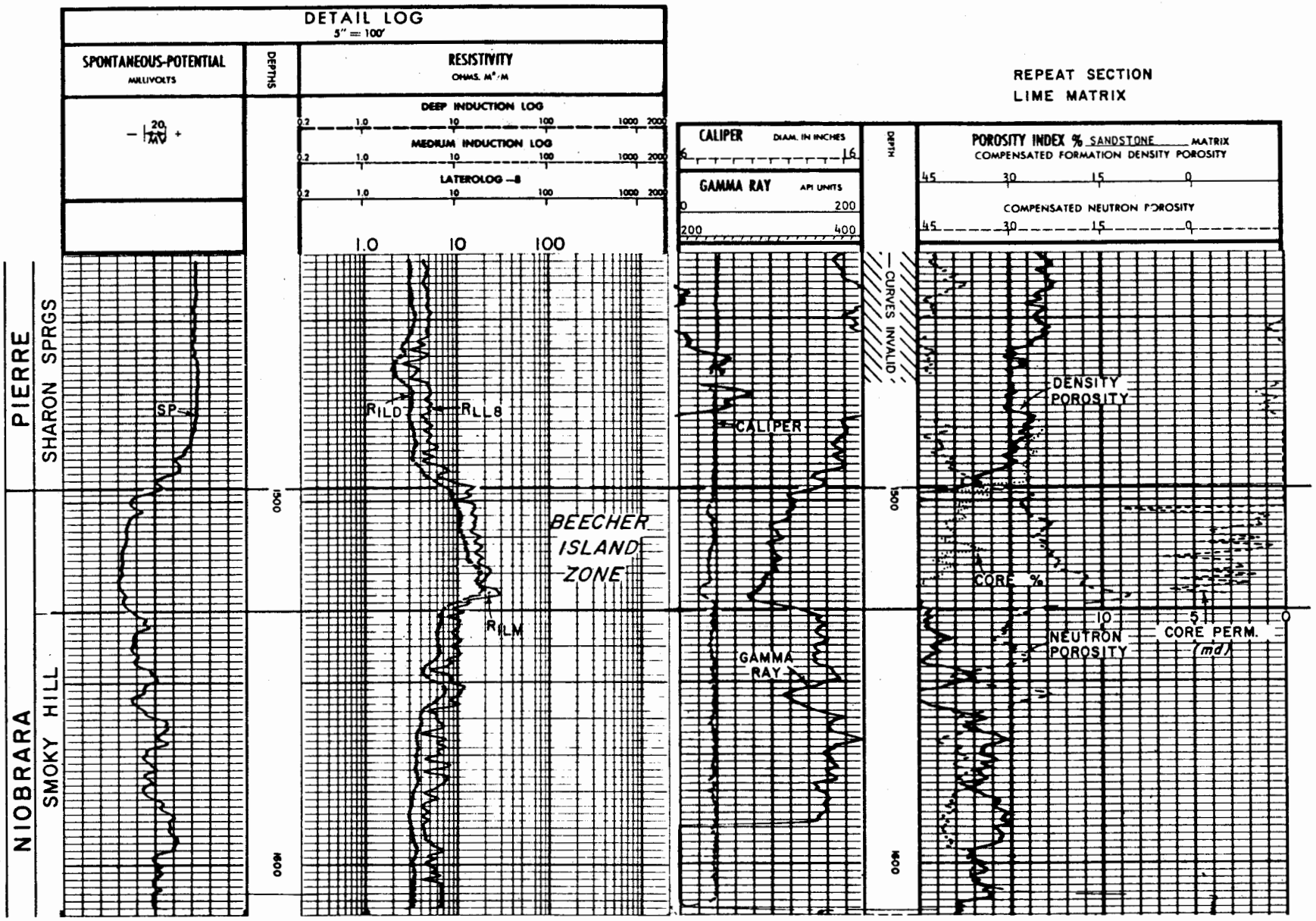

Fig. 7 — Dual Induction Laterolog and Formation Density/Compensated Neutron log, Kansas-Nebraska No. 1-32 Whomble, NE/4 Section 32-T2S-R43W, Yuma Co., Colorado, with porosity and permeability core analysis.

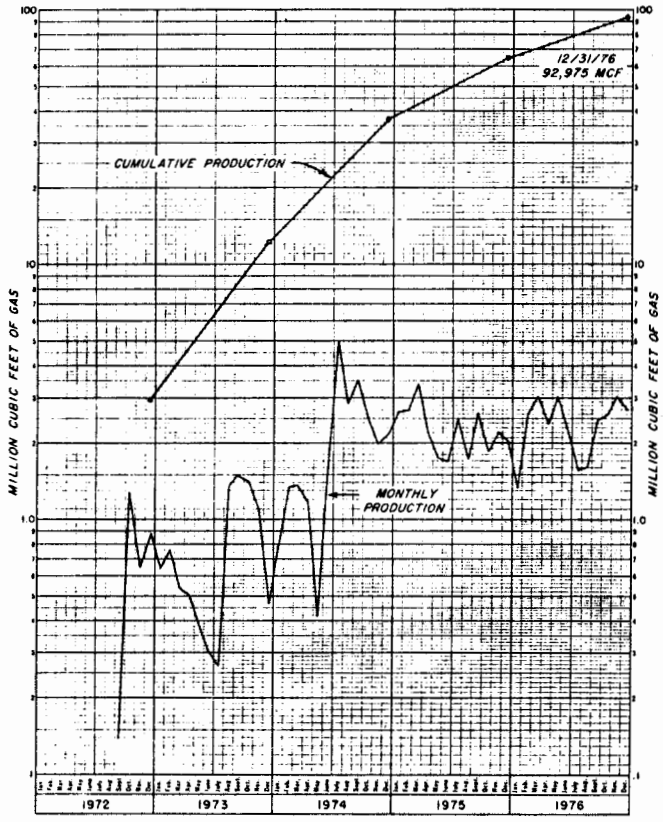

Fig. 8a — Production graph, Mountain Petroleum Ltd. No. 1-16, NE SE Section 16-T2S-R43W, Yuma Co., Colorado.

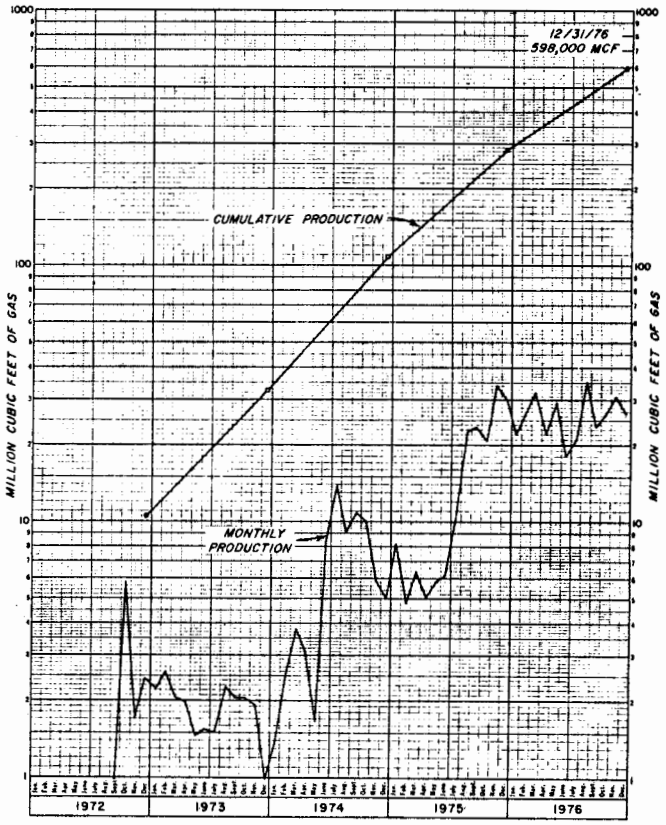

Fig. 8b — Production graph, Beecher Island field, Yuma Co., Colorado.

Island zone are characteristic of chalk which has been subjected to only modest depth of burial. Core analysis shows porosity of 33 to 45 per cent while density logs, corrected for gas effect, show porosity of 39 to 42 per cent.

Permeability from core analysis is from 1 to 6 millidarcies. This is typical of chalks with 35 to 45 per cent porosity and is a consequence of the extremely small average particle size. Although the writer believes this permeability is dominantly of a primary nature, it is appropriate to acknowledge that Core Lab consistently notes "hairline fractures" on their reports of permeability values. Calculated average permeability from a pressure curve of a drill stem test of the Beecher Island zone in the Mountain Petroleum No. 1-29 State, SW NE Section 29-T2S-R43W, is .04 millidarcy.

A Dual Induction Laterolog and Compensated Neutron-Formation Density Log from the Kansas-Nebraska No. 1-32 Whomble, NE/4 Section 32-T2S-R43W (Fig. 7), show the log characteristics for a productive "Beecher Island zone". The Self Potential and Gamma-Ray curves indicate a "cleaner" bed than most of the Smoky Hill Member. Resistivity on a deep induction curve is normally in the 5 to 15 ohm range for productive wells at Beecher Island and is characteristically higher in the lower 10 to 15 feet which has better porosity. The density log is entirely off scale (greater than 45 per cent porosity) in the No. 1-32 Whomble, while the neutron porosity is 27 to 15 per cent. This contrast, or crossover, of apparent density and neutron porosity values results from gas filled pore spaces and is an effective evaluation technique at the Beecher Island field.

Core porosity and permeability measurements are plotted on the log of the No. 1-32 Whomble. These plots have a striking similarity to the trend of the density porosity curve in wells where density porosity is not off scale.

Initial reservoir pressure (assuming no appreciable drawdown due to pre-1972 production for use on local ranches) is 340 to 345 psi. The Colorado School of Mines Quarterly, "Selected Well Logs of Colorado," did report a pressure of 450 psi (Barb, 1946).

Beecher Island gas has an average heating value of 985 BTU per MCF. The gas is interpreted to be of biogenic origin based on a fairly high percentage of light carbon isotope C_{12} (C_{13} methane of -60.7); the high ratio of methane to total gaseous

hydrocarbon (98 per cent); and the presence of nitrogen (5.17 per cent) and CO_2 (Tr) as constituents (Rice, 1975).

Estimates for the ultimate recovery of gas from the Beecher Island zone are quite speculative at this time. A calculation of gas in place has been made using the following parameters:

Porosity	40%
Interstitial Water	55%
Temperature	82°
Pressure	346 psi

GAS IN PLACE

$$43.56 \times \phi \times (1 - I.W.) \times \frac{520}{460+T} \times \frac{P + 15}{15}$$

$$43.56 \times .40 \times .45 \times \frac{520}{542} \times \frac{361}{15} = 181 \text{ MCF/ac ft}$$

181 MCF/ac ft x 30 ft x 640 ac = 3,475 MMCF per section

181 MCF/ac ft x 30 ft x 640 ac x 21 = 72,975 MMCF in the developed area

The presently developed area of 21 sections has an estimated 73 billion cubic feet of gas in place. The percentage of gas ultimately recovered may be relatively low due to poor permeability.

Gas was initially sold from the Beecher Island field in January 1974 with five wells connected. By the end of 1975 there were eleven wells producing and production since that time has been limited by compressor capacity of approximately 1,100 MCFGD. Cumulative production as of December 31, 1976 was 598,000 MCF. Compressor capacity is currently being increased to a projected 5,000 MCFGD.

COMPLETION TECHNIQUES

The four gas wells drilled by Mountain Petroleum in 1972 were open hole completions in which casing was cemented above the Niobrara and the gas pay zone was drilled with air. These wells flowed from 50 to 120 MCFGD initially but subsequent caving in the open hole necessitated recompletion or abandonment. Stimulation of the wells was first done in 1974 at the Mountain Petroleum No. 1-29 State, SW NE Section 29-T2S-R43W. The No. 1-29 State was drilled with mud and casing was cemented through the Niobrara gas zone. An open hole drill stem test flowed only 5.6 MCFGD, indicating some bore hole damage as compared with the air drilled holes. The Beecher Island zone was perforated and treated with a sand-nitrogen foam frac using 10,000 pounds of sand, 130 barrels of water and 151,000 SCF nitrogen. The No. 1-29 State was completed for a calculated absolute open flow of 2,100 MCFGD. All subsequent development wells have been stimulated with a sand-nitrogen foam frac. Stimulated wells are capable of producing 100 to 300 MCFGD for thirty day test periods. Limited compressor facilities at the field have precluded longer test periods with the stimulated wells producing near capacity.

ACKNOWLEDGEMENTS

The writer expresses appreciation to several officers and employees of Kansas-Nebraska Natural Gas Company, Inc. for their contribution of information relative to the Beecher Island Field, to Peter A. Scholle, USGS, for his most helpful discussions of chalk and for providing SEM time and photomicrographs, and to Dudley D. Rice, USGS, for isotopic analysis of gas samples.

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